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# SHIFTS IN PULSES ACREAGE: AN INTER-REGIONAL ANALYSIS OF DYNAMICS OF FARMERS' RESPONSE, UTTAR PRADESH

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The continuously declining trend in relative pulses acreage in several regions of India witnessed over the last decade has caused growing concern among agricultural scientists as well as policy-makers. This concern has arisen because of the adverse impact that downward trend in acreage movements has on domestic demand and supply conditions. Displacement of acreage under pulses has been especially marked in areas which have witnessed the introduction of new agricultural technology comprising growth promoting inputs, the high-yielding varieties (HYVs) of seeds, use of chemical fertilizers and better farming practices. Despite prices having risen, in some cases quite significantly so, the acreage under pulses has declined most markedly since 1966-67, the starting period of the so-called green revolution in the country (Appendix Tables 1 and 2). The acreage under competing crops like wheat, rice and corn, on the other hand, has since expanded although their relative prices have either remained stable or, in some cases, even fallen! The other crops which have suffered losses in acreage are millets and sorghum and other coarse grains. However, in the latter case the fall in supply has not, as with pulses, resulted in less intake of food because the coarse grains (millets, etc.) have been substituted by superior grains like wheat and rice because of expanded supply, and government's cheap food policy.

The declining trend in acreage under pulses definitely indicates that farmers have adjusted their crop acreages in accordance with shifts in techno-economic conditions. In economic analysis of the dynamics of farm supply response, price is considered the most critical economic factor that determines farmer's production decisions. Empirical evidence is available for several agricultural commodities to support the supply-price relationship. For pulses, however, few studies have been conducted to test the supply-price hypothesis. Studies by Raj Krishna[1] and Sud and Kahlon[2] show a rather weak role of prices in influencing the supply of pulses. However, not much is known about the role of factors such as yield differentials which might represent production technology, risks and irrigation which can be considerably important in influencing farmers' acreage adjustment behaviour particularly with respect to pulses.

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1. Raj Krishna, "Farm Supply Response in India-Pakistan: A Case Study of the Punjab Region", *The Economic Journal*, Vol. LXXIII, No. 291, September 1963.

2. Lalita Sud and A. S. Kahlon, "Estimation of Acreage Response to Price of Selected Crops in Punjab State", *Indian Journal of Agricultural Economics*, Vol. XXIV, No. 3, July-September 1969.

## OBJECTIVES

This study attempts to evaluate the role of both the price and the non-price factors in determining farmers' decisions affecting shifts in inter-crop acreages. Specifically, the study examines the response of pulses supply to changes in (1) post-harvest prices or prices received by farmers during the peak marketing months, (2) yields of both the pulse and the non-pulse crops grown during the particular crop season, (3) irrigation facilities, (4) average rainfall received during the critical periods of the particular crops, and (5) risks arising from price and yield variations.

Although the major focus of the study is on examination of the factors responsible for shifts in inter-crop acreages, it also attempts to project future acreage under pulses based upon estimated growth rates. This provides a basis for indicating the per capita availability of pulses in the future. The price and yield relatives are assumed to remain unchanged over the projected periods. The future growth in population is also assumed to remain the same as projected by the planning and Census authorities in the country.

## THE STUDY AREA

The study is confined to the State of Uttar Pradesh (U.P.) in India. This is one of the country's leading producers of pulses accounting for over 26 per cent of the total production (1971-72). For inter-regional analysis, the State has been divided into four major pulses producing regions. The four regions differ among themselves with respect to agro-climatic as well as techno-economic conditions. Of the four regions, the Eastern region comprises 15 districts and the Central region, nine districts. The Bundelkhand region has four districts which are mostly rainfed, while the Western region has 18 districts most of which have experienced relatively greater impact of modern farm technology than the rest in the State. The Hill region with nine districts was left out for lack of data.

## THE DATA

Of all the pulse crops, the four most important ones included in this study are: gram (*chana*), pigeonpea (*arhar*), black gram (*urd*)and green gram (*moong*). The four crops together account for 75 to 80 per cent of all pulses produced in the State. The study covers the time period starting 1950-51 to 1973-74 for which data on prices, yields, rainfall, irrigation, etc., were available from secondary sources published and/or maintained by the government (mainly the Bulletin of Agricultural Statistics for the State of Uttar Pradesh and the Monthly Bulletin of Prices and Arrivals of Agricultural Commodities).

## THE ANALYTICAL FRAMEWORK

Farm operators face a number of constraints while making production decisions in response to changes in economic environment. It is very seldom that they are able to make hundred per cent adjustments in responding to various economic stimuli, or adjust instantaneously. In an agriculture which is subject to weather uncertainties, or which is undergoing changes in production technology as is the case in some developing countries, such constraints become still more severe. Under such conditions the adjustment lag model is considered appropriate for measuring farmers' response behaviour. Following Nerlove's seminal work[3] on the dynamics of supply response, this model has been widely used by a number of researchers in agricultural supply response studies.

The long run supply $A_t^*$ is assumed, in the Nerlovian framework, to be related to $P_t$ (the prices) in a simple linear manner:

$$A_t^* = a + b\ P_{t-1} + U_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

Variations in $A_t^*$ is connected by variations in observed or actual supply by assuming the following relationship between the actual and long run desired level of supply.

$$A_t - A_{t-1} = \gamma\ [A_t^* - A_{t-1}] \quad \ldots\ldots 0 < \gamma < 1 \qquad \ldots \qquad (2)$$

The current supply then is:

$$A_t = A_{t-1} + \gamma\ [A_t^* - A_{t-1}] \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

$\gamma$ is the coefficient of adjustment. The forces which cause the difference between the short run and long run elasticities of supply will also determine $\gamma$.

When adjustment is perfect $\gamma = 1$. In real world, however, the value of $\gamma$ lies between 0 and 1. Now by substituting the value of $A_t^*$ in equation 2, we get

$$A_t - A_{t-1} = \gamma\ [\alpha + b\ P_{t-1} + U_t - A_{t-1}] \text{ or}$$

$$A_t - A_{t-1} = \alpha\ \gamma + b\ \gamma\ P_{t-1} + \gamma\ U_t - \gamma\ A_{t-1}] \text{ or}$$

$$A_t = \alpha\ \gamma + b\ \gamma\ P_{t-1} + \gamma\ U_t + A_{t-1} - \gamma\ A_{t-1}$$

$$= \alpha\ \gamma + b\ \gamma\ P_{t-1} + \gamma\ U_t + (1-\gamma)\ A_{t-1}$$

$$A_t = A + B\ P_{t-1]} + C\ P_{t-1} + V_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

where $A = \alpha\ \gamma$, $B = b\ \gamma$, $C = (1-\gamma)$,

and $V_t = \gamma\ U_t$.

Equation 4 is the computational equation the parameters of which are estimated by the least-squares method. The reduced form would remain basically the same even if we include more independent variables than the ones included in equation 4.

Besides accounting for the 'lags' that occur in farmers' adjustment behaviour, the model postulated above also helps in the estimation of both the short run and long run supply elasticities.

Using the adjustment lag model[4] as the basic frame of analysis, the response relationships in the study were estimated with the help of the following equation.

3. See Marc Nerlove: (1) The Dynamics of Supply: Estimation of Farmers' Response to Price, The Johns Hopkins Press, Baltimore, 1958, and (2) "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations", *Journal of Farm Economics*, Vol. 40, No. 2, May 1958.

4. For details, see R. D. Singh and Dinkar Rao: Supply Response of Pulses in Uttar Pradesh, India, Project Report and Working Paper, Department of Agricultural Economics, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh, 1975.

$$\text{Log ACRE}_t = \log a + b_1 \log \text{ACRE}_{t-1} + b_2 \log \text{PRMC}_{t-1} - b_3 \log \text{PRCC}_{t-1} + b_4 \log \text{YDMC}_{t-1} - b_5 \log \text{YDCC}_{t-1} - b_6 \log \text{IRRI}_t - b_7 \log \text{RAIN}_t \pm b_8 \log \text{TIMT} \pm b_9 \log \text{PRSK} \pm b_{10} \log \text{YDSK} \quad \ldots \quad (5)$$

where

$ACRE_t$ = acreage under the pulse crop;
$ACRE_{t-1}$ = one year lagged pulse acreage;
$PRMC_{t-1}$ = one year lagged own price;
$PRCC_{t-1}$ = one year lagged competing crop price;
$YDMC_{t-1}$ = one year lagged own yield;
$YDCC_{t-1}$ = one year lagged competing crop yield;
$IRRI_t$ = area under irrigation during the pulse growing season;
$RAIN_t$ = average rainfall in inches during the critical periods (September-November for gram, June 15-August 15 for others);
TIMT = time trend;
PRSK = price risk measured by the standard deviation of three preceding years' own prices; and
YDSK = yield risk represented by the standard deviation of three preceding years' yield.

The log form of the function was chosen mainly because of convenience. It provided direct estimates of supply elasticities besides saving in degrees of freedom.

Incorporation of variables such as yield, irrigation and risks rather than concentrating on only the price factor as has generally been done in the past is considered important to our understanding of the puzzle of shrinking acreage under pulses despite a rise in their prices.

Regressions were run for each of the four regions separately. The disaggregated results provide a better understanding of the factors which influence farmers' production decisions because they highlight the regional differences in response behaviour for crops like pulses in particular because these are grown under varying agro-economic conditions in the country.

The study hypothesized that the price factor does not play a significant role in influencing the supply of pulses. This is because of the following reasons. Differences in inter-crop technological innovations, whether cost-reducing, or yield-increasing, or both, would change the input-output coefficients for different crops. These changes might be such that the price variable *per se* is relegated to the background. It is a fact that the competing crops wheat, rice and corn have, in recent years, witnessed technological break-through of much greater significance than any other crops. The resulant differentials in inter-crop yields have changed the pattern of relative profitability among the various crops. Therefore, it is plausible to expect that the price factor would play a weak role in influencing the acreage under pulses.

The hypothesis pertaining to irrigation was that it would cause a reduction in the area under pulses. With expansion in areas under assured irrigation, it is expected that the farmers will substitute crops like wheat, rice, and corn for pulse crops. Water requirements of the former crops (rice, wheat and corn), especially the HYVs, are much greater than most of pulse crops. For the same reason rainfall was expected to have a similar effect on inter-crop shifts in acreages.

Risks arising from both the price and the yield variations were expected to act as deterrent factors on acreages under pulses. The farmers were hypothesized to be risk avertors.

## RESULTS AND INTERPRETATION

The estimating model initially included prices, yields, irrigation, rainfall and time trend as the independent variables, while acreage, considered as a proxy for supply, as the dependent variable. At a later stage, price and yield risks were also incorporated in the model. The results of simple correlations indicated very strong positive associations among the three price specifications, the post-harvest, the pre-sowing and the annual prices. The value of the correlation coefficient was as high as 0.8 and above in most of the cases. However, equations were estimated with all the alternate price specifications to test the relative performance of the supply model in explaining which of the price variables was most relevant to farmers' expectational behaviour concerning inter-crop acreage allocations. Interestingly, the results of regression did not indicate anything conclusive to suggest one or the other of the three prices tried as the most relevant in explaining the farmers' decisions.

Therefore, any of the three price specifications could have been used to represent the price variable for estimating the supply relationships. But since the bulk of the marketable surplus is sold by the farmers in the post-harvest period of about three to four weeks, it was decided to use the post-harvest prices in the model finally chosen for estimating the supply relationships.

### *Lagged Prices*

The results of regression analyses (Tables I and II) show that in a majority of the cases, the impact of the price variable has been either too weak, or even negative in some cases. Nothing conclusive emerges with respect to the crops own prices, or that of the competing crop prices. In fact, the supply-price response (negative in the case of own prices or positive in the case of competing crop prices) observed in this study may, when considered in isolation, even suggest a phenomenon of illogical economic relationships. However, the results have to be interpreted in the background of the fact that the continuously declining acreage under pulses has been accompanied in most of the regions under study with rising prices of pulse crops over the last decade. It is also a fact that the price factor has been almost over-swamped by the non-price factors such as technological changes in competing crops in influencing shifts in inter-crop acreages.

TABLE I—ESTIMATED COEFFICIENTS FOR SUPPLY RESPONSE MODELS WITHOUT RISK VARIABLE: LOG FUNCTION

| | Regions | | | | Regions | | | |
|---|---|---|---|---|---|---|---|---|
| | Eastern | Central | Bundel-khand | Western | Eastern | Central | Bundel-khand | Western |
| | Crop: Gram | | | | Crop: Pigeonpea | | | |
| PRMC | —·891*** (·237) | ·029 (·303) | ·135 (·239) | —·139 (·152) | —·004 (·081) | —·012 (·111) | ·150 (·125) | ·076 (·215) |
| PRCC | ·636** (·229) | .356 (·246) | —·336** (·113) | ·103 (·173) | ·269** (·110) | —·075 (·119) | —·151@ (·110) | —·130 (·164) |
| YDMC | ·220 (·218) | ·121 (·125) | —·108 (.009) | ·198 (·126) | ·021 (·086) | ·024 (·054) | ·032 (·041) | —·048 (·065) |
| YDCC | —·087 (·292) | —·062 (·123) | ·213** (·084) | —·394** (·142) | ·007 (·045) | ·032 (·077) | —·282*** (·099) | —·081 (·139) |
| IRRI | —·118 (·364) | —·175 (·230) | —·193* (·122) | —·343* (·182) | —·018 (·184) | ·248* (·121) | ·416*** (·131) | —·105 (·100) |
| RAIN | —·238*** (·079) | —·033 (·037) | ·009 (·018) | —·021 (·042) | —·090* (·052) | —·056 (·070) | —·113 (·110) | —·039 (·122) |
| TIMT | ·045 (·048) | —·003 (·032) | ·046@ (·029) | —·003 (·032) | —·009 (·023) | —·080* (·039) | —·037 (·051) | —·044 (·052) |
| LGAC | ·223 (·356) | ·029 (·303) | ·135 (·239) | ·473* (·260) | —·363* (·199) | ·024 (·305) | ·062 (·077) | ·385 (·290) |
| Constant 'a' in logs | 6·252 | 6·849 | 5·819 | 5·328 | 7·076 | 4·282 | 3·749 | 4·703 |
| $R^2$ | 76·8 | 67·2 | 79·24 | 67·63 | 81·03 | 56·54 | | 76·00 |

*** Significant at 1 per cent level.

** Significant at 5 per cent level.

* Significant at 10 per cent level.

@ Significant at 20 per cent level.

Standard errors in parentheses.

TABLE II—ESTIMATED COEFFICIENTS FOR SUPPLY RESPONSE MODELS WITHOUT RISK VARIABLE: LOG FUNCTION

| | Regions | | | | Regions | | | |
|---|---|---|---|---|---|---|---|---|
| | Eastern | Central | Bundelkhand | Western | Eastern | Central | Bundelkhand | Western |
| | Crop: Green gram | | | | Crop: Black gram | | | |
| PRMC | ·131 | —1·024*** | —·362** | ·766** | —·122 | —·209 | ·313 | ·055 |
| | (·234) | (·611) | (·129) | (·379) | (·114) | (·258) | (·240) | (·181) |
| PRCC | ·115 | ·306 | ·631*** | —·826* | —·110 | —·057 | —·185 | —·164 |
| | (·184) | (·638) | (·137) | (·470) | (·098) | (·262) | (·209) | (·208) |
| YDMC | ·234* | ·401 | —·052 | ·008 | ·236 | ·093 | ·202 | ·008 |
| | (·148) | (·306) | (·109) | (·238) | (·124) | (·151) | (·124) | (·160) |
| YDCC | ·004 | —·509@ | ·023 | —·525@ | —·017 | —·203 | ·257* | —·061 |
| | (·174) | (·343) | (·043) | (·331) | (·069) | (·155) | (·123) | (·430) |
| IRRI | —·037 | 2·672*** | —·330* | —·026 | ·259 | —·009 | ·176 | —·050 |
| | (·056) | (·524) | (·180) | (·640) | (·231) | (·289) | (·270) | (·127) |
| RAIN | —·035 | ·162 | ·646*** | ·213 | ·069 | —·067 | ·139 | —·0308 |
| | (·175) | (·439) | (·132) | (·216) | (·071) | (·159) | (·198) | (·128) |
| TIMT | —·095 | —·296** | ·115 | —·073 | ·004 | —·036 | ·168 | —·199 |
| | (·091) | (·181) | (·072) | (·080) | (·044) | (·104) | (·106) | (·178) |
| LGAC | ·450* | —·409** | ·506** | ·829*** | —·271 | ·277 | —·156 | —·161 |
| | (·232) | (·321) | (·155) | (·242) | (·283) | (·346) | (·259) | (·630) |
| Constant 'a' in logs | 1·496 | —8·089 | 1·159 | 1·361 | 4·429 | 4·882 | 3·156 | 6·632 |
| $R^2$ | 74·30 | 83·35 | 86·17 | 93·44 | 63·95 | 78·23 | 77·87 | 85·71 |

*** Significant at 1 per cent level.
** Significant at 5 per cent level.
* Significant at 10 per cent level.
@ Significant at 20 per cent level.
Standard errors in parentheses.

From the results it should not be inferred that the price factor is altogether irrelevant to the dynamics of farmers' acreage decisions pertaining to pulses acreage under all conditions. For example, in the Bundelkhand region the elasticity coefficient of own prices is positive, although non-significant in three cases, while the coefficient of the competing crop prices is negative and significant in two out of the four cases. In the Western region also, in the case of green gram, the supply-price relationship is strong with the expected signs for both the own prices and the competing crop prices (Tables I and II). Nevertheless, the fact remains that the overall supply-price relationship is weak, and in most cases the results do not support the generally expected positive supply-price response relationship.

*Crop Yields*

The acreage under gram shows a positive relationship with the own yield variable in the Eastern, Central and Western regions. In all the cases though, the elasticity coefficients are statistically non-significant. The competing crop yield variable, on the other hand, has had a deterrent impact on gram acreage in these regions, and the elasticity coefficient for this variable however appeared statistically significant only in the Western region.

The negative impact of the yield of the competing crop, which is mainly wheat, should be considered in the context of the spread of the HYVs of seeds of competing crops in a particular region. For example, the yield of wheat in the Eastern and Central regions has consistently lagged behind that of the Western region. This is because the Western region has witnessed a relatively greater impact of the recent technological break-through in agriculture than the rest of the State. This in part explains why the deterrent effect of wheat yield on gram acreage has been most pronounced in the Western region, the elasticity coefficient varying from $-0.3940$ to $-0.4352$, significant at 1 to 5 per cent level. This relationship reflects a growing technological imbalance between a pulse crop like gram and wheat—the major crop competing with pulses during the *rabi* (winter crop) season. This trend is likely to persist as long as wheat yields experience upward trend as a result of varietal improvements, and greater adoption of new technology by farmers, while the yields of pulses lag behind in this process of technological break-through.

There is also another interesting feature of the supply-yield relationship as observed in the case of the Bundelkhand region. While the yield of gram has had no significant consequence on its acreage variations, in this region the yield of wheat exercised a positive and significant impact on acreage under gram. This appears plausible because in a rainfed area like Bundelkhand, wheat and gram are grown as mixed crops as a measure of risk minimization by farmers. The two crops act more as complementary rather than as substitute crops. Therefore, as the Bundelkhand result will show, under the present conditions of scarcity of water, and fertilizers becoming not only short in supply but also costly, the farmers in such regions would tend to bring in more acreage under gram and similar other crops whose water requirements are relatively much less than their competitors.

The results of regression do not establish any relationship of significance between acreage under pigeonpea (*arhar*) and its yield. The same holds true for the competing crop yield except that the regression equation for the Bundelkhand region shows a strong negative influence of the yield of black gram (*urd*) on area under pigeonpea.

In the case of green gram (*moong*), of all the regions, the yield factor has emerged most positive and strong only in the Eastern region, with a short run supply-yield elasticity in the range of 0.2047 to 0.2459, both the coefficients being significant at 10 per cent level. In all other regions the impact of this variable has remained weak. The yield of the competing crop has had exercised a strong negative effect on area under green gram only in the Western region with an elasticity coefficient of as high as −0.5819, significant at 10 per cent level. In all other regions this variable has had no impact of any significance. In fact, when this crop is grown as a summer crop, as is generally the practice in most parts, there is hardly any competition from other crops—the *kharif* crops thus become mostly irrelevant in the context of inter-crop substitution influencing acreage under this crop.

The own yield variable in the case of black gram (*urd*) shows a relatively stronger positive influence on acreage variations in the Eastern and Bundelkhand regions. In the Bundelkhand region the acreage under this crop also shows a strong positive relationship with the yield of bajra (pearl millet) which will indicate complementarity between the two crops. In all other regions, however, the yield variable, whether in terms of crop own yield or that of the substitute, appears to exercise a weak and statistically non-significant impact on acreage variations.

*Irrigation*

With expansion in irrigation, the acreage under gram has tended to decline across all the regions of the State as shown by the negative coefficients for this variable. However, the individual regions differ in the extent of the impact of this variable on variations in acreage under pulses. The results of regression show a mixed response in respect of individual pulse crops as well as regions.

The most severe impact has been felt in the Western region with a supply-irrigation elasticity of −0.3431, significant at 10 per cent level, followed by Bundelkhand with supply elasticity of −0.1934, also significant at 10 per cent level. The elasticity coefficients for the Eastern and Central regions also had the expected negative signs, though statistically not significant.

The effect of irrigation on acreage under pigeonpea (*arhar*), on the other hand, has been positive and strong in the Bundelkhand region with an elasticity coefficient of 0.4156, significant at one per cent level, followed by the Central region where the acreage elasticity is of the order of 0.2485, significant at 10 per cent level (Table I). In the Eastern and Western regions, however, the coefficients of irrigation, though negative, appeared statistically non-significant.

The positive acreage-irrigation response in the Bundelkhand and Central regions might be explained by the widespread practice of growing pigeonpea together with maize. Maize requires relatively a greater amount of water than other crops during the season, and hence the acreage under mixed crops (maize + pigeonpea) may be expected to vary positively with expansion of irrigation facilities in the region. Normally, one would expect displacement of *arhar* acreage with increasing use of irrigation because the farmers will shift to other competing crops whose water requirements are relatively greater and returns higher.

The response of green gram (*moong*) acreage to irrigation has been negative in the Bundelkhand, Eastern and Western regions—the acreage elasticity varying between −0.0259 (Western region) and −0.3304, (Bundelkhand region). However, the regression coefficient for this variable is statistically significant only in the Bundelkhand region.

The Central region exhibits a considerably strong positive impact of irrigation on its acreage under green gram, with an elasticity coefficient as high as 2.6724, significant at one per cent level. A positive effect of irrigation is plausible when this crop is sown as a summer crop and it requires irrigation water. During this period there is generally no competition from other crops. Most of the *zaid* (summer) pulses will have this characteristic in several parts that grow pulses with the help of irrigation water.

Irrigation has had a negative impact on acreage under black gram(*urd*) in most of the cases, though the regression coefficients for this variable are non-significant in all the regions. Despite the statistically non-significant results, the deterrent effect of irrigation on *urd* area cannot be ruled out unless this crop is raised as a summer (*zaid*) crop, or like other pulse crops, some varietal improvements are introduced.

*Rainfall*

Rainfall received during the critical period, *i.e.*, during the pre-sowing months of the year shows a negative effect on gram acreage in the Eastern, Central and Western regions. The deterrent effect of rainfall appears most severe in the Eastern region. This region receives a relatively higher rainfall than the rest of the State. The coefficient of irrigation is weak and statistically non-significant in the case of other regions (Table I).

The acreage under pigeonpea (*arhar*) too has responded inversely to rainfall. In this case also the coefficient of rainfall is statistically significant only in the equation for the Eastern region. The acreage-rainfall relationship is consistently negative in all the regions.

*Moong* (green gram) acreage responds positively in the three regions while negatively in one region (Table II). The Bundelkhand region shows the most powerful positive impact of rainfall on its *moong* acreage. In all other regions the response is non-significant irrespective of the signs of the regression coefficients. Since this crop is generally raised during summer when there is not much competition for land from other crops, with greater rainfall received during this period the farmers tend to grow more of this crop.

The coefficient of rainfall in green gram (*urd*) acreage equation is positive in two regions while negative in the other two. In all cases this coefficient is statistically non-significant (Table II).

*Risk vis-a-vis Farmers' Acreage Decisions*

Agricultural production is generally subjected to two major sources of risk, one arising from variabilities in prices, and the other in yield. Fluctuations in prices reflect conditions of demand and supply including uncertainties and imperfections in marketing systems. Variabilities in yield, on the other hand, are caused by weather conditions as is the case of most of the pulse crops in India, or by changes in production technology. The relative incidence of these risks may differ among individual crops and regions. Both the kinds of risk were incorporated in the model and the results of regression are presented in Tables III and IV.

The estimating model with risk variables substituting for the price and yield variables yielded some interesting results. First, the overall performance of the model improved in terms of the explanatory power of the equations as shown by the higher values of $R^2$ in all the cases. Secondly, the trend (TIMT) variable picked up quite significantly with respect to both the strength of this variable and its statistical significance. Third, overall, the rainfall and irrigation variables showed relatively less powerful effect on acreage variations than when these were included in the model without the risk variable. Fourth, the supply model yielded mixed results pertaining both to the price and the yield risk variable vis-a-vis the farmers' acreage decisions.

The coefficient of price risk on gram acreage is negative in the Eastern and Central regions, while positive in the Bundelkhand and Western regions but in none of the regions it is statistically significant (Table III).

The same is true for the yield risk variable except for the Eastern region where this variable has exercised a relatively strong and statistically significantly deterrent influence on acreage under the crop (gram).

The acreage under pigeonpea (*arhar*) responds negatively to price risk in the Western region, while in the rest of the regions the response is positive. The positive elasticity coefficient for this variable is statistically significant at one per cent level in the Eastern region, and at 10 per cent level in the Central region. The positive elasticity coefficient for the yield risk variable is statistically significant only in the Central region.

The statistical results indicate that except for the price risk variable in one region, the pigeonpea growing farmers seem to have averted risks by putting more acreage under the crop. Comparatively, the Bundelkhand farmers appear least concerned about risks, while the farmers in the Eastern and Central regions appear to be risk lovers.

Farmers' response to yield risk is consistently positive in all the regions. The coefficient of yield risk is statistically significant only in the equation for the Central region (Table III).

TABLE III—ESTIMATED COEFFICIENTS FOR SUPPLY RESPONSE MODELS WITH RISK VARIABLE: LOG FUNCTION

| | Regions | | | | Regions | | | |
|---|---|---|---|---|---|---|---|---|
| | Eastern | Central | Bundelkhand | Western | Eastern | Central | Bundelkhand | Western |
| | Crop: Gram | | | | Crop: Pigeonpea | | | |
| PRSK .. | —·01 | —·01 | ·01 | ·01 | ·08*** | ·09* | ·004 | —·05@ |
| | (·03) | (·02) | (·01) | (·02) | (·03) | (·04) | (·040) | (·03) |
| YDSK .. | —·07* | —·02 | ·01 | ·04 | ·02 | ·08*** | ·008 | ·05 |
| | (·04) | (·02) | (·04) | (·06) | (·03) | (·03) | (·040) | (·04) |
| IRRI .. | —·13 | ·06 | ·02 | —·37@ | ·51 | ·15 | ·46@ | —·37 |
| | (·40) | (·12) | (·03) | (·27) | (·34) | (·15) | (·30) | (·36) |
| RAIN .. | ·01 | ·01 | ·06* | —·05 | —·02 | —·12@ | —·29* | —·09 |
| | (·03) | (·02) | (·02) | (·08) | (·05) | (·08) | (·17) | (·11) |
| TIMT .. | —·10*** | —·07*** | ·36@ | ·03 | —·04 | —·04 | —·07 | —·02 |
| | (·03) | (·02) | (·27) | (·71) | (·06) | (·05) | (·09) | (·14) |
| LGAC .. | ·08 | ·19 | ·36 | ·88*** | —·51* | —·51* | ·25 | ·34 |
| | (·29) | (·19) | (·27) | (·24) | (·31) | (·21) | (·28) | (·25) |
| Constant 'a' .. | 15·31 | 12·49 | 8·30 | 7·69 | 13·75 | 18·08 | 5·67 | 14·58 |
| $R^2$ .. | 84·59 | 89·72 | 61·16 | 85·90 | 70·55 | 54·06 | 66·41 | 84·74 |

*** Significant at 1 per cent level.
** Significant at 5 per cent level.
* Significant at 10 per cent level.
@ Significant at 20 per cent level.
Standard errors in parentheses.

TABLE IV—ESTIMATED COEFFICIENTS FOR SUPPLY RESPONSE MODELS WITH RISK VARIABLE: LOG FUNCTION

| | Regions | | | | Regions | | | |
|---|---|---|---|---|---|---|---|---|
| | Eastern | Central | Bundelkhand | Western | Eastern | Central | Bundelkhand | Western |
| | Crop: Green gram | | | | Crop: Black gram | | | |
| PRSK .. | —·13*** | —·10 | —1·56*** | —·16** | —·03* | —·03 | ·03 | —·007 |
| | (·03) | (0·12) | (·42) | (·06) | (·02) | (·04) | (·29) | (·01) |
| YDSK .. | —·03@ | —·24@ | —·62@ | ·03 | —·02 | ·02 | —·09 | —·01 |
| | (·02) | (·15) | (·40) | (·04) | (·05) | (·08) | (·28) | (·02) |
| IRRI .. | 1·01 | 1·99*** | —21·90*** | ·20 | ·77** | ·05 | 1·12 | ·31 |
| | (·37) | (·64) | (3·80) | (·35) | (·24) | (·29) | (2·15) | (·28) |
| RAIN .. | —·17*** | ·21 | 3·96*** | ·21 | ·06 | ·003 | ·96 | ·05 |
| | (·07) | (·36) | (1·47) | (·16) | (·05) | (·13) | (·90) | (·09) |
| TIMT .. | —·11@ | —·85*** | 6·70*** | —·41*** | —·19*** | —·13 | —·17 | —·17* |
| | (·08) | (·25) | (1·22) | (·14) | (·05) | (·16) | (·68) | (·10) |
| LGAC .. | ·76*** | ·28@ | —5·37*** | ·12 | —·12 | ·39 | ·81 | ·24 |
| | (·14) | (·18) | (1·66) | (·23) | (·19) | (·34) | (1·23) | (·31) |
| Constant 'a' in logs | —10·17 | —18·58 | 28·32 | 4·71 | 2·22 | 6·97 | —17·20 | 3·83 |
| $R^2$ .. | 78·51 | 52·56 | 78·53 | 91·97 | 68·13 | 73·96 | 25·68 | 74·51 |

*** Significant at 1 per cent level.
** Significant at 5 per cent level.
* Significant at 10 per cent level.
@ Significant at 20 per cent level.
Standard errors in parentheses.

The response of green gram (*moong*) acreage to price variabilities is negative, substantially powerful and widespread in three out of the four equations (Table IV). Of all the regions, the coefficient of price risk is the largest in the equation for Bundelkhand exceeding even unity. This indicates that the farmers in this region have reacted most powerfully to risks arising from price variations. This is followed by the Eastern and Western regions. In the Central region the impact of price risk, though negative, is statistically non-significant. As compared to the strong effect of price risk, the deterrent effect of yield risk on green gram acreage variations is much weaker and less widespread.

The acreage response model for black gram (*urd*) shows a negative coefficient for the price risk variable in three out of the four regions. The same is true for the coefficient of yield risk. However, except for the price risk coefficient in the supply model for the Eastern region where it is significant at 10 per cent level, in all other cases the coefficients of both the price and yield risks are statistically non-significant.

Overall, the results indicate that the response of *kharif* (winter) pulses has been more consistent with economic theory which suggests negative relationship between risk and crop acreage. The deterrent impact of risks whether of yields or prices will point to the need for reducing the occurrence of such risks. In order to maintain the desired level of acreage under and production of pulses, the farmers will have to be assured of not only remunerative and stable prices but also of good and stable yields. Appropriate policies will therefore need to focus on (*a*) favourable pricing (and marketing) conditions, and (*b*) technological changes in pulses like varietal improvements, disease and pests control measures, for example.

## GROWTH TREND AND FUTURE PROJECTIONS

### *Growth Trend*

The coefficient of the trend variable (TIMT) is negative in the Eastern, Central and Western regions, while positive in the Bundelkhand region for all pulses. The annual growth rates presented in Table V have been calculated with the help of a simple regression equation with the time trend as the sole explanatory variable.

Of the four regions, the Bundelkhand region shows consistently positive growth, while the rest of the three regions show negative growth in acreage under all the major pulse crops. The annual growth rate of gram varies from + 0.9 per cent in the Bundelkhand region to − 2.1 per cent in the Western region. The Western region has suffered the most in terms of displacement of acreage under all the pulse crops under study, the decline being the highest (7.5 per cent per annum) for green gram (*moong*). The results show that pulses have been a losing crop in three out of the four regions which account for the major share of total production of pulses in the State.

TABLE V—ESTIMATES OF GROWTH RATES AND FUTURE PROJECTIONS

| Crops/Regions | Estimated growth rates (per cent) | Acreage projections in thousand acres | | | |
|---|---|---|---|---|---|
| | | 1985 | 1990 | 1995 | 2000 |
| 1. Gram | | | | | |
| A. Eastern .. | —1·5 | 877 | 765 | 654 | 542 |
| B. Central .. | —1·3 | 875 | 791 | 707 | 624 |
| C. Bundelkhand .. | +0·9 | 1,847 | 1,921 | 1,995 | 2,090 |
| D. Western .. | —2·1 | 890 | 687 | 484 | 281 |
| 2. Pigeonpea | | | | | |
| A. Eastern .. | —0·5 | 374 | 361 | 347 | 334 |
| B. Central .. | —0·7 | 299 | 286 | 273 | 261 |
| C. Bundelkhand .. | +1·1 | 294 | 307 | 320 | 333 |
| D. Western .. | —2·4 | 186 | 130 | 75 | 19 |
| 3. Green gram (lentils) | | | | | |
| A. Eastern .. | —1·7 | 3 | 3*a* | 2*b* | 2*c* |
| B. Central .. | —0·7 | 6 | 5 | 5 | 5*d* |
| C. Bundelkhand .. | +1·2 | 5 | 5 | 5 | 6 |
| D. Western .. | —7·5 | — | — | — | — |
| 4. Black gram | | | | | |
| A. Eastern .. | —0·3 | 72 | 70 | 69 | 67 |
| B. Central .. | —3·4 | 36 | 1 | — | — |
| C. Bundelkhand .. | +4·8 | 84 | 93 | 104 | 113 |
| D. Western .. | —2·5 | 33 | 22 | 11 | —*e* |

(*a*) 2,659 acres.

(*b*) 2,203 acres.

(*c*) 1,748 acres.

(*d*) 4,825 acres.

(*e*) 46 acres.

The results will lend further support to the contention that the regions of relatively higher levels of production technology are also likely to experience greater diversion of land and other resources from pulses to those crops that undergo technological changes. The crops that have experienced such changes are wheat, rice and maize. The adoption of HYVs of seeds by the farmers and consequently larger acreage shifts in favour of these crops at the cost of acreages under pulses and other crops like jowar, bajra and barley since 1966 onward (Appendix Table 1) will bear testimony to this phenomenon.

*Acreage Projections*

The loss of acreage is of the highest order in the Western region for all the pulse crops considered in this study. Pulses like green gram and black gram are likely to disappear completely from this region by 1985 and 2000 A.D. respectively, if the trend so far experienced continues to persist in the years to come. The other losing regions are the Eastern and Central regions, though the magnitude of loss in these regions is less than in the Western region. There is, however, an increase in acreage under all the four pulse crops in the Bundelkhand region which is dominantly a rainfed region with relatively favourable agro-climatic conditions for the production of pulses.

Despite some minor gain in pulses acreage in the Bundelkhand region, the overall acreage under pulses will continue to decline in the State as a whole. For example, the total acreage under gram in the four regions is estimated to decline from 5.1 million acres in 1970-71 to 4.8 million acres in 1980-81, to 4.2 million acres in 1990-91, and further to 3.5 million acres in 2000-01. Similarly, the pigeonpea (*arhar*) acreage is expected to fall from 1.4 million acres in 1970-71 to 1.2 million acres in 1980-81, to 1.1 million acres in 1990-91, and to as low as 0.9 million acres in 2000-01. The area under green gram (*moong*) would decline from 20,045 acres in 1970-71 to 14,430 acres in 1980-81, to 13,505 acres in 1990-91, and further to 12,580 acres in 2000-01. The black gram (*urd*) acreage is expected to decline from 3.0 million acres in 1970-71 to 2.6 million acres in 1980-81, to 1.9 million acres in 1990-91, and to 1.8 million acres in 2000-01.

The overall results thus show two most noteworthy trends. First, the acreage under all the major pulse crops is on the decline. Second, there are quite marked inter-regional differences in the magnitude of inter-crop diversion of land, the Western region experiencing the largest decline in the case of green gram, pigeonpea and gram, while the Central region in the case of black gram.

*Projected Availability*

Based on the projected acreage and production, the per capita availability of pulses was estimated by dividing the total production (less 15 per cent on account of seeds, feed and wastage) by the total population. As revealed by the data in Table VI, the Bundelkhand region will have larger amount of pulses available than the Eastern and Western regions. Considering that there will be inter-regional transfer of pulses, the Bundelkhand region would be the major supplier especially to the Western and Eastern regions which have relatively greater concentration of population and lesser availability of pulses. The Western region would definitely face greater scarcity of supply because of diversion of relatively large pulses area to other crops. For example, taking all the pulses produced in the region the per capita availability is estimated at about 52 grams of pulses per day in 1961, 26.5 grams per day by 1981, 12.8 grams by 1991, and just 3.5 grams by 2001. Next is the Eastern region where the per capita supply from within the region would reach a drastically low level. The per capita availability in relative terms would also decline in the Bundelkhand region, though in terms of absolute level, it would still be having a much higher level of supply than the other regions of the State. The Central region too would face a fall in its per capita availability, although this region would be better off than both the Eastern and Western regions.

At the State level when one allows for inter-regional movement of pulses, the per capita availability of all pulses will be about 40 grams by 1981 and just 17.1 grams by 2001. Assuming all round scarcity of pulses in the country as a whole, the situation is not likely to improve significantly either in respect of availability, or prices.

Pulses until recently have been relatively cheaper sources of proteins to the poorer sections of population which cannot afford other sources anyway either because of the price factor, or because of consumption habits. This means that the scarcity of pulses and consequently higher prices that may be expected in the future will create serious imbalances in the dietary mix of the majority of the low income people unless substitutes are available at reasonable prices.

*Implications*

Briefly, the results of this study lead to three important implications that seem to be relevant to public policies. First, varietal improvements in pulse crops and their adoption by the farmers having comparative advantages, agro-climatic or others, will be important for maintaining production at desired levels. Second, the price and risk factors will need to be taken care of by appropriate measures in order to provide the necessary incentives to the producers; these policies must indeed go hand in hand with policies related to production technology. The third implication, although indirect, is that since dairy and poultry products may provide good substitutes to counter nutritional deficiencies arising from scarcity of pulses, efforts will need to be directed towards the promotion of enterprises like dairy and livestock in agriculture.

TABLE VI—PER CAPITA AVAILABILITY PER DAY OF MAJOR PULSES*

(*grams*)

| Pulses/Year | Regions | | | | Average of four regions |
|---|---|---|---|---|---|
| | Eastern | Western | Central | Bundelkhand | |
| 1. Gram | | | | | |
| 1961 .. .. .. | 31·57 | 43·23 | 54·49 | 240·09 | 50·60 |
| 1971 .. .. .. | 25·33 | 26·30 | 60·76 | 244·91 | 43·51 |
| 1981 .. .. .. | 13·95 | 18·48 | 32·17 | 178·06 | 27·40 |
| 1991 .. .. .. | 8·62 | 9·35 | 21·80 | 153·97 | 18·79 |
| 2001 .. .. .. | 4·87 | 3·08 | 14·08 | 135·40 | 11·77 |
| 2. Pigeonpea (*arhar*) | | | | | |
| 1961 .. .. .. | 17·63 | 7·49 | 15·29 | 10·79 | 13·08 |
| 1971 .. .. .. | 13·66 | 13·18 | 23·29 | 41·71 | 16·72 |
| 1981 .. .. .. | 8·98 | 7·63 | 10·44 | 36·62 | 11·27 |
| 1991 .. .. .. | 6·67 | 3·39 | 12·41 | 31·95 | 7·77 |
| 2001 .. .. .. | 4·93 | 0·40 | 9·27 | 28·32 | 4·91 |
| 3. Green gram (*moong*) | | | | | |
| 1961 .. .. .. | 0·077 | 0·116 | 0·112 | 0·37 | 0·11 |
| 1971 .. .. .. | 0·024 | 0·032 | 0·039 | 0·17 | 0·03 |
| 1981 .. .. .. | 0·027 | — | 0·092 | 0·31 | 0·04 |
| 1991 .. .. .. | 0·016 | — | 0·069 | 0·27 | 0·03 |
| 2001 .. .. .. | 0·008 | — | 0·051 | 0·24 | 0·02 |
| 4. Black gram (*urd*) | | | | | |
| 1961 .. .. .. | 0·741 | 0·917 | 3·13 | 1·84 | 1·32 |
| 1971 .. .. .. | 0·462 | 0·599 | 1·12 | 1·93 | 0·71 |
| 1981 .. .. .. | 0·596 | 0·343 | 1·18 | 4·55 | 0·81 |
| 1991 .. .. .. | 0·455 | 0·138 | 0·014 | 5·72 | 0·47 |
| 2001 .. .. .. | 0·347 | — | — | 4·49 | 0·35 |
| All pulses | | | | | |
| 1961 .. .. .. | 49·56 | 51·76 | 73·03 | 253·12 | 65·12 |
| 1971 .. .. .. | 39·48 | 39·57 | 85·22 | 288·74 | 60·98 |
| 1981 .. .. .. | 23·56 | 26·46 | 51·32 | 219·55 | 39·81 |
| 1991 .. .. .. | 15·77 | 12·81 | 34·29 | 190·77 | 27·07 |
| 2001 .. .. .. | 10·16 | 3·47 | 23·50 | 168·51 | 17·07 |

* These estimates are based upon the projected production and population in the regions under study.

APPENDIX TABLE 1

MOVEMENTS IN ACREAGE UNDER MAJOR PULSES AND OTHER CEREAL CROPS IN UTTAR PRADESH (1956-57—1971-72)

(*thousand acres*)

| Crops | 1956-57 | 1966-67 | 1971-72 |
|---|---|---|---|
| Pulses | | | |
| Gram .. .. .. .. .. | 6,142 | 5,887 | 4,911 |
| Pigeonpea (*arhar*) .. .. .. | 1,630 | 1,641 | 11,55 |
| Black gram (*urd*) .. .. .. | 466 | 345 | 360 |
| Green gram (*moong*) .. .. .. | 44 | 28 | 29 |
| All pulses .. .. .. .. .. | 10,821 | 10,582 | 8,702 |
| Other cereals | | | |
| Wheat .. .. .. .. .. | 9,973 | 10,853 | 14,953 |
| Rice (unhusked) .. .. .. .. | 9,524 | 10,665 | 11,663 |
| Maize .. .. .. .. .. | 2,504 | 3,368 | 3,653 |
| Barley .. .. .. .. .. | 4,930 | 3,729 | 3,240 |
| Bajra .. .. .. .. .. | 2,778 | 2,500 | 2,344 |
| Jowar .. .. .. .. .. | 2,205 | 227 | 1,533 |
| All other cereals .. .. .. .. | 33,839 | 34,740 | 39,039 |

*Source:* Computed from the Bulletin of Agricultural Statistics and other official published sources for the State of Uttar Pradesh.

APPENDIX TABLE 2

MOVEMENTS IN PRICES OF MAJOR PULSES AND NON-PULSES CROPS IN UTTAR PRADESH

| Crops | Post-harvest prices per quintal (in rupees) | | |
|---|---|---|---|
| | 1956-57 | 1966-67 | 1971-72 |
| Pulses | | | |
| Gram (*chana*) .. .. .. .. | 26·8 | 63·9 | 74·4 |
| Pigeonpea (*arhar*) .. .. .. | 40·2 | 73·2 | 88·5 |
| Black gram (*urd*) .. .. .. | 55·1 | 126·8 | 174·7 |
| Green gram (*moong*) .. .. .. | 39·0 | 118·0 | 134·9 |
| Cereals | | | |
| Wheat .. .. .. .. .. | 32·8 | 71·8 | 79·4 |
| Rice (unhusked) .. .. .. .. | 45·6 | 126·3 | 57·6 |
| Maize .. .. .. .. .. | 24·2 | 72·6 | 67·3 |

*Source:* Computed from Monthly Bulletins of Agricultural Prices and Market Arrivals, Government of Uttar Pradesh, Lucknow, Uttar Pradesh.