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ARTICLES

Supply Response of Foodgrains and Policy Actions: A Model with Rational Expectation Hypothesis

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I

INTRODUCTION

The question of the nature of supply response in agriculture and what is the effect of government policy actions on it, particularly in the context of a less developed country, has been debated for a long period. Economists have come out with different hypotheses on the supply response of farmers and these are not necessarily mutually exclusive in nature. The identification of the nature of supply response is difficult when multiple subsistence crops are considered. Behrman (1968) concluded that supply responsiveness of under-developed agriculture has been confused by the failure to make explicit distinction between (a) total production and marketed surplus; (b) total agricultural production and production of single crop. Produced quantities and marketed surplus need not respond identically to price changes and other agricultural policy actions. Since agriculture contributes a major share in national income and most of the people are engaged in that sector, government intervention in the agricultural sector in a less developed country is a common practice to achieve multiplicity of objectives. Some of the controlling instruments are direct subsidies to the farmers in the form of low input prices, support price of foodgrains, foreign trade control, etc. On the other hand, public distribution system is a key instrument of the government to achieve the goal of welfare for the poor and the urban middle class.

It has been pointed out by the policy makers that India has a comparative advantage in food prices, especially in wheat and rice. Naturally, one positive implication may be the possibility of foodgrain export. While venturing into a prospect of exploiting this advantage, it is most essential to be secured in respect of supply of the most basic of all needs, i.e., food, for the teeming millions of our country. The current food policies must take account of the facts that global demand for foodgrains is expected to rise rapidly in future and after signing as a participant of World Trade Organisation, India has to face strong competition from developed countries and, international food prices are likely to be unstable (Paulino, 1988) making self-reliance even more essential than ever.[1] A thorough knowledge of the supply responses of foodgrains and the implications of policies will be useful for planning food production and the all round development of the country.

In India the most important determinant of foodgrain supply is domestic production. Imports do contribute to supply but since they draw on scarce foreign exchange resources they are partly avoided. Stocks with the government also provide a source of supply but in the long run stocks too depend on the production performance of agriculture. But all these government operations in the market have profound impact on the production decisions of the farmers and are no less important than any technological factor. They act on both demand

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and supply sides of the market and there is no reason why a farmer should disregard them.

Since the mid-sixties the production of foodgrains in India has more than doubled owing to expansion of acreage and improvement of yield rates of crops. The growth has been particularly impressive in the last decade, about 2.7 per cent per annum between the years 1977-78 and 1988-89. But population has been growing too and it is perhaps the movement of the per capita figures relating to food supply that is more relevant in assessing the achievements of the sector towards the welfare of the nation.

This paper studies the behaviour and responses of the supply of foodgrains in India keeping in view the policy options of the government. As expectations formation of farmers is crucial in this matter, the theory behind this behaviour is discussed and the Rational Expectations hypothesis is chosen. Since rice and wheat together constitute around 70 per cent of foodgrain output in India, specifically these two crops are considered in this study.

In Section II the behaviour of foodgrain supply since 1964-65 is examined in conjunction with government actions. Section III discusses the theoretical aspects of expectations formation of farmers, concepts and applications and the relevance of the Rational Expectations model in Indian agriculture. In Section IV a model is built up for the Indian food market to estimate supply response of foodgrains using this model. Section V presents the results of the analysis, followed by a simple predictive test in Section VI. Finally, some conclusions are made in Section VII.

II

SUPPLY AND POLICY ACTIONS

Here an attempt will be made to study (1) the growth of per capita production of rice, wheat and foodgrains as a whole and (2) to find out the possible connection between different policy actions of the government, on the one hand, and production and market prices, on the other.

As noted earlier, production is the ultimate source of foodgrain supply in the country. During the twenty-five years that followed the launching of the green revolution although per capita production of foodgrains moved from 187 kg (in 1964-65) to 203 kg (in 1989-90) by about 9 per cent, the performance of the two main food crops is, as suggested by Table I, however quite distinct. While per capita wheat production shows steady increase, that of rice is rather erratic and the rise is not so remarkable in any case.

TABLE I. PER CAPITA PRODUCTION OF FOODGRAINS

(tonnes)

Year (1)	1964-65 (2)	1969-70 (3)	1974-75 (4)	1979-80 (5)	1984-85 (6)	1989-90 (7)
Rice	.0830	.0750	.0670	.0650	.0803	.0899
Wheat	.0258	.0374	.0410	.0489	.0588	.0601
Foodgrains	.1870	.1862	.1697	.1680	.1941	.2031

Source: Government of India.

To learn more about the growth of per capita rice and wheat production, linear and semi-log time trends have been fitted to the data for the period covering 1964-65 to 1990-91. The fit has not turned out to be good ($R^2 < 0.2$) in the case of rice for either of the two functional forms. It was pointed out with some optimism that rice output has been raised from the late seventies (see Rao, 1992, p. 121). In the light of this claim the trends have been fitted (a) separately for two sub-periods 1964-65 to 1977-78 and 1978-79 to 1990-91 and (b) with a dummy for post-1977-78 years. But the fit in terms of R^2 does not improve much. The results for wheat, however, are quite satisfactory as presented below.

Wheat: 1964-65 to 1990-91

$$q = .02674 + \underset{(.000111)}{.00152}\, t; \qquad R^2 = .88; \qquad D.F. = 25$$

$$\ln q = -3.57 + \underset{(.00343)}{.035388}\, t; \qquad R^2 = .81; \qquad D.F. = 25$$

where q represents the per capita wheat production and t is time.

A fairly good fit is obtained with each functional form and the trends are significant at 1 per cent level. The results, with foodgrains as a whole, are also not satisfactory as in the case of rice, and the values of R^2 are too low. Once again trends are estimated for the two sub-periods 1964-65 to 1977-78 and 1978-79 to 1990-91 to allow for a possible departure. And once again the fit has failed to improve.

Imports are said to be made to augment supplies in the years of shortfall in production. It is gratifying to note that imports of rice and wheat have come down during the period 1964-65 to 1989-90 by 60 per cent and 101 per cent respectively. The contribution of imports to net availability of foodgrains as a whole in the country has also declined from 8.8 per cent to 0.3 per cent between 1964-65 and 1984-85.

TABLE II. PROCUREMENT, DISTRIBUTION AND IMPORT OF FOODGRAINS (PER CAPITA)

(tonnes)

Year (1)	1964-65 (2)	1969-70 (3)	1974-75 (4)	1979-80 (5)	1984-85 (6)	1989-90 (7)
Procurement						
Rice	.0027	.0067	.0059	.0088	.0124	.0141
Wheat	.00019	.0045	.0032	.0123	.0124	.0132
Distribution						
Rice	.0075	.0067	.0065	.0063	.0092	.0104
Wheat	.0143	.0096	.0096	.0115	.0124	.0086
Imports						
Rice	.0016	.0003	.00024	-.00073	.00	.00061
Wheat	.0118	.0057	.00758	-.000003	.00088	-.00014

Source: Government of India.

A brief attempt may be made to know how far imports served to supplement production by using correlation analysis. The connection between production and imports (per capita levels) is found rather weak for rice, the correlation coefficient working out to be -0.15 and in some of the years such as 1974-75 and 1975-76 production and imports moved in the same direction which implies that imports served to supplement an already augmented supply and fell (even resulting in exports as in 1971-72 and 1979-80) in a year of shortfall. But this is a very unusual phenomenon. The correlation in the case of wheat is however stronger at -0.8. In fact rice import seems to be more closely correlated with the production of wheat ($r = 0.64$) than its own. Similarly, import of rice is not so much correlated with its market price ($r = 0.19$) but that of wheat is moderately correlated with market price ($r = 0.63$). In reality import decisions are based on different variables like procurement, stocks and distribution targets of the government and the variables relating to each crop may be profoundly influencing those of the others.

The procurement of foodgrains is made either through compulsory levies or voluntary sales at government announced support/procurement prices. In the last ten years or so the coercive element has diminished particularly so in the case of wheat (Dantwala, 1993) and much of the so-called procurement has been protective of the farmers in allowing them to sell at the support prices fixed by the government. However, it may also be kept in mind that the actual amount of grains procured has indirect influences on the market prices and in that sense the farmers' freedom in the market has been tampered with.

The procurement of grains per capita has been increasing with the growth in output. Taking 1965-66 as a base the increase in government procurement of rice and wheat works out to be 110 per cent and 194 per cent respectively. The percentage of total output procured has also improved remarkably from 9 per cent to 16 per cent in the case of rice and from 12 per cent to 22 per cent in the case of wheat. This has largely accounted for the increasing stocks of foodgrains with the government (44 per cent for rice and 63 per cent for wheat as between 1965-66 and 1985-86). While procurement and buffer stock operations impose enormous expenditure burden on the government, by and large, they have served in evening out the effects of fluctuations in production and in helping to tide over years of shortage (Dantwala, 1993).

Since procurement price may have some bearing on crop price the movement of this price may be looked at in Table III. Although the announced procurement price has gone up evidently, when deflated by consumer price index, it does not show any rising tendency (see also Sidhu, 1990). Procurement prices are set to be remunerative to the farmers, guiding them in allocating resources and choosing the crop mix but at the same time they are meant to safeguard the interests of the consumers and their gains in the better technology. A balance between the two forces is important for the ultimate gain of the same consumers.

TABLE III. PRICES OF RICE AND WHEAT

	Rice				
Year (1)	1964-65 (2)	1969-70 (3)	1974-75 (4)	1979-80 (5)	1984-85 (6)
Procurement price (Rs./qtl.)	37.00	45.00	74.00	95.00	137.00
Procurement price (deflated)	0.281	0.253	0.239	0.245	0.234
Market price (deflated)	0.966	1.105	1.191	0.955	0.937
	Wheat				
Procurement price (Rs./qtl.)	37.50	76.00	105.00	117.00	152.00
Procurement price (deflated)	0.285	0.428	0.339	0.302	0.266
Market price (deflated)	1.045	1.208	1.233	0.865	0.746

Source: Government of India.

Note: Market price refers to wholesale price and the indices are at base 1960-61. All prices are per quintal, deflated by Consumer Price Index (general).

Public distribution of grains at subsidised prices is basically meant to protect the poor, especially the urban poor against price rise. Although rationed distribution is expected to move in line with market price, no significantly positive relation between the two emerges since the correlation coefficients are estimated to be -0.42 for rice and 0.086 for wheat over the period 1965-66 to 1985-86. This once again indicates that the relations in the food market are quite complex, when the public distribution may have some influence on market price also. The distribution targets have also been the result of socio-econ omic as well as political considerations (Ahmed, 1988, p. 64).

Finally, since production is found to be significantly price elastic (for example, the elasticity values are 0.69 and 0.56 for wheat and rice respectively as estimated by Sidhu and Kaul, 1990 for Punjab), it is worth looking at the behaviour of prices. Table III presents the wholesale price index and the procurement price both deflated by the consumer price index and the actual procurement price announced. The relative prices of both the crops have been fairly high, more so for wheat, until the mid-seventies but dipped subsequently. While this adverse turn in food prices is bound to affect the supply responses of the crops, one positive implication may be the possibility of grain exports. Even compared to world prices domestic official exchange rates are placed at 0.72 for rice and 0.80 for wheat (Ahmed, 1988), indicating India's comparative advantage in the two crops.

III

PRICE EXPECTATIONS IN SUPPLY RESPONSE

In agriculture, supply decisions are taken months before the actual products reach the market and prices are realised. The production decisions are therefore taken on the basis of expected prices. There are several hypotheses regarding formation of price expectations.

Cobweb Model

The commonly used proxy for expected price is the previous year's actual price, i.e., $P^e_t = P_{t-1}$.

Adaptive Expectations

This formulation too supposes that price expectation is based on past price or prices, but the agents are allowed to learn from past mistakes so that expected price is given by

$$P^e_t = P_{t-1} + (P_t - P^e_{t-1}).$$

This is sometimes combined with the hypothesis of partial adjustment of supply and other relevant variables influencing supply.

ARIMA Process Expectations

The ARIMA process expectation also assumes that past prices determine price expectations but past disturbances are taken into account as well. Here

The expected signs of coefficients of the first four variables in equation (1) are negative, positive, negative and positive respectively. The parameter for variable R is normally expected to be negative, but a strong income effect from the increased distribution of subsidised grains may lead to a positive sign.

Expected signs of coefficients of the variables in equation (2) are negative, positive and negative respectively.

The signs of equation (3) should be positive, negative and negative respectively.

The production response function is given by equation (4) and the lagged production is included to allow for possible partial adjustment of supply (β_4 is adjustment coefficient, expected to be positive and fractional).

Now since market supply is given by the identity (5), the market clearing condition (6) implies that market price (theoretically expected) is a function of all the variables (again theoretically expected) in the model including the expected prices.

Finally, the Rational Expectations Hypothesis (REH), defined by equation (7) would imply that expected price P^e is a function of the expected values of all the variables of the model, exogenous and pre-determined that are determined outside the model at hand.

The REH establishes a connection between the farmer's expectations and the actual stochastic behaviour of the variables. It is the same for exogenous variables, but unlike the case of the endogenous ones these expectations have no influence over the determination of the actual variables. It is therefore common to predict the exogenous variables through suitable stochastic processes which are estimated separately or together with the main model. However in the present case the predictive equations are substituted for the expected exogenous variables, so that the expected price becomes a function of only those variables known to the farmer at the time of sowing. The forecast of price is thus made on the basis of past experiences and policy variables disclosed in advance. It may be noted that the expected price of the substitute crop appearing in equation (4) is an endogenous variable. This endogeneity can be removed by considering the equations for expected prices of the two competing crops together and solving for the two expected prices. This yields the expected price of each crop as a function of all the exogenous and pre-determined variables related to both the crops.

Information regarding private stocks (SP) may not be accessible but the previous year's production and price may help in estimating it (equation 8). Possible rationed quantities may be predicted on the basis of past experience as also previous year's production which influences government stock position (equation 9). Procurement normally depends on the procurement price as well as the market price (equation 10). Irrigation and weather conditions are to a certain extent known and taken into account at the time of planting decisions. A simple one period autoregressive process is taken to characterise income (equation 11). Finally, although information on government stock holdings is available, a process similar to that of private stocks is assumed to describe or determine this variable (equation 12) due to convenience of estimation.[3]

When the expression for expected price is put back in the production function (equation 4) of each crop, the following reduced form equation of the production response is obtained:

$$Q_t = (Y_{t-1}, R_{t-1}, PP_t, I_t, F_t, W_t, P_{t-1}, Q_{t-1}, R^*_{t-1}, PP^*_t, I^*_t, F^*_t, P^*_{t-1}, Q^*_{t-1}) \quad ....(13)$$

where the variables are all observable. In other words, equation (13) gives the production of a crop in terms of different variables operating directly or indirectly in the market, all of which are known to the farmer at the time of sowing and guide him in his decisions.

Estimation

Rational expectations models can be estimated by single equation methods like instrumental variable approach or full information methods. Since rational expectations are a property of the whole system, the information contained in all the equations is utilised here by adopting a systems approach to estimate the model. All the eight equations (1), (2), (3), and (13)for both the crops are estimated simultaneously by Ordinary Least Squares (OLS) method, considering the errors to be contemporaneously related across equations. Although crop price(s) (P) in equation (1) for each crop appears as an exogenous variable, the model assumes market prices to be determined from within the system. Hence P is actually endogenous. To avoid a simultaneity bias, the price of a crop is regressed (using OLS) separately on the exogenous variables of the model (equation 14) and the estimated price is used as an instrument in equation (1) of the model.

$$P_t = (Y_{t-1}, R_{t-1}, PP_t, I_t, F_t, W_t, P_{t-1}, Q_{t-1}, R^*_{t-1}, PP^*_t, I^*_t, F^*_t, P^*_{t-1}, Q^*_{t-1}) \quad ....(14)$$

As already mentioned, the exogenous processes are embodied in the model during estimation. All the variables are taken at per capita levels. Prices are deflated by the consumer price index (CPI) as in Table III. Per capita national income at factor cost at constant prices (1971) is taken for the variable Y and weather W is considered as a dummy equal to 1 for a good year and 0 for others.[4] Irrigation (I) is the proportion of crop area irrigated and fertiliser application is in kilograms per hectare over all crops, since cropwise data are not available. The data on relevant variables for the 22 years, i.e., 1964-65 to 1985-86 have been used. However, out of this period the data for the first fifteen years have been used for the regression analysis to estimate the different parameters and the data for the last seven years are used for forecasting and testing the model. The sample period 1964-65 to 1978-79 starts with the beginning of the green revolution era and also before 1964-65 no vigorous price policy on agriculture had been taken by the Government of India.[5]

When estimating the model not all variables are acceptable in terms of signs and standard errors. The reason may partly be due to multicollinearity of data. The inclusion of income makes the results meaningless and the use of weather variable along with irrigation renders both their impacts insignificant. In selecting the variables conditional omitted variable (COV) estimation (see Maddala, 1977, p. 191) is employed, i.e., those variables for which the parameter values are less than their standard errors are omitted in the equations presented in Table IV. The same criterion is used for estimating the price equation (14) to generate the price variables for equation (1).

V

RESULTS

The results given in Table IV suggest that the substitution of rice and wheat is weak. There is none on the production side and on the demand side some substitutability is indicated by the presence of the term R* in the demand function of wheat and therefore also of lagged R* in the supply function of the same. While subsidised distribution of rice enters the wheat eater's demand, the reverse is not true. The near absence of substitution between the two major foodgrains is understandable considering that they are predominantly grown in two different parts of India (West Bengal produces 15.3 per cent of total rice output of the country whereas the contribution of Punjab and Haryana together is 10.5 per cent. The shares of these two states in wheat production are 22.9 per cent and 11 per cent respectively compared to West Bengal's share of 1.2 per cent). However, Uttar Pradesh alone contributes 12.5 per cent of rice output and 36 per cent of wheat output, so that there may be some competition between the crops for land and other inputs here. On the demand side, food habits differ among Indians, the people of eastern and southern India being basically rice eaters, while in north India wheat is the more dominant staple.

TABLE IV (A). MODEL RESULTS: ESTIMATED EQUATIONS OF THE MODEL: RICE

Independent variables	Equation numbers and dependent variables				
	1	2	3	13	14
	Demand D_t	Import M_t	Stock addition G_t	Output Q_t	Price P_t
(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.0663*	0.0009	0.0059*	-0.1368*	4.8549*
	(0.0223)	(0.0009)	(0.0032)	(0.0464)	(0.9489)
R_t	-2.1537	0.4193*			-100.5490*
	(1.5713)	(0.0932)			(25.4055)
P_t	-0.0263				
	(0.0181)				
P_{t-1}	0.0403*			0.0254*	
	(0.0135)			(0.0095)	
PC_t		-0.2227*	0.5593*		26.4553*
		(0.0460)	(0.1700)		(11.8824)
Q_{t-1}			-0.1148*	-0.4228*	
			(0.0397)	(0.1272)	
PP_t				0.2520*	
				(0.0696)	
I_t				0.4119*	-7.9516*
				(0.0838)	(2.1270)
R_{t-1}				-1.0923*	-38.8578*
				(0.9927)	(18.5412)
R^2	0.13	0.74	0.25	0.81	0.64
Corr.	0.40	0.86	0.53	0.89	

Notes: Figures in parentheses are standard errors of estimates.
Corr. is the correlation coefficient between the observed and estimated variables.
* Significant at 5 per cent level.

TABLE IV (B). MODEL RESULTS: ESTIMATED EQUATIONS OF THE MODEL: WHEAT

Independent variables	Equation numbers and dependent variables				
	1 Demand D_t	2 Import M_t	3 Stock addition G_t	13 Output Q_t	14 Price P_t
(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.1198*	0.0025	0.0071*	0.0077	1.3869*
	(0.0153)	(0.0033)	(0.0036)	(0.0054)	(0.4951)
R_t	-1.7690*	· 0.7467*			-15.2745
	(0.3486)	(0.2193)			(14.5162)
P_t	-0.0324*				
	(0.0098)				
PC_t		-0.5895*	1.5119*		
		(0.2340)	(0.4464)		
Q_{t-1}			-0.3911*	0.2283*	
			(0.1438)	(0.0800)	
PP_t					1.0212
					(0.5792)
I_t				0.0194	
				(0.0114)	
R_{t-1}				-0.9053*	
				(0.1529)	
R^*_{t-1}				-1.2719*	
				(0.2734)	
PP_{t-1}				0.0548*	
				(0.0082)	
F_t				0.0007*	-0.0113*
				(0.0001)	(0.0057)
R^*_t	-4.6410*				-53.9949
	(1.132)				(36.7020)
R^2	0.75	0.52	0.23	0.97	0.52
Corr.	0.87	0.72	0.48	0.99	

Notes: Same as in Table IV(A).

To judge the fit of this simultaneous equation model to the data, R^2 is computed for each equation as well as the correlation coefficients between the observed and estimated variables. In addition, since the supply or output function is our central concern, the root mean squared errors for the same corresponding to the two crops are also computed.

The R^2 of the demand function of rice and the stock addition functions of the crops are poor. However, both R^2 and the correlation coefficients between the observed and estimated variables for output functions are fairly good. The root mean squared error or estimation is 3.6 per cent and 4.6 per cent for rice and wheat respectively.

The reduced form equations for both the crops, used for obtaining instrument for P_t in the demand function, have fairly good values of R^2 and the signs of the parameters estimated are consistent with theoretical expectation.

The signs of the parameters of equations (1) to (3) for each crop are consistent with expectations. Equation (13) may be judged in the light of the model as the variables often have contradictory effects on supply. The demand functions have positive and significant intercepts. The intercepts of the import and stock addition functions are all positive, and remarkably, that of the latter is significant in wheat, implying that even in the absence of any procurement the government would (by importing) add to its stocks. The constant term in the supply function of rice is negative. A discussion of the coefficients and elasticities follows.

TABLE IV (C). MODEL RESULTS: ESTIMATED ELASTICITIES OF THE VARIABLES

Independent variables	Equation numbers and dependent variables			
	1 Demand D_t	2 Import M_t	3 Stock addition G_t	13 Output Q_t
(1)	(2)	(3)	(4)	(5)
Rice				
R_t	-0.205	6.14		
P_t	-0.415			
P_{t-1}	0.637			0.364
PC_t		-3.24	3.754	
Q_{t-1}			-0.892	-0.421
PP_t				0.852
I_t				2.134
R_{t-1}				-0.092
Wheat				
R_t	-0.588	1.087		
P_t	-1.010			
PC_t		-0.401	10.205	
Q_{t-1}			-18.157	0.210
I_t				0.266
R_{t-1}				0.260
R^*_{t-1}	-0.864			0.203
PP_{t-1}				0.517
F_t				0.270
R^*_t	-0.864			

Note: Elasticities are computed at mean values.

Rice

As apparent from the signs in the supply function, lagged price and rationed distribution act from the demand side [Table IV(a)]. Any upward revision of procurement price heralds the possibility of greater withdrawal from market supply, pushing up expectations about the market price. This highlights the power of the policy maker to influence production. Irrigation, as expected, has a positive and significant impact on supply. Noticeably, lagged production has a negative coefficient, implying that stocks carried over have enough influence on market demand (Q_{t-1} can have a negative effect on D_t) and supply [Q_{t-1} affects supply S_t negatively via import (M) and positively via stock addition (G)] and thereby on production, although a partial adjustment of Q_{t-1} has to be positive (fractional). Demand is found to be inelastic to price and rations. Imports and stock addition are highly elastic to the variables considered. Elasticity of supply to lagged price (this is often measured as the price elasticity of supply) is 0.36 and elasticity to rationed amount is as low as 0.092 [see Table IV(C)]. The elasticity with respect to procurement price is reasonably high, indicating that a hundred per cent rise in the relative value of this price will give sufficient incentive to produce 85 per cent more rice. Among all the variables irrigation has the highest elasticity.

Wheat

The results are somewhat different in this case. Although a high existing stock level appears to deter government from withdrawing grains from circulation as seen in equation 3 of Table IV(B), the consequent influence on production via market price is not borne out by the supply response where the positive coefficient of the lagged production term indicates that partial adjustment effect dominates. Also, publicly distributed foodgrains of both kinds act as a substitute to wheat purchased in the market (equation 1) and therefore have negative effect on the supply (the lagged ration terms of equation 3). Once again procurement price and inputs fertiliser and irrigation, most notably the former, emerge as important variables that the government may manipulate. Incidentally, fertiliser, which appears to be more significant than irrigation in deciding supply here, did not emerge as an acceptable variable for rice.

Lagged production Q_{t-1} (or resultantly, buffer stock holding) has not decided imports and the elasticity of imports to procurement, unlike for rice, is less than one. Addition to stocks is, however, highly elastic with respect to procurement (PC) and lagged production (Q_{t-1}). Demand for wheat is surprisingly price elastic and the elasticities to rationed distribution of both the grains are fairly high. The elasticities of supply to the latter variables are also high compared to rice. Once again it is technology that has the highest supply elasticity, bringing out the overriding importance of technology as a factor of growth. But this time fertiliser shares the credit with irrigation. Other technology variables are not considered here but it may be pointed out that the area devoted to high-yielding varieties (HYVs) is intimately linked to availability of irrigation and fertiliser. If such is the circumstance, not much information has been lost.

Implications of the Model on Growth

The implications of the model on the performance of the crops during the sample period may be studied by comparing the relative contributions of different factors to growth between 1964-65 and 1978-79, both years of good rainfall. One variable is taken at a time and set at 1978-79 value, keeping others at the base values and the production is simulated using parameters of the model. The difference between this value and the base year (1964-65) production is the contribution of the change in the *variable in consideration. The contributions of different variables are presented in Table VI.

TABLE V. MEAN VALUES OF VARIABLES

Variable (1)	Rice (2)	Wheat (3)	Variable (4)	Rice (5)	Wheat (6)
Price (P)	1.0649	1.078	Irrigation (I)	0.386	0.542
Ration (R)	0.0064	0.0115	Fertiliser (F)	14.69	14.69
Procurement (PC)	0.0064	0.0054	Stock addition(G)	0.00095	0.0008
Procurement price (PP)	0.252	0.3720	Imports (M)	0.00044	0.0079
Income (Y)	6.22	6.2200	Demand (D)	0.0674	0.0346

Notes: Prices are relative to CPI per quintal; quantities are in tonnes per capita; income in thousand rupees per capita at constant prices; irrigation as a proportion and fertiliser is in kg/ha.

TABLE VI. CONTRIBUTIONS OF EXPLANATORY VARIABLES TO GROWTH OF SUPPLY (1964-65 TO 1978-79)

Variables (1)	Q_t (2)	R_{t-1} (3)	R^*_{t-1} (4)	PP_t (5)	I_t (6)	F_t (7)	Q_{t-1} (8)
Rice							
Increase (per cent)	7.2	30.00	-	-10.3	9.5	-	5.26
Contribution (per cent)	100.0	-23.4	-	-130.7	265.3	-	-31.8
Wheat							
Increase (per cent)	109.9	24.2	30.0	19.8	68.6	497.5	138.7
Contribution (per cent)	100.0	-6.1	-5.2	10.5	17.7	60.2	22.9

Notes: Above figures are for the percentage increase in variables between 1964-65 and 1978-79 and the percentage of contribution of the variables to the absolute increase in production.

The net impact of the changes in variables which have moved in diverse directions and have contradictory influences on supply has been a 7.2 per cent increase in the production of rice and a 110 per cent rise in wheat output. For rice this meagre gain has not been much helped by policy actions except for a 10 per cent improvement in irrigation intensity which by itself may have yielded 265.3 per cent of the growth. The falling procurement price offered in real terms and the increasing offtakes by the public distribution system dampened the potential created by irrigation facilities. In the case of wheat, however, technological development has been aided by the price policy. The farmer's tendency to adjust to circumstances only partially, i.e., to go by past behaviour also, has reinforced the impact of input and procurement policies through time. Although irrigation facility improved dramatically, the contribution to growth of output is not so remarkable as in the case of rice which benefited less, but a 500 per cent rise in fertiliser application has commendable credit in bringing about the growth.

VI

TEST OF THE MODEL

The model specification as well as the hypothesis of rational expectations may be tested for by the appropriateness of the signs of parameters satisfying the underlying constraints for signs of structural parameters and by a simple predictive test of the model (Sheffrin, 1983, p. 163).[6]

Firstly, it may be seen how well the model simulates for the sample period. In Table VII the observed and estimated values of production are provided for all the fifteen years along with the percentage of error. The model has estimated fairly accurately, with errors lying within 10 per cent and the root mean squared error working out to be 3.6 per cent and 4.6 per cent for rice and wheat respectively. It has also been more or less able to trace the movements of supply including the dips encountered in 1965-66 and 1966-67 and 1972-73 through 1974-75.

TABLE VII. ERRORS IN ESTIMATION OF SUPPLY

Year	Rice			Wheat		
	Observed	Estimated	Error (per cent)	Observed	Estimated	Error (per cent)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1964-65	.0258	.0267	3.45	.0828	.0774	6.46
1965-66	.0214	.0216	1.10	.0630	.0626	0.62
1966-67	.0228	.0238	4.38	.0610	.0642	5.25
1967-68	.0324	.0321	0.84	.0736	.0760	3.21
1968-69	.0356	.0353	0.84	.0759	.0713	6.06
1969-70	.0374	.0398	6.34	.0753	.0778	3.29
1970-71	.0433	.0434	0.25	.0767	.0800	4.35
1971-72	.0479	.0448	6.49	.0781	.0796	2.00
1972-73	.0439	.0441	0.52	.0696	.0715	2.72
1973-74	.0383	.0415	8.22	.0760	.0721	5.16
1974-75	.0410	.0388	5.28	.0670	.0677	1.07
1975-76	.0480	.0458	4.52	.0811	.0826	1.88
1976-77	.0473	.0464	1.89	.0684	.0723	5.70
1977-78	.0507	.0513	1.21	.0842	.0789	6.29
1978-79	.0556	.0560	0.70	.0840	.0830	1.14

Note: Error = | (Estimated – Observed) | /Observed × 100.

Forecasts are made with the model for a few post-sample years 1979-80 through 1985-86 for which data are consistently available. Once again the forecasts and actual values are matched and the errors are presented in Table VIII. Barring two years 1979-80 and 1982-83, the errors lie within 10 per cent and the mean squared errors are 12.64 per cent and 8.25 per cent for rice and wheat respectively.

TABLE VIII. PREDICTIONS WITH THE MODEL AND PREDICTIVE ERRORS

Years (1)	1979-80 (2)	1980-81 (3)	1981-82 (4)	1982-83 (5)	1983-84 (6)	1984-85 (7)	1985-86 (8)
			Rice				
Actual	.06503	.07848	.07613	.06582	.08203	.07780	.08359
Predicted	.08396	.07706	.07779	.07560	.08234	.08134	.07975
	(29.12)	(1.81)	(2.18)	(14.95)	(0.38)	(4.56)	(4.59)
			Wheat				
Actual	.04890	.05314	.05355	.05937	.06207	.05877	.06131
Predicted	.05568	.04942	.05103	.05498	.05854	.06341	.06618
	(13.87)	(6.99)	(4.7)	(7.40)	(5.69)	(7.89)	(4.80)

Note: Figures in parentheses are errors = | (Pred. – Actual) | /Actual × 100.

The model has, however, failed to predict the downturn of the first post-sample year 1979-80. Curiously, although the year witnessed poor harvests in general the monsoons having failed, statistics reveal an increased irrigation intensity for both the crops considered. Possibly, this lack of correlation between rainfall and irrigation is the cause of the inadequacy of the model (weather could not be included as a variable in the model).

VII

CONCLUDING REMARKS

Although Muth's original paper (1961) on rational expectations hypothesis (REH) studied agricultural examples, the application of REH in agriculture has been rather sparing. The Nerlovian model has been the most extensively used one to study supply responses in agriculture particularly in India. The latter is basically extrapolative in character with a fixed expectation formula and fails to answer how expectations change when the underlying structure changes or government revises its policies. In India during the last three decades technology has been dynamic and input applications and consequently yield rates and acreages have hardly remained invariant. The government pursues a vigorous dual market policy in foodgrains, deliberately to guide the farmers' decisions. From the experiences of the past, the farmers are found to be rational and responsive to incentives and policies, bringing about a green revolution in the sixties and seventies. Whatever went wrong cannot stem from their irrationality or inflexibility but from lopsidedness of input and price policies although much of this may have been from force of circumstances. Geographical and financial limitations as well as obligations to look after the interests of the consumers, particularly the poor, cannot be ignored. However, the impact of every action on foodgrain supply must be understood carefully and future actions to be taken with this knowledge and the exact objective before us should be clearly specified. The REH model is a way to grasp the response of supply to such important variables, which has been changing continuously, taking account of the complications and interconnectedness of factors in the food market.

The present application of the model reveals that while technology as well as the price policy favoured wheat, the same is not true for rice. Procurement price has been declining and subsidised distribution has been increasing but not in step with the prices or production (Section II). Irrigation has also not improved impressively. Stocking of grains has produced an inverse adjustment of production to past production decelerating any growth impetus.

The model may, however, be improved upon and made more sophisticated by forecasting the exogenous variables by suitable lag models integrated in the model. This may also provide other stringent tests for the model. However, with the simplistic formulations adopted in this study, the results are consistent implying that REH could be used as an alternative to the extrapolative formulations.

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NOTES

1. In a recent paper by Hanumantha Rao and Gulati (1995) for a IFPRI-ICAR project, the authors have remarked: "The favourable incentive effects of liberalising trade by increasing the prices of foodgrains have to be reconciled with the need to protect the vulnerable section of society by strictly targeting food subsidies to the poor through the public distribution system."

2. For a detailed review of issues and literature pertaining to expectations formation, see Narayana (1988).

3. When closing stocks carried over by government was used as a variable, the standard errors of some of the variables went up significantly, possibly owing to multicollinearity with previous year's production.

4. Judgement is made on the basis of rainfall data and description as available in the different issues of the *Statistical Abstract, India* and production performances in general of agriculture. The rainfall indices derived by Narayana and Parikh (1987) were of much help.

5. In 1964 the recommendations of the Jha Committee (Government of India, 1964) provided the foundation for a

sound agricultural price policy and a systematic determination of producer prices of major foodgrains.

6. A more stringent test for REH may be made by incorporating overidentifying restrictions on parameters implied by REH and comparing the estimates with and without restrictions as applied by Goodwin and Sheffrin (1982).

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APPENDIX

Derivation of reduced form price equation:
From equation (5) and (6) we can write:

$$k_1 + \alpha_1 P_t + \beta_1 Y_t + \gamma_1 SP_{t-1} + \delta_1 P^*_t + \theta_1 R_t = k_4 + \alpha_4 P^e_t + \beta_4 I_t + \gamma_4 F_t + \delta_4 Q_{t-1} + \phi_4 P_\bullet t^e + \theta_4 W_t$$

$$+ k_2 + \alpha_2 PC_t + \beta_1 R_t + \gamma_2 SG_{t-1} - R_t - k_3 - \alpha_3 PC_t - \beta_3 R_t - \gamma_3 SG_{t-1} \qquad \text{....(A1)}$$

Solving P_t from equation (A1), we have

$$P_t = a_0 - a_1 Y_t - a_2 Q_{t-1} - a_3 P_{t-1} - a_4 P^{*e}_t - a_5 R_{t-1} + a_6 I_t + a_7 F_t + a_8 W_t + a_9 PP_t \quad ....(A2)$$

where

$a_0 = (k_2 + k_3 + k_4 - k_1)$;

$a_1 = \beta_1 / Z_1$; $a_2 = Z_2 / Z_1$; $a_3 = Z_3 / Z_1$

$a_4 = Z_4 / Z_1$; $a_5 = Z_5 / Z_1$; $a_6 = \beta_4$

$a_7 = \alpha_4$; $a_8 = \theta_4$; $a_9 = Z_6 / Z_1$

and

$$Z_1 = \alpha_1 + \alpha_2\beta_{10} - \alpha_4 - \alpha_3\beta_{10}$$
$$Z_2 = \gamma_1\alpha_8 + \theta_1\beta_9 - \delta_4 - \beta_2\beta_9 - \gamma_2\alpha_{12} + \beta_9 + \beta_3\beta_9 + \gamma_3\alpha_{12}$$
$$Z_3 = \gamma_1\beta_8 - \gamma_3\beta_{12} + \gamma_2\beta_{12}$$
$$Z_4 = \delta_1 - \phi_4$$
$$Z_5 = \theta_1\alpha_9 - \beta_2\alpha_9 + \alpha_9 - \beta_3\alpha_9$$
$$Z_6 = \alpha_2\alpha_{10} - \alpha_3\alpha_{10}$$

Substituting the value of P^{*e}_t in equation (A2), we have the final reduced form price equation:

$$P_t = A_0 - A_1 Y_t - A_2 Q_{t-1} - A_3 P_{t-1} - A_4 R_{t-1} + A_5 I_t + A_6 F_t + A_7 W_t + A_8 PP_t - A_9 Q^*_{t-1} - A_{10} P^*_{t-1} + A_{11} R^*_{t-1} + A_{12} I^*_t + A_{13} PP^*_t \quad ....(A3)$$

where

$A_0 = (a_0 - a_4 a'_0)/b$

$A_1 = (a_1 - a_4 a'_1)/b$

$A_2 = a_2/b$

$A_3 = a_3/b$

$A_4 = a_5/b$

$A_5 = a_6/b$

$A_6 = (a_7 + a_4 a'_7)/b$

$A_7 = (a_8 + a_4 a'_8)/b$

$A_8 = a_9/b$

$A_9 = a_4 a'_2/b$

$A_{10} = a_4 a'_3/b$

$A_{11} = a_4 a'_5/b$

$A_{12} = a_4 a'_6/b$

$A_{13} = a_4 a'_9/b$

[$b = (1 + a_4 a'_4)$ and a'_i implies coefficient of variable of substitute crop.]