WP-2006-009

Supply Response of Indian Farmers: Pre and Post Reforms

G. Mythili

Indira Gandhi Institute of Development Research, Mumbai
November 2006

Supply Response of Indian Farmers: Pre and Post Reforms[1]

G. Mythili

Associate Professor
Indira Gandhi Institute of Development Research (IGIDR)
General Arun Kumar Vaidya Marg
Goregaon (E), Mumbai- 400065, INDIA
Email: mythili@igidr.ac.in

Abstract

Supply response to price changes is likely to increase with the increasing liberalization of the agricultural sector. Past studies revealed weak supply response for Indian agriculture. There are no recent reliable estimates to see if the response has improved after the economic reforms introduced in early 90s in India. This study estimates supply response for major crops during pre and post reform periods using Nerlovian adjustment cum adaptive expectation model. Estimation is based on dynamic panel data approach with pooled cross section - time series data across states for India. The standard procedure is to use area as an indicator of supply due to the reason that area decision is totally under the control of farmers. Moreover using supply conceals some variations in area and yield if they move in the opposite directions. In this paper, it is hypothesized that acreage response underestimates supply response and farmers respond to price incentives partly through intensive application of other inputs given the same area, which is reflected in yield. Acreage and yield response functions were estimated and the supply response estimates were derived from these two responses. The significant feature of the specification used in the study is both main and substitutable crops are jointly estimated by a single equation by introducing varying slope coefficients to capture different responses. As expected, foodgrains reveal less response than non-foodgrains. The study found no significant difference in supply elasticities between pre and post reform periods for majority of crops. It raises questions such as whether the constraints are properly identified by the policies or if the impact of reform is yet to be felt in order to make a prominent impact on response parameters. In this study, infrastructural variables other than irrigation could not be introduced due to lack of information for a long time series. Results confirmed that farmers respond to price incentives equally by more intensive application of non-land inputs. Further analysis of the reasons for little impact of reforms on the responses is awaited.

Key words: Dynamic panel model, supply elasticity, acreage and yield response.

JEL Code: C13, C23, Q11

[1] The financial assistance provided by United States Dapartment of Agriculture, Economic Research Service for conducting this study is gratefully acknowledged.

Supply Response of Indian Farmers: Pre and post reforms

G. Mythili

1. Introduction

With the introduction of reforms in early nineties in India, accompanied by trade and exchange rate liberalisation, it was expected Indian farmers would benefit considerably from the increased market incentives (Rao, 2003). The impact of liberalization on the growth of agriculture crucially depends on how the farmers respond to various price incentives. During the last five decades, a large volume of literature on supply response indicated that the response is much weaker. Non-price factors seem to dominate over price factors in farmers' decision problem.(Krishna, 1962; Narain, 1965; Askari and Cummings, 1976; Gulati and Kelly, 1999). If we believe that introduction of reform process in early nineties in India helped removing some of the constraints that Indian farmers were facing in responding to the market incentives, then more response is expected in the post reforms period.

However there is no firm evidence so far, which supports this hypothesis. Is it because the policies are still not able to identify and target the proper constraints? Or is it due to the nature of specification and methodology used in the literature? Or is it that the time lag of the response to liberalization is still longer so that the impacts are yet to be seen fully? Keeping this in the background, this paper will examine the literature from the viewpoint of (a) methodology and 2) specification and measurement issues. Following this, this paper attempts studying acreage/supply response of major crops using state level panel data during pre and post reform periods.

2. Background of the Study

There are many arguments to support the notion that farmers in less developed countries do not respond to economic incentives like price and income. The numerous studies available for India at the crop level have more or less arrived at the same result that the supply response is less elastic. Reasons cited for poor response varied from factors such as constraints on irrigation, infrastructure etc. to lack of complementary agricultural policies. There are varying results of various degree of response. Two sets of explanation were offered to why the results vary and also what have been overlooked in the process. The first in this list is conceptual problems in identifying correct price and climate variables. The second set of problems arises in the formulation of empirical model. For instance, the specification of supply function, viz. lagged price of single lag or distributed lag, failure to recognize identification problem, improper choice of competing crops, failure to identify the correct set of non market factors, all these contribute to varying results. In short, it may be true that the farmers are responding to incentives subject to the constraints but the result has not been clearly documented due to the explanation given above.

The importance of non- price factors has drawn adequate attention in the literature: rainfall, irrigation, market access for both inputs and output and literacy. One of the reasons for a low response to prices in backward regions is the limited access to input and product markets or high transaction costs associated with their use. Limited market access may be either due to absence of proper road links or the distances involved between the road and the markets. However even those studies, which tried to incorporate some of these attributes could not gain much in terms of level of response.

Many studies, which provided estimates for India, have mostly used time series aggregated data. This type of data set conceals variations across states. The state specific characteristics and its contribution to the varying supply response would provide better information for drawing inferences at the national level. Panel data has a distinct advantage of providing regional and temporal variations for dynamic models. Very few scholars have worked with panel data in supply response analysis. Study by Gulati *et al* (1999) and Kumar *et al.* (1997) are the few which used pooled cross section- time series data across regions of India. This gives pre reform elasticity estimates as the period covers up to 1990. There is a dearth of studies on supply response in post reform era. This study aims to fill this gap.

3. Summary Statistics of Changes in Cropping Pattern and Yield

It can be noted that over the years area shifts have mainly occurred from foodgrains to non foodgrains; *viz.* from coarse cereals and pulses towards oilseeds, sugarcane and non food crops (Table 1).

Regionwise pattern shows that Southern and Western regions are more diversified over the years and the shifts have taken place mainly in favour of oilseed crops; especially in Tamil Nadu, crop diversification from rice to groundnut and sugarcane is significant in 80s (Table 2). In Karnataka area shifts occurred in favour of fruits and vegetables. Climatic conditions and government supported programs favoured this crop. Northern region is specializing in main cereals. Coarse cereals and pulses are being replaced by rice and wheat in this region. Sugarcane is also gaining importance in this region. Eastern region is the least diversified of all. It is mainly concentrating in foodgrains.

Table 1: Cropping Pattern - all India

(percent)

Crops	1960-61	1970-71	1980-81	1990-91	1995-96	2000-01	Annual % change 80s	Annual % change 90s
Rice	22.34	22.67	23.26	22.98	22.96	24.03	-0.12	0.46
Wheat	8.46	11.00	12.91	13.01	13.41	13.84	0.08	0.64
Coarse Cereals	29.43	27.72	24.20	19.55	16.55	16.56	-1.92	-1.53
Pulses	15.42	13.60	13.01	13.28	11.94	11.40	0.21	-1.42
Foodgrains	75.66	74.99	73.38	68.83	64.86	65.83	-0.62	-0.44
Oilseeds	9.01	10.04	10.20	13.00	13.92	13.56	2.75	0.43
Cotton	4.98	4.59	4.53	4.01	4.85	4.61	-1.15	1.50
Sugarcane	1.58	1.58	1.55	1.99	2.22	2.46	2.84	2.36
Non-foodgrains	24.34	25.01	26.62	31.17	35.14	34.17	1.71	0.96
Cropped area (in million hectares)	152.77	165.79	172.63	185.74	186.56	186.36	0.76	0.03

Source: Agricultural Statistics at a Glance and www.indiastat.com

There are high variations across regions in crop wise percentage of irrigated area . For instance, in the case of cotton crop, more than 90% is irrigated in Punjab, while it is less than 5% in Maharashtra. This is reflected in the variations in the average yield across regions.

It can be inferred from Table 3 that the yield increase has mainly occurred in 70s and 80s due to the impact of technological changes. In 90s during the period after liberalization, the yield increase for commercial crops like oilseeds and sugarcane is not up to the expected level. However liberal import policies in oilseeds on the other hand have affected the domestic growth of area and productivity of oilseeds.

Table 2: States where Gain and Reduction in Area occurred for Major Crops

Crops	70s & 80s		90s	
	Gain	Reductiom	Gain	Reduction
Rice	MP, Punjab, UP and West Bengal	Tamil Nadu	MP, Punjab and UP	AP and Bihar
Wheat	All the major producing states		All the major producing states	
Coarse Cereals				
Maize	MP and Rajasthan	Bihar and UP	AP	UP
Jowar		All the major producing states		All the major producing states
Grams	MP, Maharashtra, Rajasthan	UP	MP, Maharashtra	UP
Groundnut$	AP, Gujrat	Maharashtra		AP, Gujarat and Maharashtra
Rapeseed &Mustard	Rajasthan MP, Haryana and WB	UP	Rajasthan and MP	
Sugarcane	Karnataka and UP		AP, Maharashtra, Karnataka, TN and UP	
Cotton	Andhra and Punjab	Gujarat and Karnataka	AP, Gujarat and Maharashtra	Punjab and Karnataka

Note: 70s refer to the period 1970-71 to 1979-80. 80s refer to 1980-81 to 1989-90.
90s refer to 1990-91 to1999-2000.
$ For Tamilnadu , cropped area under groundnut is fluctuating around the mean.

Table 3: States which recorded significant increase in Yield

Crops	70s	80s	90s
Rice	Punjab*, AP	TN*, WB*, UP*, Orissa and Bihar	Bihar*, UP and WB
Wheat	Punjab , UP and Haryana	All the major producing states	All the major producing states
Grams	Maharashtra, Haryana and Rajasthan	Haryana* and Maharashtra	Rajasthan and MP
Groundnut	TN* and Maharashtra	Maharashtra, TN, AP and Karnataka	Gujarat* and TN
Rapeseed & Mustard		Gujarat, Haryana*UP* MP and Rajasthan	
Sugarcane	Maharashtra and TN	Gujarat	Karnataka
Cotton	AP*, Maharashtra* and Karnataka*	Karnataka*, TN* Punjab* Gujarat, MP, Maharashtra and Rajasthan	MP* and Gujarat, Maharashtra and Karnataka

Significant refers to annual compound growth rate of above 2% and less than 5%.
*very significant refers to annual compound growth rate of above 5%.

4. Theoretical and Analytical Developments

4.1 Basic Model

There are broadly two frameworks developed in the literature to conduct supply response analysis: (a) Nerlovian expectation model which facilitates the analysis of both the speed and level of adjustment of actual acreage towards desired acreage and (b) Supply function derived from the profit maximizing framework. The second approach involves joint estimation of output supply and input demand functions. This requires detailed information on all the input prices. Moreover the agricultural input markets are not functioning in a competitive environment in India, particularly land and labour markets. Market intervention in delivering material inputs to the farmers is a common practice. It is difficult to get information on price at which the inputs are supplied to the farmers. Keeping in view these aspects, this study has chosen Nerlovian approach.

The pioneering work of Nerlove (1958) on supply response enables one to determine short run and long run elasticities; also it gives the flexibility to introduce non-price shift variables in the model. According to the Nerlove-Koyck adjustment model, the desired acreage A_t* is a function of 'expected normal price', while the actual acreage A_t adjusts to the desired acreage with some lag[2]. The model is as follows:

$$A_t^* = \beta_0 P_t^{*\beta_1} e^u$$

$$\frac{A_t}{A_{t-1}} = \left(\frac{A_t^*}{A_{t-1}}\right)^{\delta} \qquad 0 \prec \delta \leq 1$$

$$\frac{P^*_t}{P^*_{t-1}} = \left(\frac{P_{t-1}}{P^*_{t-1}}\right)^{\gamma} \qquad 0 \prec \gamma \leq 1$$

By substitution, the structural form equation with variables in logarithmic form can be specified as:

$$Y_t = \beta_0\gamma\delta + \beta_1\gamma\delta P_{t-1} + [(1-\gamma)+(1-\delta)]Y_{t-1} - (1-\delta)(1-\gamma)Y_{t-2} + [\delta u_t - \delta(1-\gamma)u_{t-1}]$$

The final reduced form equation after including other exogenous non-price variable $X_{t,}$ is

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 P_{t-1} + \alpha_4 X_t + v_t$$

It should be noted that even though the final reduced form is linear in parameters, the original structural form is non linear in parameters; also problems of over-identification have to be dealt with in going uniquely from reduced form to structural form parameters. 'δ' and 'γ' are coefficients of adjustment and expectation. The reduced form is a distributed lag models with lagged dependent variables appearing as independent variables. Coefficient of each explanatory variable directly gives short run elasticities and the long run elasticities are obtained by dividing short run elasticities by (1- coefficient of the lagged area variables). The assumption underlying this model is that all the long run elasticities exceed short run elasticities. If the adjustment coefficient is close to 1, then it implies farmers' adjustment of actual acreage to desired acreage is fast. If the adjustment coefficient is close to zero, then the adjustment takes place slowly. The crucial dynamic elements are incorporated in the model in the form of description of price expectation formation. i.e. the third equation. Prices are revised in each period in proportion to the difference between last period's observed price and the previous expectation. P_t^* is the average price expected to prevail in all future periods. The reason that the farmer responds rationally based not on next period's forecast but rather to some average 'normal' level rests on the notion that there are costs of adjustments. The

[2] The specific feature of the model has been summarized in Narayana and Parikh (1981).

twin problem of stochastic explanatory variable and autoregressive error structure in the reduced form equation pose estimation problems.

In 60s, modifications in the basic Nerlovian model has been made with respect to food crops in developing economies ; the reason being part of the product is used as self consumption[3]. Hence the variable of interest is marketed surplus than total output. The noted studies based on this concept are Krishna (1962) and Behrman (1966). The point emerged from these studies is the need to take into consideration the income elasticity of consumption within the farm household. Askari and Cummings (1976) surveyed large number of studies to infer the reason behind large variation in supply response elasticities across studies. They identified many non-price factors that influence the elasticities. Some of the non-price factors that explain the variations are farm size, access to irrigation, yield risk, literacy level, and ownership vs. tenancy so on which influence the degree of price response.

The period after 70s and 80s witnessed further development of dynamic models. In the context of supply response, Nerlove (1979) pointed out the adhoc nature of formulation of distributed lag models in empirical literature. The development of literature following this is the formulation of 'econometrically relevant' dynamic models. As Nerlove himself argued, econometrically relevant dynamic model should characterize response paths of producer under dynamic conditions and form expectation of the future on the basis of all information available to them(e.g Eckstein, 1984). Simultaneously there were developments on the estimation front, of dynamic models using panel data. Panel data possess specific characteristics which are complex to handle and hence estimation methodology needs to be modified. Some of the important contributions on the methodology of panel data dynamic models are Nerlove (1971), Anderson and Hsiao (1981) Chamberlain (1984), Arellano and Bond (1991).

[3] Foodgrains were considered as subsistence crops; however, after the onset of green revolution, major cereals were no more treated as subsistence crops, because it has been yielding lucrative revenue with higher yield due to increasing use of modern varieties of seeds and chemical fertilizers.

4.2 Specification: Some issues

The statistical estimation involves decision on proper specification of variables apart from usual estimation related problems. The crucial variables which encounter specification problems are climate, price and risk related variables.

Various studies attributed problems in measurement of variables and the methodologies used for estimation as reasons for highly varying elasticities even within a region. If we peruse the literature starting from Nerlovian (1958) model of supply response, improvement in the specification was attempted by introducing competing crops concept where relative prices were introduced instead of absolute prices. The next stage of development was the introduction of risk and uncertainty in the model. Behrman (1968) introduced standard deviation of price and yield measured from previous three years' data. This was criticized for the fact that the Nerlovian price expectation model is not consistent with changing variance of the subjective probability distributions. Nowshirvani (1971) modeled farmers' land allocation decision that accounted for uncertainties in prices and yields. Incorporating risk, Nowshirvani has found that area-price response turned out to be negative, implying stabilization schemes may sometimes be more effective policy instrument than price in bringing about area shifts among crops. Many scholars use relative profitability rather than relative price, the reason being that it better explains farmers' choice behaviour. However profit calculation has its own measurement problem such as identifying proper imputation methods for own inputs and appropriate type of costs to compute profits and problems related to common costs. Moreover price is a direct policy instrument and hence the results are handy for policy purpose. In view of the above factors, this study uses output price as the incentive variable. Even though the present study recognizes the importance of non-price factors, the aim of the study is to find acreage–price response after controlling for non-price factors.

Which is the proper dependent variable to study farmers' response to price: Area or Supply? This is an important issue to be resolved at the outset. Those who support acreage function view that output is subject to more fluctuation than area because of uncertain random factors such as temperature, rainfall etc. Hence to understand the behavioral pattern, area is the appropriate variable. Even in land variable, one has to distinguish between explaining total area changes and area shifts between crops given the total land size. Hence even if farmers are profit maximisers in a neoclassical sense total cultivated area is not likely to respond to price in the short run. Therefore the price response is likely to be confined mainly to area allocation between crops rather than to total cultivated area. Some studies utilize ratio of acreage under a crop to total cropped area for studying shifts in area among the crops. This has its own limitation that the simultaneous changes in the crop area and the total area will conceal variations. Due to this factor, absolute area is used in the study.

Regarding rainfall variable, so far no satisfactory measure of this variable has been found in the literature. Variables used in the studies are- Average quantum of total rainfall in a crop season, rainfall in pre sowing period, absolute deviation from normal rainfall, frequency of number of stations reported below 20% normal to total in a region. It is to be mentioned that rainfall is more meaningful on the impact side than on the source side. Depending on the factors such as the quality of soil to withhold moisture, drainage system of the area, and how equally it is distributed across months in a season all impinge on productivity. Information on even some of these attributes would be useful for explaining the impact. Consistent data on these is very difficult to obtain.

Regarding area allocation between individual crops, the response will be constrained by following factors: 1) when monoculture is practised; viz. entire sown area belongs to one crop. 2) Some areas are more suited to specific crops, so flexibility is not high. Crop rotation possibility may be restrained and so it hinders shifting areas between crops in the short run but given sufficiently longer time, shift can occur. Hence specificity affect extent of area shifts or the promptness with which they occur rather than preclude their occurrences altogether (Dharm Narain, 1965). It is also important to distinguish between small and large farmers. Can the response be same between small and large? Small farmers are likely to face more constraints in comparison with the large farmers and hence the flexibility with which the crops can be shifted may be less among small farmers. ‘Small vs. large farmer’ distinction is of more interest in the analysis of farm level data.

The standard procedure to model supply response is a two stage approach. First farmers allocate land based on expected prices. In the second stage yield is determined based on other inputs and climate variable given the area. It is hypothesized that farmers make substantial revisions in the decision on other inputs after the area allocation is made and the input changes will be reflected overall in the deterministic component of the yield. Hence it is reasonable to assume both area and yield are influenced by expected price of the output. The idea of yield response to price is further convinced by the earlier discussion in the literature that area function might underestimate actual level of supply response (Tyagi,1974). The reason attributed is farmers may display response by adopting better technology of production with no change in area or by adopting intensive cultivation by using more or better quality of inputs. This will change the output without changing the area, something that is hidden in the acreage function. The intensive nature of cultivation will not be revealed just by the input application alone but also reflected in quality of inputs and the timing and the method of application. Assuming that these factors will be reflected in yield, yield equation has been specified in our model as a function of price, rainfall and irrigation. Past studies have found that 'rural literacy rate' influences choice of technology (e.g. Mittal and Kumar, 2000). Hence both irrigated area and literacy rate can be treated as proxies for technology.

It is to be mentioned that increase in prices may also bring more marginal inferior lands which were previously not cultivated. This at the regional level may bring down average yield. There is no adequate information to see if more marginal lands were brought into cultivation in response to increase in output price. Hence these estimates should be interpreted with such limitation. Turning to yield function, we realize the importance of relative price of output over inputs in the yield function specification. However the complexity of deriving weighted inputs price index and problems in identifying relevant input price data at the state level constrained us from using the relative index. Hence in the present study output price is used in the yield function.

Farmers frame decision according to some expected price. How do we construct relevant output price variable? Regarding ratio of own price to competing price, it is difficult to arrive at a single index if there are more substitutes. Also in the interregional analysis, competing crop may be different across regions. It is preferable to use a weighted average price index where the relative price is ratio of crop concerned over weighted average of substitutes' prices (e.g. Falcon,1964). Narayana and Parikh (1981) found that specifying same coefficients for principal and competing crops might not always provide meaningful results.

Gulati *et al.*(1999) corroborated the notion that agro-climatic conditions, land characteristics and farmer's knowledge about the crop along with the price variable simultaneously affect cropping decisions. They found that low degree of risk bearing ability would weaken the acreage – price response if the crops of higher relative profit are more risky. Also the major determining factors at the individual household level may be quite different from the state, zonal or national level.

4.3 A Review of Estimation Methodology

The experience of the researchers with the Nerlovian model is varied. The advantages of using pooled cross sectional-time series data set over the others is well known. Such type of data provide valuable information about the diversity of the attributes because the data contain both inter regional and temporal variations. The present study will make use of pooled cross sectional - time series data. The detailed information about the data used is presented in the relevant section.

In the context of supply response, the study by Narayana *et al.* (1981) made improvement upon the conventional econometric techniques, and the necessity for improvement arises because of the following reasons: The traditional Nerlovian model of adaptive expectation does not separate past prices into stationary component and random component. It attaches same weights to both the components for predicting future prices.
Narayana *et al*. (1981) deviate from this in two ways.

(i) use expected revenue instead of expected price
(ii) Formulate revenue expectation function for each crop by isolating stationary and random components in past prices and attach suitable weights for both in prediction. The method is based on ARIMA technique combined with BOX-Jenkins procedure for estimations

Similar method was applied to analyse farmers' acreage response in Kenya by Narayana and Shah (1982). This study mainly distinguished between the responses of small farmers versus large farmers. Small farmers' area adjustment parameters towards the desired acreage in the case of food crops are much higher than for non-food crops; whereas for large farms, the adjustment towards desired acreage is higher for commercial crops like sugarcane. Application of non-linear models in supply response is also becoming popular. Surekha (2005) developed a non-linear autoregressive distributed lag models to study supply response for rice. He criticized the standard methods saying that most of the structural form parameters are either non linear functions or ratios of reduced form parameters and as a result the structural form parameters do not possess finite moments. Such estimators are likely to be inconsistent and also very often lead to low estimates. He felt this could be one source of trouble in wide range of studies obtaining low elasticities from Nerlovian Supply Response Models. As a method to overcome this problem, Surekha used an alternative estimation method based on Bayesian paradigm, which takes care of the problem stated above. Taking into account appropriate variance covariance structure of the error term, he estimated the parameters using Bayesian two step procedure. Using the two stage Bayesian estimator he found a large value for supply response as compared to the estimated derived standard least square method. This seems to have explained the low supply response estimated by many empirical researchers. He further found low adjustment coefficient that explains farmers' reluctance to make larger changes in main cereal crops like rice. However the empirical model is based on time series aggregate data and hence suppresses regional variation.

4.4 Past Studies based on Panel data

Study by Kumar *et al.* (1997) is one of the few, which used pooled cross section- time series data across regions of India pre reform period. Joint estimation of area, yield and input demand in recursive block system has been adopted by employing Zellner's SUR estimation technique. Expected revenue has been used as a price incentive indicator. The dynamic response has been estimated within a static framework by including lagged dependent variable. Gulati *et al.* (1999) analysed supply using pooled data. They identified 23 crop zones in the Indian SAT. By utilizing cross-sectional district data covering the period 1970-71 to 1990-91, the estimates were derived zonewise for various crops. The study found that non-price factors mostly explain shift in cropping pattern.

Brauw et al. (2003) studied both flexibility and supply responsiveness of Chinese farmers using pooled cross section, time-series data for the period 1975-1995. Supply responsiveness of Chinese farmers has been studied introducing a new concept of degree of flexibility in the adjustment of quasi-fixed factors. Quasi fixed is defined as those inputs which take more than one period to adjust to changes in relative prices or other exogenous factors. They adopted simultaneous estimation of input demand and output supply following Gallant's (1992) method of non-linear three stage least square estimation simultaneously for two quasi fixed inputs and three outputs. The dynamic value function specified by Epstein (1981) has been utilized in this paper. A dummy variable representing early reform period and late reform period has been introduced. From the findings, it is confirmed that land and labour are less flexible for adjustment in the early reform period and the flexibility has significantly increased in the late reform period where market is fully liberalized. By introducing a period dummy-price interaction term, the study allowed the price response to change between early reform and late reforms periods. The results show that the own price response variable displayed significant increase in the late reform period especially for labour but not much change is seen in the case of area response. However farmers increased their speed of adjustment between early and late reforms periods. The study confirmed that gradual reform process has worked to the advantage of Chinese agriculture.

5. A Note on Estimation Technique followed in the Present Study

In this section, we elaborate on the estimation procedure used in the present study. In pooled panel data, the error structure may have one or all of the following characteristics: (1) errors may have non-constant variances across panel units that leads to heteroscedasticity problem (2) error structure across time may be autocorrelated (3) errors can be contemporaneously correlated across panel units. Presence of any of these problems leads to a situation where OLS is not an efficient technique and one has to seek alternative methods. Serial autocorrelation or heteroscedasticity can be handled by Generalized Least Square technique whereas for contemporaneous correlation, Zellner's (1962) seemingly unrelated regression (SUR) can be resorted. An alternative method is error component analysis. In this, a special case is, where error structure is decomposed into individual specific time invariant error (v_i) and a general error (e_{it}), which varies with respect to individual and time. Appropriate independence and autocorrelation assumptions can be maintained in the estimation stage.

It is important to decide on the nature of state specific effects of the model (fixed vs. random). We conducted a test (LM test) for this and the test rejected fixed state specific effects. This means that the state effects cannot be fully captured by introducing dummy variables. Arellano and Bond's (1991) 'Generalised Method of Moments' (GMM) estimator is robust to differences in the specification of data generating process. They are consistent and asymptotically efficient. In this particular model, the regressor is correlated with error terms of all the previous years. For instance if X_t is the stochastic regressor, then

$$\mathrm{Cov}\,[X_t,\varepsilon_s] = 0 \text{ if } s \geq t$$
$$\neq 0 \text{ if } s < t$$

GMM is basically an instrumental variable technique. Conditional expectation of product of lagged dependent variable and disburbance term is non zero and hence use of proper instrumental variables would eliminate this problem. Moreover the 'zero moment equations' are also efficiently utilized. The estimation retains the error component with panel specific random terms. First differencing of the variables eliminates the panel specific effects leaving out pure random terms. By first differencing we also adjust for non-stationarity of the series. This estimation method optimally exploits all the moment conditions. GMM is a suitable method for estimating reduced form equations involving lagged dependent variables. Instrumental variables based on lagged period estimates have been used for lagged dependent variables[4] and hence this is chosen for the present analysis. (For more details refer Greene, 2006). The random terms are tested for serial correlation and adjustments are made by adding more instruments. The software (STATA) also provides test for overidentifying restrictions in the model.

6. Empirical Analysis

The present study is based on state level data pertaining to major crops for India during the period 1970-71 to 1999-2000. The whole period is divided into two; pre reform period pertains to 1970-71 to 1989-90; post reform period covers 1990-91 to 1999-2000. In the first section we present the crop wise state selection scheme and the classification of crops by groups according to the nature of substitutability. It is followed by supply response elasticity estimation using econometric tools briefed in the earlier section.

6.1 Selection of States for each crop

For selection of states for each crop, first, the contribution of output of each state to all- India has been studied[5]. The states which contributed 4% or more to the total have been selected. The selected states for each crop is presented in Table 4

---

[4] Ahn and Schmidt (1995) have shown how to exploit all information in the sample to arrive at more efficient estimators.

[5] We looked at the data of crop output share of each state to all India for the years 70-71, 80-81, 90-91 and 1999-2000 and the selection is based on if the state share is around 4% or more consistently for atleast 2 or 3 reference years.

Table 4 : Selected States for each Crop

Crops	Selected states
Rice	Andhra Pradesh, Karnataka, Tamilnadu Madhya Pradesh, Bihar, Orissa* and West Bengal Assam, Punjab and Uttar Pradesh
Wheat	Bihar, MP, Rajasthan, Haryana, Punjab and UP
Coarse Cereals- Maize, jowar and bajra	Maize: AP, Karnataka, MP, Bihar, Rajasthan and UP Jowar: AP, Karnataka, Tamilnadu, Maharashtra, MP and UP Bajra : Karnataka, Tamilnadu, Gujarat, Maharashtra, Rajasthan, Haryana, and UP
Grams	Haryana, MP, Maharashtra, Rajasthan and UP
Groundnut	AP, Karnataka, Tamilnadu, Gujarat and Maharashtra
Rapeseed and Mustard	Gujarat, MP, Rajasthan, Haryana and UP
Sugarcane	AP, Karnataka, Tamilnadu, Gujarat, Maharashtra and UP
Cotton	AP, Karnataka, Tamilnadu Gujarat, Maharashtra , MP, Rajasthan, Punjab and Haryana

In the next stage we divided the crops in to groups so that crops within a group are substitutable. Rice is cultivated predominantly in irrigated conditions in southern region and Punjab. We have selected sugarcane as the competing crop for rice. In states like Bihar and West Bengal, more than 50% account for rainfed area. However in these two states there is really no competing crop for rice. Taking into consideration all these factors we keep rice and sugarcane in one group. On the same line, we have decided other groups of crops. For wheat, which is mainly cultivated in the northern region during rabi season, the competing crops are grams and rapeseed & mustard. The selected groups of crops are listed in Table 5. The next group consists of those crops mostly grown in kharif season under rainfed conditions; groundnut, cotton and coarse cereals. We have considered maize, jowar and bajra. Of the three, bajra is drought resistant than other cereals and is generally preferred in low rainfall areas.

Table 5 Classification by substitutable Crops

Groups	Sustitutable Crops
Group1	Rice and Sugarcane
Group2 (Rabi crops)	Wheat, Rapeseed& Mustard and Grams
Group3	Groundnut, cotton and coarse cereals (consisting of jowar, bajra and maize).

6.2 Data and Variables

The state level data for the period 1970-71 to 1999-2000 have been used for the analysis. Area, Yield, Relative Farm harvest price (FHP) of main crop over competing crop, total rainfall (RAIN), deviation from normal rainfall (DEVR), proportion of area irrigated and rural literacy are variables on which information were collected[6]. For area regression, price, rainfall, deviation from normal and rural literacy were initially tried as explanatory variables. For yield regression, in addition to the above, proportion of area irrigated was also considered. After experimenting with few trials, final set of variables was chosen. All the variables except dummy coefficients are incorporated in logarithms. For rice, there exists dual market price, viz. open market price and government procurement price. We studied the food procurement pattern of various states for rice and found only in Andhra and Punjab, the procurement is important because it forms 50% or more in these states. Initially we attempted finding weighted average of the two prices for these two states but the time series pattern was not significantly different from market price series. Hence we ultimately decided to use farm harvest price for all the crops.

[6] Sources of data are Government Reports on "Estimation of Area and Production of Principal Crops in India" , "Farm Harvest Prices of Principal Crops in India" , State Reports, Planning Commission Reports and www.indiastat.com

The specific feature of this study is that the main and substitutable crops are jointly estimated by introducing varying intercepts and varying slope coefficients in the same regression equation. Period dummy-price interaction term has been used to maintain different response parameters for pre and post reform period. The choice on specification was made after performing few specification tests.

Preliminary investigation with measures such as mean and variation over time revealed that in general, variation in yield is higher than variation in area because of random weather factors. The time series pattern of area, yield and price is depicted in Figures1 to 6 for major foodgrains, sugarcane , oilseeds and cotton. Yield fluctuations are quite high for groundnut and cotton. It is to be mentioned, that the dry crop yield depicts significant fluctuation for these two crops. It is expected whenever there is an average yield increase, farmers would be motivated to increase area allocated to the crop given the other factors constant. However this hypothesis does not hold true always. There are situations where yield increase is followed by significant area decline or vice versa. One can explain the inverse relation between area and yield as follows: if the marginal lands are withdrawn from the crop that gives higher yield, then it is bound to increase the average yield. On the similar note, if more marginal lands are added to the existing area, then it is bound to bring down average yield. This partly explains inverse relation between area and yield.

6.4 Econometric Estimation of Acreage, Yield and Supply Response

(i) Data and Variables Specification

Preliminary investigation of the data and the data availability and the meaningfulness of the variable at the state level largely determined our variables selection. The variables included in the final form of acreage function are relative price index and rainfall as quantitative variables and period dummy reflecting the period before and after liberalization (period 1 : 1971-1990; period 2: 1991 – 2000) and crop dummy variable. As mentioned earlier we have pooled the set of competing crops and there are 3 sets totally (refer Table 5). To introduce varying response coefficients, different elasticities for two periods were considered. This is accomplished by considering period dummy- price interaction term. The price is introduced with differing slopes for crops and pre and post reform periods as follows.

$$Y = \alpha + \alpha_1 D_{reform} + \alpha_2 D_s + \gamma_{11} P_{t-1} D_{pre} + \gamma_{12} P_{t-1} D_{post} + \gamma_{21} P_{t-1} D_{pre} D_s + \gamma_{22} P_{t-1} D_{post} D_s + \dots\dots\dots$$

D_{reform} is a period specific dummy. D_{pre} and D_{post} are dummies representing pre and post reform periods. D_s is a crop specific dummy taking '0' for main crop and '1' for substitute crop. Hence, the pre and post reform period specific main crop response coefficients are γ_{11} and γ_{12}. The respective substitute crops coefficients are $\gamma_{11} + \gamma_{21}$ *and* $\gamma_{12} + \gamma_{22}$

For yield response function, besides price and rainfall, percentage of irrigated area to capture technology effects and rural literacy rate were also additionally added. For the third group of crops which are raised mostly under rainfed conditions, rainfall deviation from normal was found to be more suitable than actual rainfall. Hence wherever appropriate, deviation from normal was considered. We also considered initially yield variability and price variability as measures of risk variables. Our data supported the view that risk factor at the regional level is less significant factor for area response. Hence risk variable was dropped in the final analysis The reason could be that these variables are more meaningful at the individual level than at the aggregate level. Further disaggregated level of data would be preferable to analyze the effect of risk on response coefficients. It also requires better methodology to bring in risk variable from the theoretical constructs than just introducing it in an adhoc manner. Irrigation is one of the crucial variables, which would explain area shifts among crops. Irrigation acts as a yield augmenting as well as risk protecting variable. When more area is brought under irrigation, the crop which was cultivated previously under rainfed, is expected to respond more to price. The reason is, rainfed crop is more susceptible to the risk of monsoon failure as well as pest attacks. Therefore, this is a constraint, which mitigates the degree of response. Rural literacy rates were available only for the census years. We have interpolated the data for in-between years.

(ii) Estimation of elasticities by dynamic panel data model

Estimation problems occur largely because of autocorrelation, heteroscedasticity and contemporaneous correlation among the panel observation. After performing all the tests finally we found that the appropriate method is Dynamic Panel Data model. The details of the technique underlying Arellano-Bond's GMM estimates have been presented in the earlier section. The results are presented in Tables 6 to 8.

All the variables except dummy variables are introduced in logarithms. The model and specification were finalized after doing a few specification tests. From Table 6, it is evident that all the crucial variables in the acreage equation is statistically significant for rice and the competing crop sugarcane. Also, significant yield response to output price is seen in the case of sugarcane. It is of interest to explore why the response has not been enhanced in the post reform period in the case of rice. One of the reasons observed by scholars is that domestic farm liberalization has not taken place as much as that occurred in the border trade. The adjustment coefficient for area is 1-0.80 (=0.20) which is very small indicating that farmers adjust very slowly towards desired acreage. This result supported the view of many researchers (e.g. Surekha, 2005) that farmers seem to be reluctant to make larger adjustments in main cereal crops which are used for self consumption.

Past studies pertaining to individual states using data up to 1995 with OLS methodology have yielded very low short run elasticity estimates for rice ranging from 0.06 to 0.12 (Bhalla and Singh , 1996 for Punjab and Mythili, 2001 for Tamil Nadu) and long run estimates of very high variation ranging between 0.15 to 0.93.

Table 6: Results of Acreage and Yield Response Equations from the Estimation of Dynamic Panel Data Model – Rice & Sugarcane

Variables	Area	Yield[#]
Lagged dependent	0.794*	0.280*
Rice- output price-pre reform	0.084*	0.071
Rice- output price-post reform	0.081*	0.080
Sugarcane- output price-pre reform	0.260*	0.122*
Sugarcane- output price-post reform	0.256*	0.113*
Rainfall	0.041*	
% absolute deviation from normal rainfall		-0.005*
% of irrigated area-rice		0.128*
Period dummy	-0.0047	-0.007
Crop dummy - Rice	0.0079*	
Constant	-0.009*	0.027*

Note: All variables except dummy are in logarithmic form. Sample size = 413
Period of analysis is 1970-71 to 1999-2000.
Rural literacy variable was tried initially and subsequently dropped due to insignificance.
Tests for price coefficients different between pre and post reform yielded significant difference in yield response for the crop sugarcane
 # Yield regressions were separately run for rice and sugarcane because the irrigated area ratio is almost one for sugarcane and hence could not be included in sugarcane equation; and it is a significant variable for rice equation.
**significant at 5% level.*

Gulati *et al*. (1999) has found that the price factor is not a significant variable explaining area changes. Only for 6 out of 16 paddy growing zones the area was found to be responsive and the elasticities fell within a narrow range of 0.06 to 0.17. Kumar *et al.* (1997) has made joint estimation of input and output for the period 1970-71 to 1987-88 for cereal crops and coarse cereals. The acreage response elasticity for rice estimates turned out to be very low ranging between 0.019 in the short run and 0.12 in the long run in this study. Using the annual data for the period 1952-53 to 1985-86 for rice crop for India based on non-linear model, Surekha (2005) found a long run elasticity of 1.9 using Bayesian estimation method against 0.538 obtained by the standard least square estimate. His study confirmed the high sensitivity of estimates to estimation techniques. The estimates of Narayana *et al.* (1981) are for the period from 50s to 70s and hence the comparison may not be meaningful.

From both area and yield estimates, we infer that they do support the argument that farmers respond to increasing prices to some degree by intensive application of other inputs besides extending the area.

Table 7 provides estimates for rabi season competing crops. Wheat's short run price response coefficients are better than rice coefficients for both area and yield. However in terms of significance of individual coefficients, this is not a better fit as compared to rice equation. Rural literacy rate turned out to be a significant variable explaining yield variation. Perhaps Punjab's high yield and a better literacy rate partly explain this. Kumar's (1997) estimates of wheat gives a very low elasticity of 0.06 in the short run and 0.23 in the long run. In Gulati *et al's* (1999) study, own price and competing prices turned out to be insignificant and output elasticities were in the range of 0.06 to 0.98. Among oilseed crops, rapeseed & mustard (R&M) display better response to price than groundnut (Tables 7 and 8). However it must be noted that the R&M is a winter crop grown predominantly in irrigated condition, whereas groundnut is grown more in kharif season rainfed condition and hence subject to more instability in output. Gulati's result for groundnut indicated that, in the two large groundnut growing regions, acreage response were poor. Across zones, the elasticity varies between 0.05 and 0.52. His estimates pertain to pre-reform period. For sugarcane, the study obtained negative elasticities. His study led to the conclusion that own price plays a less important role in acreage decision and non price factors have larger role to play.

Overall, from the present study, it may be concluded that the rabi crops have shown better response than the kharif crops. Statistical tests pertaining to the difference between pre reform and post reform estimates provided very few rejection of hypothesis of equality of coefficients. The significant difference is obtained only in yield response for sugarcane and rapeseed&mustard and area response only for groundnut. There are no clear evidences to support that the response has improved post reforms.

Table 7: Results of Acreage and Yield Response Equations from the Estimation of Dynamic Panel Data Model – Wheat-Rapeseed & Mustard and Grams

Variables	Area	Yield
Lagged dependent	0.706*	0.081*
Wheat- output price-pre reform	0.183*	0.150*
Wheat- output price-post reform	0.190*	0.162*
Rapeseed&Mustard- output Price- pre reform	0.345	0.213
Rapeseed&Mustard -output Price- post reform	0.345	0.203
Grams -output Price-pre reform	0.338	0.078
Grams-output price- post reform	0.284	0.106
Rainfall		0.006*
% of irrigated area	0.0094*	
Rural literacy rate		0.025*
Period Dummy	-0.0174*	-0.028*
Crop dummy-rapeseed&mustard	0.0082	0.009
Crop dummy -grams	-0.0114	-0.014
Constant	-0.0028	-0.1112

Note: All variables except dummy are in logarithmic form. Sample size =448
Period dummy=1 for post reform period, =0 for pre reform period
Tests for price coefficients different between pre and post reform yielded significant difference only in yield response for the crop Rapeseed & Mustard
** significant at 5% level.*

The response coefficient for coarse cereals is around 0.12 and it is same as the estimate obtained by Kumar's (1997) study. For cotton, both area and yield response coefficients are significant but area adjustment is very slow for cotton.

Table 8: Results of Acreage and Yield Response Equations from the Estimation of Dynamic Panel Data Model – Cotton, Groundnut and Coarse Cereals

Variables	Area	Yield
Lagged dependent-one period	0.561*	0.054
Lagged dependent-two periods	0.283*	0.129*
Cotton- output price pre reform	0.167*	0.135*
Cotton- output price post reform	0.165*	0.139*
Groundnut- output price -pre reform	0.052*	0.195
Groundnut -output Price- post reform	0.034*	0.204
Coarse Cereals -output price – pre reform	0.122	0.321*
Coarse Cereals -output price -post reform	0.119	0.324*
Rainfall		
absolute deviation from normal rainfall	-0.0047	-0.0114
% of irrigated area	0.0022*	0.2237*
Period Dummy	-0.0060*	-0.0194*
Crop dummy-groundnut	0.0137*	-0.0110
Crop dummy –coarse cereals	0.0069*	0.0019
Constant	-0.0171*	0.0029

Note: All variables except dummy are in logarithmic form. Sample size=912
Period dummy=1 for post reform period, =0 for pre reform period
Tests for price coefficients different between pre and post reform yielded significant difference in area response for the crop groundnut
** significant at 5% level.*

The supply elasticities are derived by adding area and yield elasticities and the results are presented in Tables 9 to 11. The comparison of various estimates indicates that the long run supply elasticities are greater than unity for coarse cereals, grams, sugarcane and rapeseed and mustard. Further investigation revealed that among the coarse cereals, jowar crop has better acreage response. This crop is mainly grown in southern and western regions of India in rainfed conditions. Maize's response is lower than jowar. Our result supports the findings of Kumar *et al.*(1997) where the short run acreage elasticity of maize is 0.12.

For oilseeds, liberalization on trade front is likely to have more impact on domestic price as the proportion of imports in total supply is higher. After mid-nineties, the prices of oilseeds relative to other crops have been declining. Pandey *et al.* (2005) has conducted an analysis of supply response of oilseeds for selected individual states to see if domestic price fluctuation is having negative impact on oilseeds production. Four oilseed crops, groundnut, rapeseed&mustard, soyabean and sunflower have been considered. The period of analysis is 1986-87 to 2001-02. The study confirmed that the oilseeds production respond to expected prices and price risk, reflected in fluctuation in domestic market price, due to increasing imports. It was found that the supply elasticiity for groundnut is 0.59 for Andhra and 0.87 for Gujarat. For rapeseed&mustard, it is 0.644 for Punjab and 0.885 for Rajasthan. The estimates for groundnut are higher than what the present study has obtained. But our analysis covered more states in the sample.

Table 9: Short run and Long run Elasticity to Output Price-Food grains

Particulars	Pre reform			Post reform		
Rice						
	Area	Yield	Supply	Area	Yield	Supply
Short run	0.084	0.071	0.155	0.081	0.080	0.161
Long run	0.408	0.10	0.508	0.393	0.11	0.503
Wheat						
Short run	0.183	0.150	0.333	0.190	0.162	0.352
Long run	0.622	0.163	0.785	0.646	0.176	0.822
Coarse Cereals						
Short run	0.122	0.321	0.443	0.119	0.324	0.443
Long run	0.782	0.393	1.175	0.763	0.397	1.160
Grams						
Short run	0.338	0.078	0.416	0.284	0.106	0.390
Long run	1.15	0.085	1.235	0.965	0.115	1.080

Comparison between pre and post reform indicate that in the case of foodgrains, for coarse cereals and grams which displayed high elasticity, the elasticity has declined post reform. Among non- foodgrains, Sugarcane and Rapeseed&mustard respond quite significantly to prices in both acreage and other inputs.

Table 10: Short run and Long run Elasticity to Output Price-Cotton and Sugarcane

Particulars	Pre reform			Post reform		
Cotton						
	Area	Yield	Supply	Area	Yield	Supply
Short Run	0.167	0.135	0.302	0.165	0.139	0.304
Long Run	0.380	0.142	0.522	0.376	0.147	0.523
Sugarcane						
	Area	Yield	Supply	Area	Yield	Supply
Short Run	0.26	0.122	0.382	0.256	0.113	0.369
Long Run	1.26	0.169	1.429	1.243	0.157	1.40

Table 11: Short run and Long run Elasticity to Output Price-Oilseeds

Particulars	Pre reform			Post reform		
Groundnut						
	Area	Yield	Supply	Area	Yield	Supply
Short Run	0.052	0.195	0.247	0.034	0.204	0.238
Long Run	0.118	0.206	0.324	0.077	0.216	0.293
Rapeseed & Mustard						
	Area	Yield	Supply	Area	Yield	Supply
Short Run	0.345	0.203	0.548	0.338	0.078	0.416
Long Run	1.17	0.221	1.391	1.15	0.085	1.235

7. Concluding Remarks

This study mostly supports the results of available literature that farmers' response to price is very low in the short run and their adjustment mechanism towards reaching the desired level is slow for foodgrains. However we found evidence that farmers also respond by intensive application of other inputs as the flexibility to shift acreage could be restricted in farming. Using panel data models, the study has rejected the hypothesis that economic liberalization has improved the acreage response. But one could not simply dismiss that, efforts to improve agricultural growth through price incentives is a futile exercise. It was felt important to explore response of non-area inputs and this study specified yield response function with respect to output price to analyse this. Various discussions on the supply response theme in the academic literature and in the policy arena clearly pointed out that turning attention to removing some of the physical infrastructural constraints as well as credit constraints will go a long way in increasing the supply response. In the last decade lots of reforms took place in the agricultural credit market. Easy access to credit was expected to strengthen the supply response. The time period included after reforms is only 10 years. Perhaps after some periods down the line, the impact would be seen. Acquiring information on physical infrastructural variable such a road index, for a long time series, is difficult. Price risk is a crucial adverse factor that influences acreage response. Agricultural diversification requires risk management, and private sector involvement in agro-processing opens up opportunities for sharing risk with the farmers through contract farming. Production risk due to adverse climatic condition is an equally important factor, but we were not able to find significant effect of risk variables. Hence we could not add this variable in the final analysis. Some more probing is needed to identify appropriate risk variable which needs further analysis.

This study supports the view that farmers respond to prices to some extent by intensive application of other inputs given the same area, though they do not significantly differ between pre and post reform for many crops. This is confirmed by yield response function. It is true that mere reforms would not contribute to the strengthening of response unless adequately supported by improvement in the output and input market infrastructure, expansion of irrigation and risk reducing instruments. Our attempts to include some of these variables have not been successful though, due to either lack of data or lack of sufficient variation in the data.

REFERENCES

Ahn S.C. and Schmidt, P. (1995) "Efficient Estimation of Models for Dynamic Panel Data" *Journal of Econometrics*, 68, 1, pp 5-28.

Anderson, T.W. and Hsiao, C. (1981) 'Estimation of Dynamic Models with Error Components" *Journal of the American Statistical Association,* 76, 598-606.

Arellano, M and Stephen Bond (1991) "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations" *The Review of Economic Studies,* Vol 58, No. 2, 277-97.

Askari, A. and J. T. Cummings (1976) *Agricultural Supply Responses: A Survey of the Econometric Evidence*, Paralgar Publishers, New York.

Behrman , J.R. (1968) *Supply Response in Underdeveloped Agriculture: A Case Study of Four Major Annual Crops in Thailand 1937-63*, Amsterdam: North Holland Pub. Co.

Behrman J.R. (1966) " Price Elasticity of the Marketed Surplus of a Subsistence Crop", *Journal of Farm Economics*, 48, 875-93.

Chamberlain G. .(1984) "Panel Data" in Griliches Z. and Intriligator, M.d. (eds), *Handbook of Econometrics,* Vol II, Elsevier Sceince

Bhalla, G. S. and G. Singh (1996) "Impact of GATT on Punjab Agriculture" Institute for Development and Communication, Monograph Series II.

Brauw, Alan De, J. Huang and S. Rozelle (2003) "Sequencing and the Success of Gradualism : Empirical Evidence from China's Agricultural Reform", Presented at JUNU-IFPRI workshop on *The Dragon and the Elephant: A Comparative Study of Economic and Agricultural Reforms in China and India.*

Dharm Narain (1965) *The impact of price movements on areas under selected crops in India 1900-1939,* Cambridge University Press.

Eckstein Zvi, (1984) "A Rational Expectations Model of Agricultural Supply" , The Journal of Political Economy, Vol 92, No. 1, pp1-19.

Epstein L. (1981) "Duality Theory and Functional Forms for Dynamic Factor Demands" *Review of Economic Studies*, 48, 81-95.

Falcon, W.P. (1964) " Farmer Response to Price in a Subsistence Economy: the case of West Pakistan", *American Economic Review,* Vol 54, No.3.

Gallant A. (1992) " Three stage Least Square Estimation for a System of Simultaneous Non linear Implicit Equations", *Journal of Econometrics* 5, 71-88.

Greene W.H. (2006) *Econometric Analysis,* Fifth Edition, Pearson Education.

Gulati, Ashok and Tim Kelley (1999) *Trade Liberalization and Indian Agriculture,* Oxford University Press.

Krishna, Raj (1962) "A Note on the Elasticity of the Marketable Surplus of a Subsistence Crop" , *Indian Journal of Agricultural Economics,* 17, 79-84.

Kumar, P. and M. Rosegrant (1997) " Dynamic Supply Response of Cereals and Supply projections: A 2020 Vision" , *Agricultural Economic Research Review*, Vol 10, No.1.

Mittal, S. and Kumar, P. (2000) " Literacy, Technology Adoption Factor Demand and Productivity : An Econometric Analysis" , *Indian Journal of Agricultural Marketing*, 55(3): 490-99.

Mythili G. (2001) " A Note on Acreage Response for Major Crops in the Selected States" in *Accelerating Growth through Globalisation of Indian Agriculture*, (ed.) Kalirajan K.P. G. Mythili and U. Sankar, Macmillan India Ltd.

Narayana N.S.S. and Kirit S. Parikh, (1981) "Estimation of Farm Supply Response and Acreage Allocation: A Case Study of Indian Agriculture" Research Report – 81-1 , International Institute for Applied systems Analysis.

Narayana, N.S.S. and M.M. Shah (1982) "Farm Supply Response in Kenya: Acreage Allocation Model", Working Paper – 82-103 , International Institute for Applied Systems Analysis.

Nerlove, M. (1958) *The Dynamics of Supply: Estimation of Farmers' Response to Price,* John Hopkins Press.

Nerlove, M. (1971) 'Further evidence on the Estimation of Dynamic Economic Relations from a time series of Cross sections" *Econometrica,* 39, 359-382..

Nerlove (1979), "The Dynamics of Supply: Retrospect and Prospect", *American Journal of Agricultural Economics,* Vol 61, No.5, 874-888.

Nowshirvani, V.F. (1971) "Land Allocation under Uncertainty in Subsistence Agriculture", *Oxford Economic Papers,* 23 (3), 445.

Pandey, L.M., Sant Kumar and Mruthyunjaya, (2005) " Instability, Supply Response and Insurance in Oilseeds Production in India", *Agricultural Economic Research Review*, Vol 18.

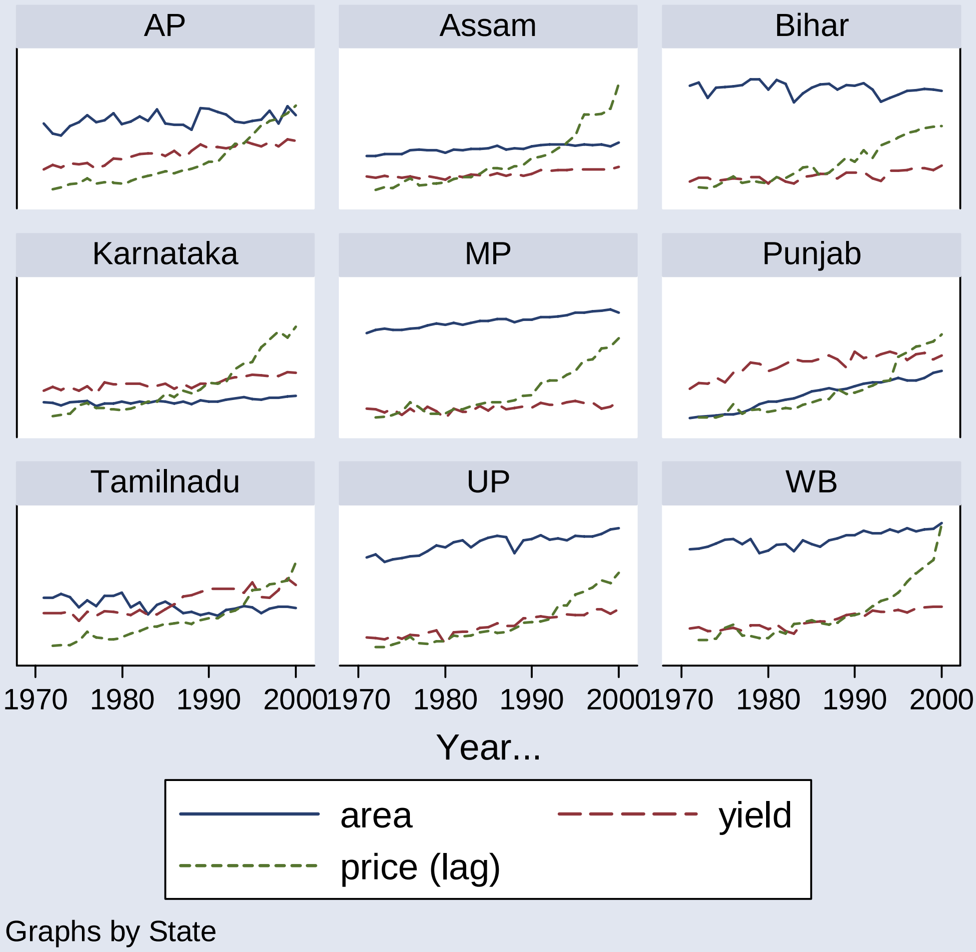
Rao, C.H.H. (2003) "Reform Agenda for Agriculture" , EPW Perspectives, Economic and Political Weekly, Feb 15.

Surekha K. (2005) "Modeling Nonlinear Autoregressive Distributed Lag Models: A New Approach" *, Journal of Quantitative Economics*, 101-114.

Tyagi, D. S. (1974) *Farmer's Response to Agricultural Prices in India: A Study in Decision Making*, Heritage Publishers.

Zellner A. (1962) "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias", *Journal of American Statistical Association,* 57, 348-368.

Figure 1
Rice Area, Yield and Price over Time



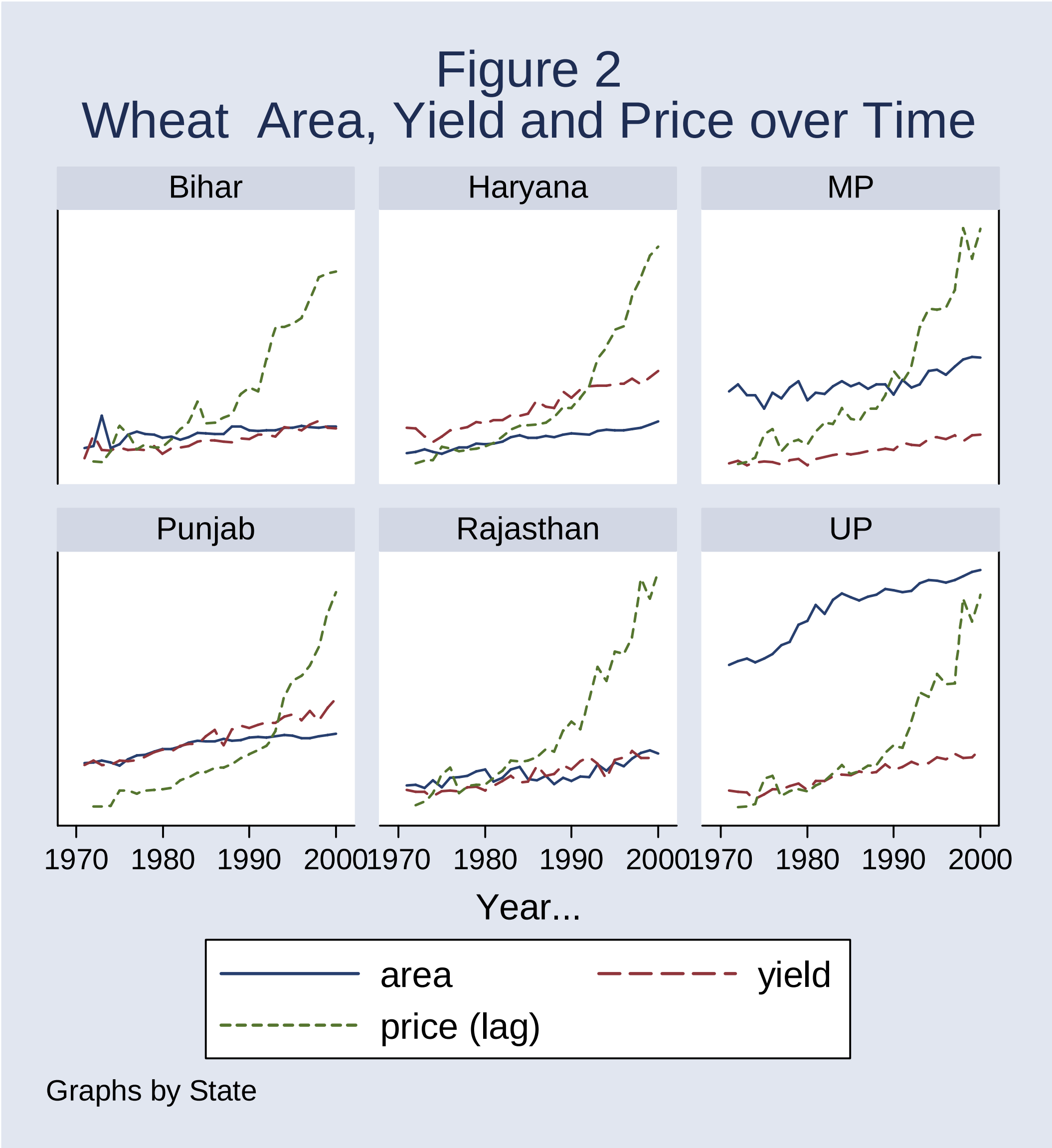


Figure 2
Wheat Area, Yield and Price over Time
Bihar
Haryana
MP
Punjab
Rajasthan
UP
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

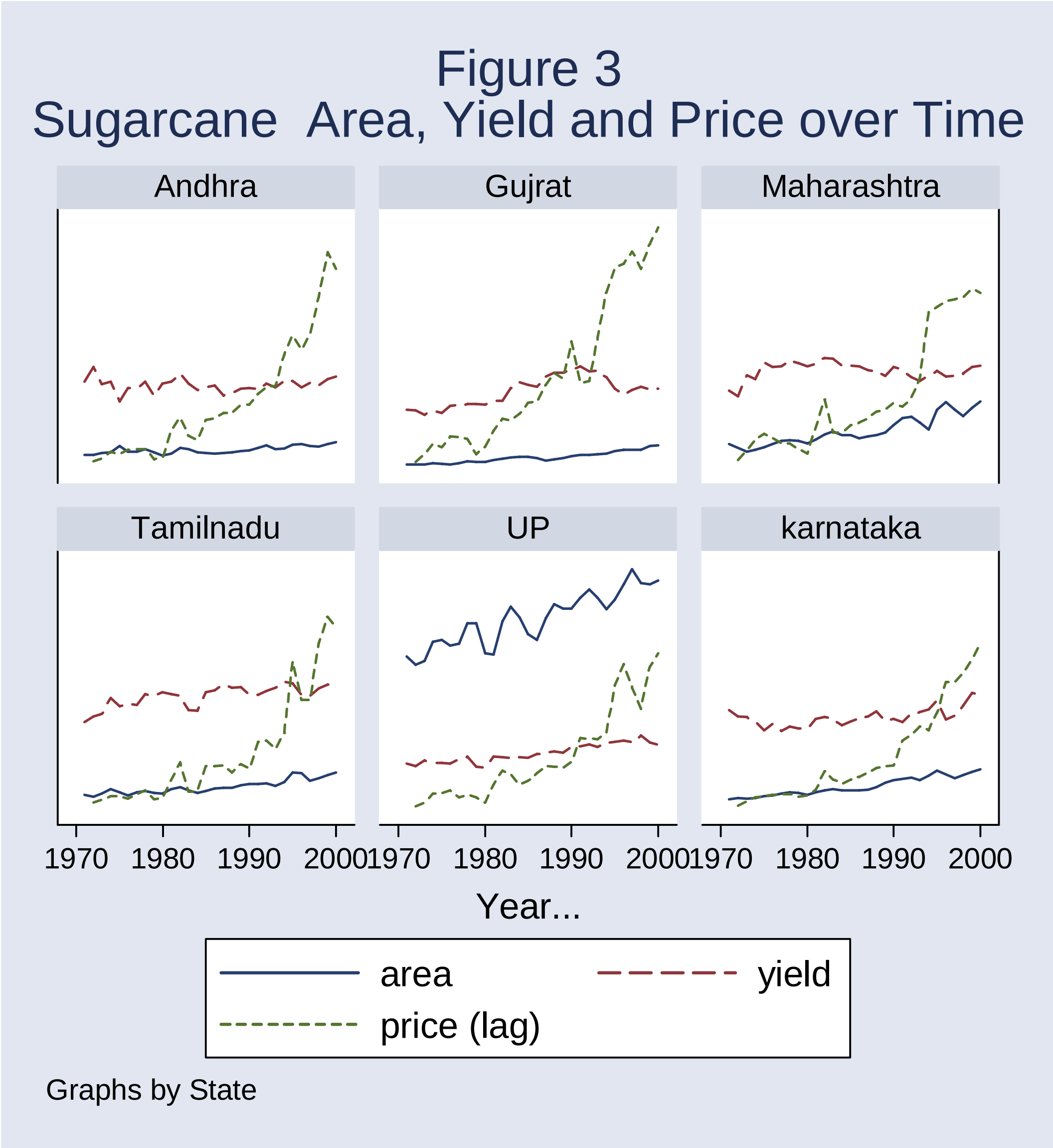


Figure 3
Sugarcane Area, Yield and Price over Time
Andhra
Gujrat
Maharashtra
Tamilnadu
UP
karnataka
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

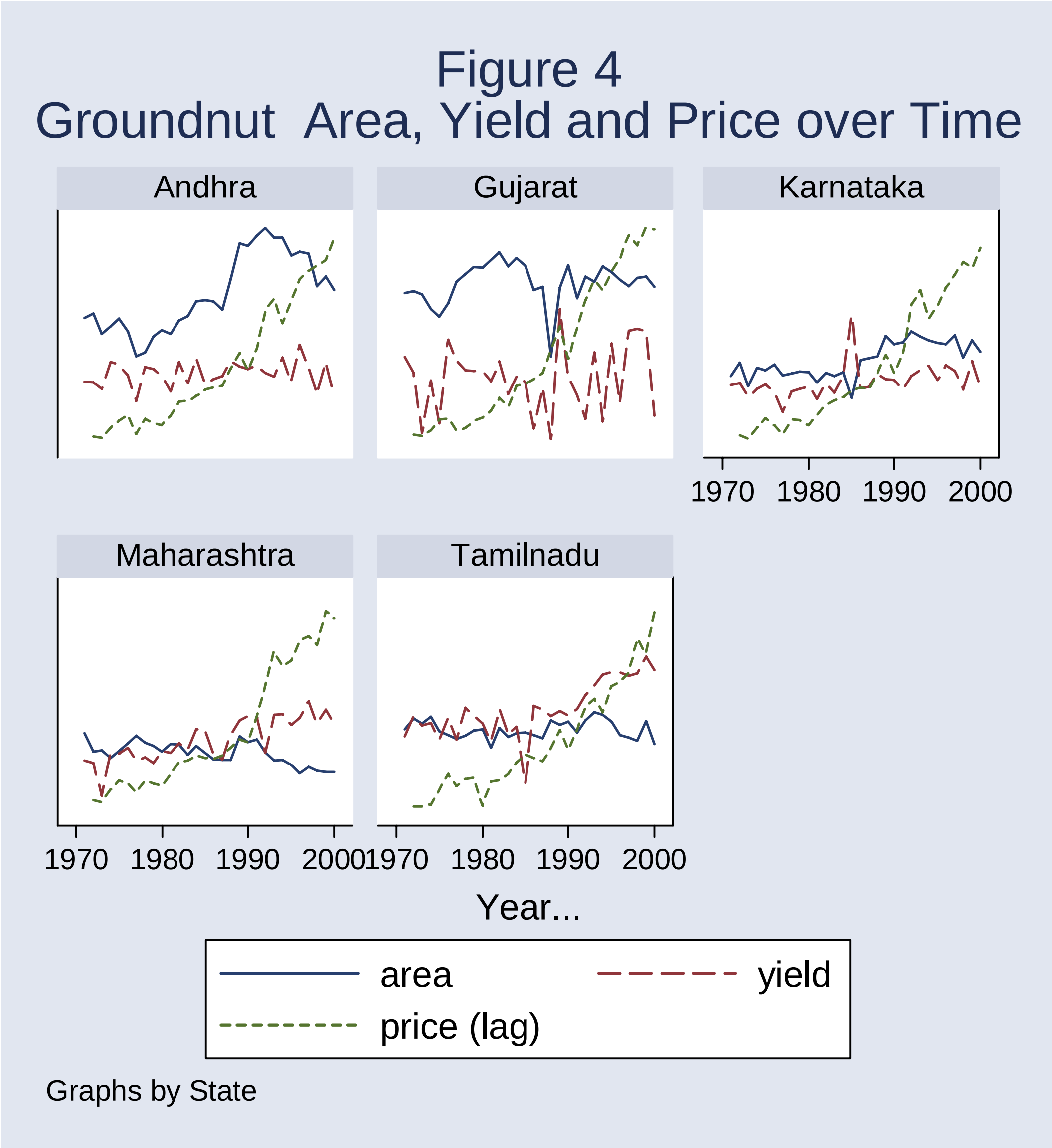


Figure 4
Groundnut Area, Yield and Price over Time
Andhra
Gujarat
Karnataka
Maharashtra
Tamilnadu
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

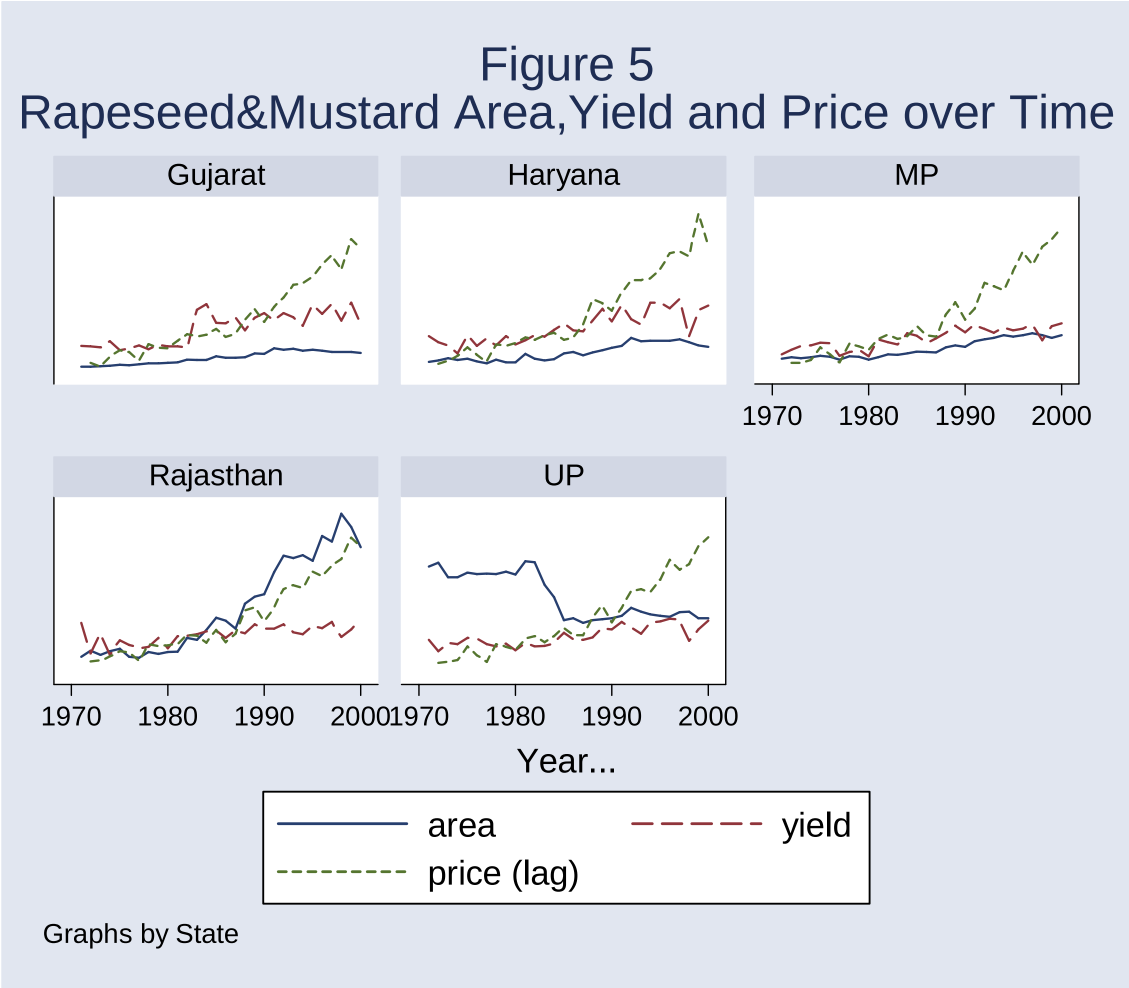


Figure 5
Rapeseed&Mustard Area,Yield and Price over Time
Gujarat
Haryana
MP
1970
1980
1990
2000
Rajasthan
UP
1970
1980
1990
2000
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

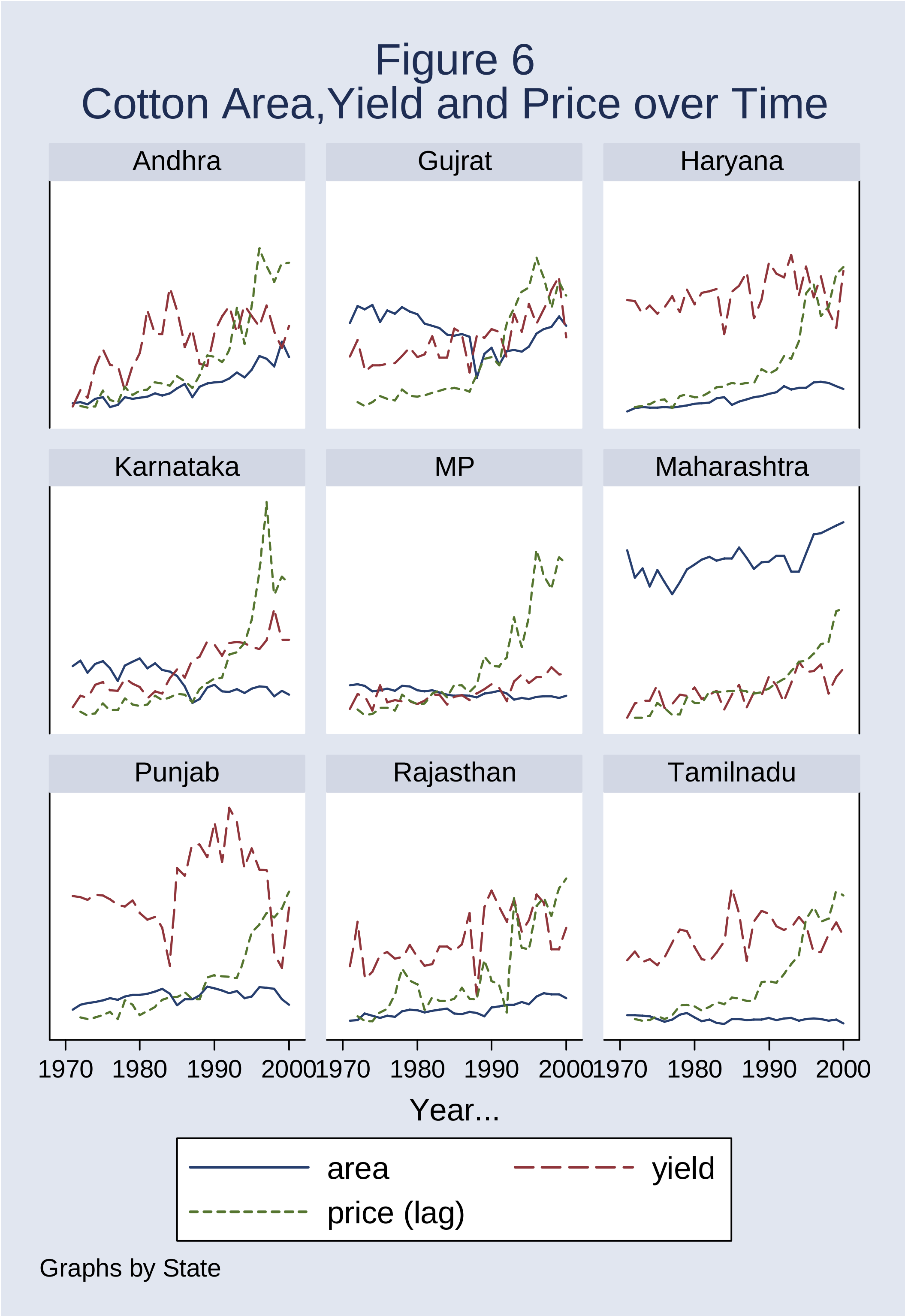


Figure 6
Cotton Area,Yield and Price over Time
Andhra
Gujrat
Haryana
Karnataka
MP
Maharashtra
Punjab
Rajasthan
Tamilnadu
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State