PP-061

Acreage and Yield Response for Major Crops in the Pre- and Post-Reform Periods in India:
A Dynamic Panel Data Approach

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January 2008
http://www.igidr.ac.in/pdf/publication/PP-061.pdf

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Report prepared for
IGIDR – ERS/ USDA Project: Agricultural Markets and Policy

January 2008

Abstract

Supply response to price changes is likely to increase with the increasing liberalization of the agricultural sector in India. Past studies revealed a weak supply response for Indian agriculture. No recent reliable estimates are available to determine whether the response has improved after the economic reforms introduced in the early 1990s in India. This report estimates supply response for major crops during the pre- and post-reform periods using the Nerlovian adjustment cum adaptive expectation model. Estimation is based on dynamic panel data technique using pooled cross-sectional time-series data across the states of India for the period 1970-71 to 2004-05. As expected, food grains reveal less response than nonfood grains. With proper specification of the price variable, the acreage elasticity significantly increased by about 20 to 40% post reforms as compared to pre reforms for all crops, except cotton and groundnut. Yield response is higher than acreage response for the main cereals, rice and wheat. Treating yield variable as a proxy for non-acreage inputs, the results confirmed that farmers respond to price incentives increasingly by adjusting non-acreage inputs than acreage for main cereal crops.

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This project was conducted by Indira Gandhi Institute of Development Research, Mumbai, India under the Cooperative Research Agreement with the Economic Research Service, U.S. Department of Agriculture. Comments and suggestions received from the seminar participants at IGIDR and USDA/ERS are gratefully acknowledged. The views expressed are those of the author and not necessarily those of ERS or USDA.

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Acreage and Yield Response for Major Crops in the Pre- and Post-Reform Periods in India: A Dynamic Panel Data Approach

Executive Summary

The effect 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 in India indicated that the supply is less elastic. Non price factors dominate price factors in the farmers' decision making. The introduction of the economic reforms is expected to improve the responses since some market constraints are relaxed due to the reforms. However, there is no systematic evidence to document this hypothesis. Moreover the literature based on the post-reform period is scarce for India. This report estimates and compares pre- and post-reform supply elasticities using cross-sectional time series panel data adopting a dynamic methodology.

The methodology for the analysis is the Nerlovian adjustment cum adaptive expectation model. This framework enables one to find short run and long run response parameters. Non price factors considered in the model were the irrigation variable, rural literacy rate, rainfall and yield risk apart from regional dummy and reform period specific dummy coefficients. The set of crops was classified under three different groups based on the criterion of substitutability. Rice and sugarcane constitute the first group. The second group consists of crops predominantly cultivated in the rabi (winter) season (wheat, rapeseed & mustard, pulses). The third group includes cotton and groundnut. It is maintained that the farmers respond to market incentives not only by adjusting acreage,

but also by adjusting other inputs. Yield variable is treated as a proxy for non-acreage inputs.

Depending on the specification of the price variable, two versions were attempted. In the first version, price variable was computed as the ratio of the farm harvest price of the main crop to the substitutes' price average. In the second version, the price variable referred to the ratio of main crop price over the average variable cost. The second version is considered important because farmers consider not only output price, but also the profit in decision making.

For the first analysis, the period of study is 1970-71 to 2004-2005. The whole period is divided into two; pre reform period pertains to 1970-71 to 1989-90; post reform period covers 1990-91 to 2004-05. For the latter analysis, the study period is confined to 1980-81 to 2004-2005 due to lack of cost data for the earlier years. The pre reform period is 1980-81 to 1989-90 and the post reform, 1990-91 to 2004-05.

The results indicate that post-reform supply elasticities were higher for rice, wheat, and rabi oilseed, and rapeseed and mustard when compared with the pre-reform supply elasticities. The results confirm the fact that farmers respond more by non-acreage inputs than acreage input for food grains in the short run. For crops such as groundnuts and cotton, where fluctuation in yield is large, risk variable, measured as past 3 years' standard deviation in yield, turned out to be an adverse factor. For both the crops, post-reform elasticities have declined. Inconsistent data for the infrastructure prevented the inclusion of infrastructure variables other than irrigation. This is a limitation of this study since the infrastructure growth and institututional reforms in the post-reform period is likely to enhance farmers' responses to market incentives.

Acreage and Yield Response for Major Crops in the Pre- and Post-Reform Periods in India: A Dynamic Panel Data Approach

Introduction

With the introduction of economic reforms in the early 1990s in India, accompanied by trade and exchange rate liberalization, indian farmers were expected to benefit from the increased market incentives (Rao, 2003). The effect of liberalization on the growth of agriculture crucially depends on how farmers respond to various price incentives. Since the 1950s, a large volume of literature on supply response indicated that the response is much weaker. Non-price factors seem to dominate price factors in farmers' decision making (Krishna, 1962; Narain, 1965; Askari and Cummings, 1976; and Gulati and Kelly, 1999). It is widely believed that the reforms of 1990s would help remove some of the constraints that Indian farmers has been facing in responding to market incentives, and hence a greater response is expected in the post-reform period. However, there are no firm evidence so far to support such a hypothesis.

The lack of response may be because the policies are still unable to identify and target the proper constraints. An alternative view is that the farmers' response to liberalization is a lengthy process and hence in the short span of 10 to 15 years, the full effects are yet to be realized. In the academic literature, the argument is, it may be due to the nature of specification and the methodology used in estimation. With these considerations in the background, this report examines the literature from the viewpoint of methodology, specification and measurement issues, and then empirically analyzes the acreage/supply responses of major crops using state-level panel data.

In this report, it is hypothesized that acreage response under-estimates 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 separately, and the supply response estimates were derived from these two estimates. The significant feature of the specification used in this report is that the main and substitutable crops were jointly estimated by a single set of equations and by the introduction of varying slope coefficients to capture different responses.

The methodology for the analysis is the Nerlovian adjustment cum expectation model. The Nerlovian framework is superior to alternative models in that they facilitate computing short run and long run responses and the speed of adjustment in moving from actual to desired level of land and other inputs. Further, the alternative model requires detailed information on input prices which are difficult to obtain.

Background

The notion that farmers in less developed countries respond slowly to economic incentives such as price and income has been supported by many findings. Numerous studies available for India at the crop level concluded that the supply response is less elastic (Askari and Cummings, 1976; Gulati and Kelly, 1999). Reasons cited for poor response varied from factors such as constraints on irrigation and infrastructure to a lack of complementary agricultural policies. There are varying degrees of response. Two sets of explanations were offered as to why the results varied and what had been overlooked in the process: first, conceptual problems in identifying correct price and climate variables; second, the formulation of the empirical model. For instance, the specification of the supply function (lagged price of single lag or distributed lag), failure to recognize an identification problem, improper choice of competing crops, and failure to identify the correct set of non-market factors—contributed to the varying results.

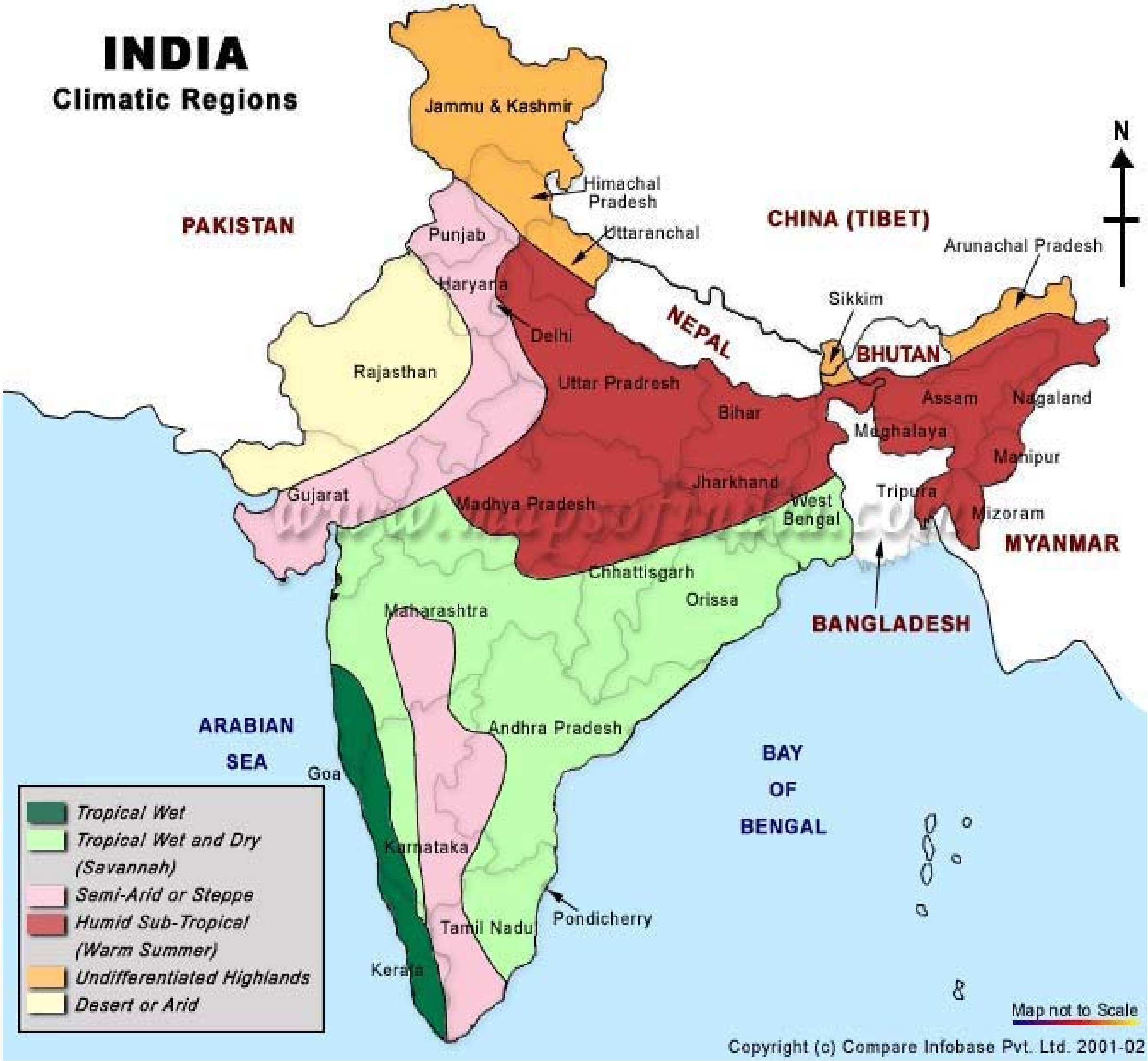
The importance of non-price factors drew adequate attention in the literature: rainfall, irrigation, market access for both inputs and output, and literacy. The reason cited for a low response to prices in less developed economy is the limited access to input and product markets or high transaction costs associated with their use. Limited market access may be either due to physical constraints such as absence of proper road links or the distances involved between the roads and the markets, or institutional constraints like presence of intermediaries. However, even those studies that tried to incorporate some of these attributes could not bring out a clear relation.

Several studies that present estimates for India mostly used time-series aggregated data, which conceal variations across states. The state-specific characteristics and its contribution to the varying supply response 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. Few scholars worked with panel data in supply response analysis. Gulati and Kelley (1999), Kumar and Rosegrant (1997), and Kanwar (2004) are the few who used pooled cross-section-time-series data across regions of India. Only Kanwar's study included the post-reform period, but it did not separate the data between pre-reform and post-reform periods. There is a dearth of studies which analyze response in the post-reform era systematically. This report aims to fill this gap.

Agroclimatic System in India

Agroclimatic system in India can be classified under 5 broad categories: Arid, Coastal, Irrigated, Rainfed and Hill & Mountain. The classification of agrosystems and the agroecology based regional classification are given respectively in Figure 1 and Table1.

Figure 1. Ecological regions of India



Source: http://www.mapsofindia.com/maps/india/climaticregions.htm

Table 1—Classification of production by agro-ecosystem in India

No.	Agro-ecosystem	Crop production System	States
1	Arid	Pearl millet and oilseeds	Gujarat and Rajasthan
		Pearl millet	Rajasthan
2	Coastal	Rice and groundnuts	Andhra, Tamil Nadu, and Orissa
		Coconut and rice	Karnataka, Kerala, Goa, Maharashtra, and Tamil Nadu
3	Irrigated	Rice and wheat	Bihar, Haryana, Punjab, Uttar Pradesh, and West Bengal
		Cotton and wheat	Haryana, Punjab, and Rajasthan
		Sugarcane and wheat	Haryana, and Uttar Pradesh
4	Rainfed	Rice	Assam, Bihar, Madhya Pradesh, Maharashtra, Orissa, and West Bengal
		Coarse cereals	Karnataka and Maharashtra
		Oilseeds	Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan, Tamil Nadu, and Uttar Pradesh
		Cotton	Gujarat and Maharashtra
5	Hill and mountain	Rice, maize, and fruits	Northeastern states, Assam, and West Bengal
		Rice, wheat, and fruits	Uttar Pradesh, Himachal Pradesh, Jammu, and Kashmir
		Horticulture	Himachal Pradesh, and Jammu and Kashmir

Source: National Centre for Agricultural Economics and Policy Research, New Delhi, India 2001.

Changes in Cropping Pattern and Yield

Changes in cropping patterns between 1960 and 2001 indicate shifts from food grains to nonfood grains, especially from coarse cereals and pulses to oilseeds, sugarcane, and nonfood crops (Table 2).

Table 2—Cropping pattern for India

Crops	**1960-61**	**1970-71**	**1980-81**	**1990-91**	**1995-96**	**2000-01**	**Annual change 1980s (%)**	**Annual change 1990s (%)**
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
Food grains	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
Nonfood grains	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

Note: Figures except the last row refer to percentage of area under the crop to the total cropped area.
Sources: Agricultural Statistics at a Glance; http://www.indiastat.com.

The regional pattern shows that the southern and western regions are more diversified over the years, and the shifts took place mainly in favor of oilseed crops. Especially in Tamil Nadu, crop diversification from rice to groundnut and sugarcane was seen in the 1980s. In Karnataka, area shifts occurred in favor of fruit and vegetables. Climatic conditions and government-supported programs favored this crop. The northern region is specializing in the primary cereals. Coarse cereals and pulses are being replaced by rice and wheat in this region (Table 3). Sugarcane is also gaining importance in this region. Eastern region is the least diversified of all; it is mainly concentrating in foodgrains.

There are large variations across regions in the percentage of irrigated cropland. For instance, more than 90 percent of cotton is irrigated in Punjab, while less than 5 percent is irrigated in Maharashtra. This is reflected in the yield variations across regions.

Yields increased mainly in the 1970s and 1980s due to the effect of technological innovation (Table 4). In the 1990s, (the post-reform period), the yield increases for commercial crops, for example, oilseeds and sugarcane, were not up to the expected level. For oilseeds, liberal import policies affected the domestic growth of area and productivity.

Table 3—Gains and reductions in area for major crops, by state

Crops	1970s and 1980s		1990s	
	Gain	**Reduction**	**Gain**	**Reduction**
Rice	Madhya Pradesh, Punjab, Uttar Pradesh, and West Bengal	Tamil Nadu	Madhya Pradesh, Punjab, and Uttar Pradesh	Andhra Pradesh and Bihar
Wheat	Major producing states		Major producing states	
Coarse cereals:				
Maize	Madhya Pradesh and Rajasthan	Bihar and Uttar Pradesh	Andhra Pradesh	Uttar Pradesh
Jowar		Major producing states		Major producing states
Grams	Madhya Pradesh, Maharashtra, and Rajasthan	Uttar Pradesh	Madhya Pradesh and Maharashtra	Uttar Pradesh
Groundnut**	Andhra Pradesh and Gujarat	Maharashtra		Andhra Pradesh, Gujarat, and Maharashtra
Rapeseed and mustard	Rajasthan, Madhya Pradesh, Haryana, and West Bengal	Uttar Pradesh	Rajasthan and Madhya Pradesh	
Sugarcane	Karnataka and Uttar Pradesh		Andhra Pradesh, Tamil Nadu Maharashtra, Karnataka, and Uttar Pradesh	
Cotton	Andhra Pradesh and Punjab	Gujarat and Karnataka	Andhra Pradesh, Gujarat, and Maharashtra	Punjab and Karnataka

Source of Data: www.indiastat.com
Notes: 1970s refer to the period 1970-71 to 1979-80; 1980s refer to 1980-81 to 1989-90; and 1990s refer to 1990-91 to 1999-2000.
** for Tamil Nadu, cropped area under groundnuts is fluctuating around the mean level.

Table 4—States that recorded significant increase in yield

Crops	1970s	1980s	1990s
Rice	Punjab*and Andhra Pradesh	Tamil Nadu* West Bengal* Uttar Pradesh* Orissa, and Bihar	Bihar* , Uttar Pradesh, and West Bengal
Wheat	Punjab, Uttar Pradesh, and Haryana	Major producing states	Major producing states
Grams	Maharashtra, Haryana, and Rajasthan	Haryana* and Maharashtra	Rajasthan and Madhya Pradesh
Groundnuts	Tamil Nadu* and Maharashtra	Maharashtra, Tamil Nadu, Andhra Pradesh, and Karnataka	Gujarat* and Tamil Nadu
Rapeseed and mustard		Gujarat, Haryana* Uttar Pradesh* Madhya Pradesh, and Rajasthan	
Sugarcane	Maharashtra and Tamil Nadu	Gujarat	Karnataka
Cotton	Andhra Pradesh* Maharashtra* and Karnataka*	Karnataka* Tamil Nadu*, Punjab* Gujarat, Madhya Pradesh, Maharashtra, and Rajasthan	Madhya Pradesh* and Gujarat, Maharashtra, and Karnataka

NOTE: Only the increase to the order of more than 2 percent of annual compound growth rate is reported in this table.
* refers to annual compound growth of more than 5 percent.

Theoretical and Analytical Developments

Basic Model

There are broadly two frameworks identified in the literature to conduct supply response analysis: (a) the Nerlovian expectation model, which facilitates the analysis of both the speed and level of adjustment of actual acreage toward desired acreage and (b) the supply function derived from the profit-maximizing framework. The second approach which involves joint estimation of output supply and input demand functions requires detailed information on all the input prices. Moreover, the agricultural input markets are not functioning in a competitive environment in India, particularly the land and labor markets. Government intervention in the delivery of material inputs to farmers is common. It is difficult to get information on prices that farmers pay for inputs. Because of these reasons, this study used the Nerlovian approach.

The pioneering work of Nerlove (1958) enables one to determine short run and long run elasticities, and 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,[1] while the actual acreage, A_t, adjusts to the desired acreage with some lag.[2] The model is as follows:

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

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

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

[1] Future price has not been considered in the formation of the expected price due to future and forward contracts not being widely practiced and even when they are practiced, they seem to benefit the traders more than the farmers.

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

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

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

Even though the final reduced form is linear in parameters, the original structural form is nonlinear in parameters; also problems of over-identification need 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 model with lagged dependent variables appearing as independent variables. The 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 that, farmers' adjustments 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 by adding price expectation formation—the third equation. Prices were revised in each period in proportion to the difference between the 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 farmers' responses are based not on next period's forecast, but rather on some average (normal) level rests on the notion that there are costs of adjustments. The twin problems of a stochastic explanatory variable and autoregressive error structure in the reduced-form equation render the estimation complex.

In the 1960s, the basic Nerlovian model was modified for food crops in developing economies because farmers use some of their product for their own consumption.[3] Hence, the variable of interest is marketed surplus rather than total output. The studies of Krishna (1962) and Behrman (1966), are based on this concept. They pointed out the need to consider the income elasticity of consumption within the farm household. However with the advent of Green Revolution, use of modern inputs for main cereal crops, and large volume produced for the market, the distinction between total supply and marketed surplus has lost its importance.

The period after the 1970s and 1980s witnessed further development of dynamic models. Nerlove (1979) indicated the ad hoc nature of the formulation of distributed-lag models in empirical literature. In his view, the econometrically relevant dynamic model should characterize response paths of the producer under dynamic conditions and form expectations of the future on the basis of all information available (e.g., Eckstein, 1984). Simultaneously, there were developments on the estimation front of dynamic models

[3]Food grains were considered as subsistence crops. After the onset of the green revolution, however, major cereals were no longer treated as subsistence crops. They are giving higher yields due to increasing use of modern varieties of seeds and chemical fertilizers and hence becoming important sources of revenue.

using panel data. Panel data are often complex, requiring modifications in the estimation methodology. Some important contributions on the methodology of panel data dynamic models are Nerlove (1971), Anderson and Hsiao (1981), Chamberlain (1984), and Arellano and Bond (1991).

Specification: Some Issues

Statistical estimation involves making decisions on proper specification of variables apart from the usual estimation-related problems. The crucial variables that 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. Beginning with Nerlove's 1958 model of supply response, researchers attempted to improve the specifications by introducing a competing crop concept that used relative prices instead of absolute prices. Next was the introduction of risk and uncertainty in the model. Behrman (1968) introduced standard deviations of prices and yields measured from the previous 3 years of data. This modification was criticized on the basis that the Nerlovian price expectation model is inconsistent with changing variance of the subjective probability distributions. Nowshirvani (1971) modeled farmers' land allocation decision, which accounted for uncertainties in prices and yields. Incorporating risk, Nowshirvani found that area-price response coefficient is negative, implying that stabilization schemes may sometimes be more effective than price in bringing about area shifts among crops. Many scholars use relative profitability rather than relative price, because it better explains farmers' choice behavior. However, profit calculation has its own measurement problem, such as identifying proper imputation methods for own inputs and appropriate types of costs to compute profits and problems related to common costs. Moreover, price is a direct policy instrument, and, hence, the results are convenient for policymaking. In view of the above factors, this study uses output price, either standardized for competing crop price or input prices, as the incentive variable, with the ultimate goal of finding acreage/yield–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 the acreage function believe that output is subject to more fluctuation than area because of uncertain random factors such as temperature and rainfall. Hence, to understand the behavioral pattern, area is the appropriate variable. Even in the land variable, one needs to distinguish between explaining total area changes and area shifts between crops given the total land size. Hence, even if farmers are profit maximizers in a neoclassical sense, total cultivated area is unlikely to change in response 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 use the ratio of crop acreage to total cropped area for studying shifts in area among the crops. This approach has its own limitation, in that the simultaneous changes in the crop area and the total area will conceal variations. Absolute area, therefore, is used in this study.

Regarding the rainfall variable, no satisfactory measure of this variable was found in the literature. Variables used in the literature are: average total rainfall in a crop season, rainfall in the pre-sowing period, absolute deviation from normal rainfall and number of stations reported below 20 percent of normal to the total in a region. Rainfall is more meaningful for its effect than its source. Many factors affect productivity: the soil's ability to hold moisture, how rapidly water drains from an area, and how equally rainfall is distributed across months in a season. Information on even some of these attributes would be useful for explaining the impact of rainfall. Consistent data on these is difficult to obtain.

Allocating land among different crops will be difficult if monoculture is practiced (i.e., entire sown area belongs to one crop) or if an area is more suited to specific crops. In such cases, crop rotation may be restrained, particularly in the short run; but given sufficiently longer time, shifts can occur. Hence, crop specificity affects the extent of shifts in land allocation or the promptness with which they occur rather than precluding their occurrence (Narain, 1965). Small farms are likely to face more constraints compared with large farms. Hence, the flexibility with which the crops can be shifted may be less among small farms.

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. It is hypothesized that farmers make substantial revisions in the decision on other inputs after they allocate the land, and overall input changes will be reflected in the yield. Hence, it is reasonable to assume that both area and yield are influenced by the expected output price. The idea of yield response to price is further supported by the literature that area function alone might under-estimate the actual level of supply response (Tyagi, 1974). Farmers may display response by adopting better technology of production with no change in area or by using more or better quality of inputs. Such responses 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 by the input application alone, but will also be reflected in the quality of inputs and the timing and the method of application. Assuming that these factors will be reflected in yield, the yield equation is also specified in our model as a function of price and non-price variables. Past studies found that the rural literacy rate influences the choice of technology (e.g., Mittal and Kumar, 2000). Hence, both irrigated area and the literacy rate are included as proxies for technology.

Increase in prices may also bring into cultivation more marginal lands, lands that previously were left uncultivated. At the regional level, such a response may reduce average yield. There is no adequate information to see if more marginal lands were brought into cultivation in response to higher output prices. Hence, these estimates should be interpreted with caution.

Farmers frame decisions according to some expected price. The modeler's task is to construct relevant output price variables. Regarding the ratio of own price to competing price, it is difficult to arrive at a single index if there are a variety of substitutes. Also, in the interregional analysis, the competing crop may differ from one region to another. It is preferable to use a weighted average price index where the relative price is the ratio of the crop of interest to a weighted average of substitutes' prices (e.g. Falcon, 1964). Gulati and Kelley (1999) corroborated the notion that agro-climatic conditions, land characteristics, and the farmers' knowledge about the crop, along with the price variable, simultaneously affect cropping decisions. They found that a low degree of risk-bearing ability would weaken the acreage–price response if the more profitable crops were also more risky. Also, the major determining factors at the individual household level may be quite different from those at the state, zonal, or national level. Askari and Cummings (1976) surveyed a large number of studies to ascertain the reason for the large variation in supply response elasticities across studies. They identified many non price factors that influence the elasticities, including farm size, access to irrigation, yield risk, literacy level, and ownership vs. tenancy.

A Review of Estimation Methodology

The experience of the researchers with the Nerlovian model is varied. The advantage of using pooled cross-sectional time-series data set is well known. Such data set provides valuable information about the diversity of the attributes because the data contain both inter-regional and temporal variations. This report uses pooled cross-sectional time-series panel data. The detailed information about the data used is presented in the relevant section.

In the context of supply response, Narayana and Parikh (1981) modified the conventional econometric techniques to overcome a limitation of the traditional Nerlovian model, which did not separate past prices into stationary components and random components. It attaches the same weights to both the components for predicting future prices. Narayana *et al*. deviated from this in two ways:

(i) expected revenue was used instead of expected price, and

(ii) a revenue expectation function was formulated for each crop by isolating stationary and random components in past prices and suitable weights were attached for both in prediction. The method is based on the Autoregressive Integrated Moving Average technique combined with the Box-Jenkins procedure for estimations.

A similar method was applied to analyze farmers' acreage response in Kenya by Narayana and Shah (1984). This study mainly distinguished between the responses of small farms and large farms. Small farms' land adjustments tended to shift to raising more food crops, whereas large farms' land area adjustment tended to shift to raising more commercial crops, like sugarcane.

Application of nonlinear models in supply response is also becoming popular. Surekha (2005) developed a nonlinear autoregressive distributed-lag model to study supply response for rice. He criticized the standard methods, saying that most of the structural form parameters are either nonlinear 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 often lead to low estimates. He felt this could be one source of trouble in a wide range of studies that used Nerlovian models, obtaining low elasticities. To overcome this problem, Surekha used an alternative estimation method based on a Bayesian paradigm, which takes care of the problem stated above. Taking into account the appropriate variance/covariance structure of the error term, the author estimated the parameters using a Bayesian two-step procedure and obtained a higher elasticity for supply response compared with the estimates derived from standard least square method. This could partly explain the low supply response estimates obtained in studies using conventional method. Surekha further found a low adjustment coefficient that explains farmers' reluctance to make larger changes in the major cereal crops like rice. However, the empirical model is based on time-series aggregate data and hence suppresses regional variation.

Past Studies based on Panel Data

A study by Kumar and Rosegrant (1997) was one of the few to have used pooled cross-sectional time-series data across regions of India to examine the pre-reform period. They used Zellner's (1962) seemingly unrelated regression (SUR) estimation technique for joint estimation of area, yield, and input demand in the recursive block system. Expected revenue was used as a price incentive indicator. This study has estimated dynamic response within a static framework by including a lagged dependent variable. Gulati and Kelley (1999) analyzed supply using pooled data and identified 23 crop zones in the Indian semi arid tropic regions. By using cross-sectional district data covering the period 1970-71 to 1990-91, the estimates were derived for various crops in each region. The study found that non-market factors explained most of the shift in cropping patterns.

Brauw et al. (2002) studied both flexibility and supply responsiveness of Chinese farmers by using pooled cross-section time-series data for the period 1975-95. The study introduced a new concept of 'degree of flexibility' in the adjustment of quasi-fixed factors. “Quasi–fixed” is defined as those inputs that take more than one period to adjust to changes in relative prices or other exogenous factors. The authors adopted simultaneous estimation of input demand and output supply following Gallant’s (1992) method of nonlinear three-stage least square estimation technique for two quasi-fixed inputs and three outputs. The authors used the dynamic value function specified by Epstein (1981). They found that land and labor were less flexible for adjustment in the early reform period and more flexible in the late reform period when markets were fully liberalized. By introducing a period dummy/price interaction term, the study allowed the price response to change between the early reform and late reform periods. The results show that the own-price response variable displayed a significant increase in the late reform period for labor but showed little change for area response. However, farmers increased their speed of adjustment between early and late reform periods. The study confirmed that the gradual reform process worked to the advantage of Chinese agriculture.

Estimation Technique

This section describes 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 nonconstant variances across panel units that lead to heteroscedasticity problems, (2) error structure across time may be autocorrelated, and (3) errors may be contemporaneously correlated across panel units. The presence of any of these problems leads to a situation where ‘Ordinary Least Square’ is not an efficient technique and one needs to seek alternative methods. Serial autocorrelation or heteroscedasticity can be handled by the generalized least square technique, whereas for contemporaneous correlation, Zellner's (1962) SUR can be used. An alternative method is the error component analysis in which the error structure is decomposed into individual specific time invariant error (v_i) and a general error (ε_{it}) that varies with respect to panel and time.

It is important to decide on the nature of state-specific effects of the model (fixed vs. random). We conducted a Lagrange Multiplier test for this and the test rejected fixed state-specific effects. In other words, the state effects cannot be fully captured by introducing dummy variables. This result prompted us to try the random effects model, specifically the technique developed by Arellano and Bond (1991). Arellano and Bond's Generalized Method of Moments (GMM) estimator is robust to differences in the specification of the data-generating process. These estimates are consistent and asymptotically efficient. This method is an extension of Hausman and Taylor's (1981) formulation of the random effects model. In random effect model, the assumption that state-specific random effects are uncorrelated with explanatory (X's) variables is relaxed. Hausman *et al.*, split the four X variables into two sets: (1) those that are uncorrelated with general error ε_{it} and those that are correlated with general error ε_{it} (for instance, lagged dependent), and (2) those that are the components of state-specific term v_i (correlated and uncorrelated with general error ε_{it}). In the present model, we assume state-specific random is uncorrelated with general error as follows:

$$y_{it} = \varphi' Z_{it} + \varepsilon_{it}$$

$$where \quad Z_{it} = (X_{it,} Y_{i,t-1,} R_i)$$

R_i's are state-specific variables that by assumption are uncorrelated with the general error component ε_{it}.

In the present model—due to the introduction of a lagged dependent as a regressor—in each period, this variable is correlated with error terms of all the previous years. In general, if we have some stochastic regressors, X_t, then the nature of covariance would be as follows:

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

$$\neq 0 \text{ if } s < t\,.$$

GMM is basically an instrumental variable technique. The conditional expectation of the product of the lagged dependent variable and the disturbance term is nonzero, hence, use of proper instrumental variables would eliminate this problem. Moreover, the zero moment equations were also fully exploited in Arellano *et al.* In particular, the following moment conditions were used in addition to those used by Hausman and Taylor:

$$E\begin{bmatrix} X_{it} \\ Y_{it-1} \\ R_i \\ \bar{X}_i \end{bmatrix}\left(\varepsilon_{ir} - \bar{\varepsilon}_i\right) = 0 \text{ for some } r \neq t.$$

The estimation retains the error component with panel-specific random terms. First, differencing of the variables eliminates the panel-specific effects. By first differencing, we also adjust for nonstationarity 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 were used for lagged dependent variables[4] (Greene, 2006). The model is identified as long as the number of explanatory variables that are uncorrelated with the general error term is at least as large as the number of state-specific time invariant variables that are correlated with the general error term. The software also provides test statistic to check over-identifying restrictions in the model.

Empirical Analysis

The data set comprises state-level data pertaining to the major crops of India. The whole analysis was done with two alternative price variables: relative real output price over substitutes' price, and the ratio of own-output price over average variable cost. For the former, the period of analysis is 1970-71 to 2004-05. The whole period is divided into two: the pre-reform period pertains to 1970-71 to 1989-90; the post-reform period covers 1990-91 to 2004-05.[5] For the latter, the period of analysis is confined to 1980-81 to 2004-05 due to a lack of cost data for the earlier years. The pre-reform period is 1980-81 to 1989-90, and the post-reform is 1990-91 to 2004-05.[6]

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

[5] The liberalization attribute is considered merely by dividing the period into pre- and post-reforms, and hence we have not gone into detailed crop-specific liberalization measures over time. Liberalization constitutes market-based and institutional reforms for better participation of farmers in the market process, which constitute enhancement of infrastructure, increased private entry in storage and processing, removal of nontariff barriers, and rationalizing of subsidies and tariffs.

[6] In the second analysis, grams were omitted due to lack of cost data.

Crops by Selected States

For selection of states for each crop, first, the contribution of output of each state to all- India has been studied[7]. The states which contributed 4% or more to the total have been selected. The selected states for each crop is presented in Table 5.

Table 5—Selected states for each crop

Crops	**Selected states**
Rice	Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh, Bihar and West Bengal Assam, Punjab, and Uttar Pradesh
Wheat	Bihar, Madhya Pradesh, Rajasthan, Haryana, Punjab, and Uttar Pradesh
Coarse cereals, maize, jowar, and bajra	Maize: Andhra Pradesh, Karnataka, Madhya Pradesh, Bihar, Rajasthan, and Uttar Pradesh Jowar: Andhra Pradesh, Karnataka, Tamilnadu, Maharashtra, Madhya Pradesh, and Uttar Pradesh Bajra: Karnataka, Tamilnadu, Gujarat, Maharashtra, Rajasthan, Haryana, and Uttar Pradesh
Grams	Haryana, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh
Groundnuts	Andhra Pradesh, Karnataka, Tamilnadu, Gujarat, and Maharashtra

[7] First we perused the data of crop output share of each state to all India for the reference years 70-71, 80-81, 90-91 and 1999-2000 and the selection is based on the criterion if the state share is 4% or more consistently for atleast 2 reference years.

Rapeseed and mustard	Gujarat, Madhya Pradesh, Rajasthan, Haryana, and Uttar Pradesh
Sugarcane	Andhra Pradesh, Karnataka, Tamilnadu, Gujarat, Maharashtra, and Uttar Pradesh
Cotton	Andhra Pradesh, Karnataka, Tamilnadu Gujarat, Maharashtra, Madhya Pradesh, Rajasthan, Punjab, and Haryana

In the next stage, we divided the crops into groups so that crops within a group were substitutable. Rice is cultivated chiefly in irrigated conditions in the southern region and Punjab. We selected sugarcane as the competing crop for rice. Bihar and West Bengal accounted for more than 50 percent of India's rainfed area. However, in these two states, there is really no competing crop for rice. Taking into consideration all these factors, we kept rice and sugarcane in one group. For wheat, which is mainly cultivated in the northern region during rabi season, the competing crops are grams and rapeseed & mustard (Table 6). The next group consists of crops mostly grown in the kharif season under rainfed conditions: groundnuts, cotton, and coarse cereals. We considered maize, jowar, and bajra for coarse cereals. Of the three, bajra is more drought resistant than other cereals and is generally preferred in low-rainfall areas.

Table 6—Classification by substitutable crops

Groups	Substitutable crops
Group 1	Rice and sugarcane
Group 2 (rabi crops)	Wheat, rapeseed and mustard, and grams
Group 3	Groundnuts, cotton, and coarse cereals[8] (consisting of jowar, bajra, and maize).

Data Source and Variables

Area, yield, farm harvest price, variable cost per quintal, total rainfall, deviation from normal rainfall, proportion of area irrigated, and rural literacy are the variables on which information was collected. 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", "Reports of the Commission for Agricultural Costs and Prices", state reports, planning commission reports, and www.indiastat.com.

For the first analysis, the price variable is the ratio of lagged real own-output price to real prices of competing crops. If there is more than one competing crop, an average of prices is considered. In the second analysis, the price variable is the ratio of lagged own-output

[8] Coarse cereals were finally omitted due to data gaps after 2000.

price to average variable cost. Price, rainfall, deviation from normal rainfall, proportion of area irrigated, rural literacy rate, and yield risk were initially tried as explanatory variables. All the variables except dummy variables are incorporated in logarithms. For rice and cotton, with a substantial regional variation in output depending on whether the crop is rainfed or irrigated, we included a dummy to represent regions where the crops are cultivated mainly as irrigated crops. For rice, the region includes Andhra, Karnataka, Punjab, Tamil Nadu, and Uttar Pradesh; for cotton, the region includes Punjab, Haryana, and Rajasthan. After experimenting with a few trials, a final set of variables was chosen. Rice has a dual market price, namely open market price and government procurement price. We found that only in Andhra and Punjab is the government procurement important; in those states, it accounts for 50 percent or more of rice purchases. Initially, we calculated a 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 used farm harvest price for all crops.

The specific feature of this study is that the main and substitutable crops are jointly estimated by introducing varying intercepts and varying slope coefficients for the price variable in the same regression equation. The period dummy-price interaction term was used to maintain different response parameters for the pre- and post-reform periods. The choice on specification was made after performing a few specification tests. The test for different coefficients for the lagged dependent variable between main and substitutable crops was rejected in all three sets of equations. Hence, the equations were estimated using the same coefficients for the lagged variables in each pair of crops.

Preliminary investigation with measures such as mean and variation over time revealed that, in general, yield variation is greater than acreage variation because of random weather factors. The time series pattern of area, yield, and price is depicted in figures 1 to 6 for major food grains, sugarcane, oilseeds, and cotton. There is a large yield fluctuation for the two crops groundnut and cotton (Figures 4 and 6). This can be attributed to the fact that for both the crops more area fall under dry cropping and dry crops depict high temporal fluctuation in yield. Whenever average yields increase, farmers are expected to be motivated to increase area allocated to the crop, given that the relative prices are constant. However, this hypothesis does not always hold true. There are situations where yield increase is followed by significant area decline (or vice versa), with marginal or no change in prices. This inverse relation between area and yield is explained as follows: if marginal lands are withdrawn from the crop that gives higher yield, then the average yield is likely to increase. Similarly, if farmers bring more marginal land into production, average yield is likely to decline. This partly explains the inverse relation between area and yield.

Econometric Estimation of Acreage, Yield, and Supply Response

Preliminary investigation of the data, the data availability, and the meaningfulness of the variables at the state level largely determined our selection of variables. The variables included in the final form of the acreage function are the lagged relative price index and rainfall as quantitative variables, a crop dummy variable, and a period dummy—reflecting the period before and after liberalization. As mentioned earlier, we have jointly estimated main and competing crops for each group and there are three groups altogether (Table 6). To introduce varying response coefficients, we considered different elasticities for the two periods with the period dummy-price interaction term. The price is introduced with different slopes for crops and for pre- and post-reform periods as follows:

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

D_{reform} is a period-specific dummy, taking a value of 1 for the post reform period. D_{pre} is a pre-reform dummy variable. D_s is a crop-specific dummy, with a value of zero for the main crop and 1 for the substitute crop. Hence, the specific main crop response coefficients are γ_{11} and γ_{12} for the pre- and post-reform periods. The respective substitute crop coefficients are $\gamma_{11} + \gamma_{21}$ *and* $\gamma_{12} + \gamma_{22}$.

For the yield response function, besides price and rainfall, the percentage of irrigated area (to capture technology effects) and the rural literacy rate were also added. For the third group of crops, which are raised mostly under rainfed conditions, rainfall deviation from normal is more suitable than actual rainfall. Hence, wherever appropriate, deviation from normal was considered. We initially considered yield variability and price variability as measures of risk variables, but, after preliminary analysis, we dropped the price risk variable. Irrigation is one of the crucial variables to explain area shifts among crops. Irrigation acts as a yield-augmenting as well as risk-protecting variable. When more area is being brought under irrigation, the crop which was cultivated previously under rainfed, is expected to respond more. The reason is, rainfed crop is more susceptible to the risk of monsoon failure as well as pest attacks. Therefore, more crop area under rainfed cultivation is expected to mitigate the degree of response. Rural literacy rates were available only for the census years. We interpolated the data for the intervening years.

Estimation of Elasticities by Dynamic Panel Data Model

Analysis 1: Price Variable is Ratio of Output Prices of Own-Crop to Substitute-Crop

The first set of analysis corresponds to the scenario where relative output price is considered as the price variable. This is measured as ratio of own crop to substitute crop output price in the respective region. If there is more than one substitute crop, the average of the substitutes' price is used. The period of analysis is 1970-71 to 2004-05. Estimation problems occur largely because of autocorrelation, heteroscedasticity, and contemporaneous correlation among the panel observation. After performing all the tests, we found that a dynamic panel data model was the appropriate one. The details of the technique underlying Arellano-Bond's GMM estimates were presented earlier. The results are presented in Tables 7, 8 and 9.

All the variables except dummy variables are expressed in logarithmic form. The model and specification were finalized after doing a few specification tests. Initially, substitutes' prices were introduced separately to accommodate cross-price elasticities. However, in many instances, cross-price variables either did not provide meaningful signs or did not provide significant coefficients. As a result, the model with cross-price elasticity was dropped for the final analysis. Some preliminary results on the cross-price elasticity version of the model are presented in the appendix.

All the crucial variables in the acreage equation are statistically significant for rice and its competing crop, sugarcane (Table 7). Also, significant yield response to output price is seen for rice. The adjustment coefficient for area is 1 - 0.82 (= 0.18), which is very small and indicates that farmers adjust slowly toward the desired acreage. This result supported the view of many researchers (e.g., Surekha, 2005) that farmers are reluctant to make larger adjustments in main cereal crops that are used for self-consumption.

Table 7—Results of acreage and yield response equations for Rice and Sugarcane Price variable: Ratio of output prices of own-crop to substitute-crop

Variables	Area	Yield
Lagged dependent	0.823*	0.242*
Rice—output price—pre-reform	.075*	.164*
Rice—output price—post-reform	.078*	.198*
Sugarcane—output price—pre-reform	.267*	.102*
Sugarcane—output price—post-reform	.268*	.100*
Rainfall	.050	.046*
Percent absolute deviation from normal rainfall		-.005
Percent of irrigated area—rice		.802*
Rural literacy rate		.593
Period dummy	-.008*	.044*
Crop dummy—rice	.011*	
Irrigated crop region dummy		.010*
Constant	-.013*	-.054*

Notes: All variables except the dummy variable are in logarithmic form.
Sample size = 495.
Period of analysis is 1970-71 to 2004-05.
Tests for price coefficients between pre- and post-reform yielded significant differences in yield response for rice.
*Significant at the 5-percent level.

Past studies pertaining to individual states with data restricted up to 1995 following OLS methodology yielded 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 high variability ranging from 0.15 to 0.93. Gulati and Kelley (1999) concluded that price was not a significant variable explaining area changes. They found area to be responsive to price changes in only 6 of 16 paddy-growing zones, and the elasticities fell within a narrow range of 0.06 to 0.17. Kumar and Rosegrant (1997) conducted joint estimation of input and output for the period 1970-71 to 1987-88 for cereal crops and coarse cereals. Their estimates for acreage response elasticity for rice were low, ranging between 0.019 in the short run and 0.12 in the long run. Based on annual data from 1952-53 to 1985-86 and nonlinear model for rice, Surekha (2005) found a long run elasticity of 1.9 following Bayesian estimation method against 0.538 obtained by using the standard least square method. His study confirmed high sensitivity of estimates to estimation techniques.

Our findings for both area and yield equations for rice support the argument that farmers respond to increasing prices by intensive and proper application of non-acreage inputs besides expanding the area. For sugarcane, however, we did not observe the similar pattern.

Table 8 provides estimates for rabi season competing crops. Wheat's price response coefficients reveal that yield response is greater than acreage response. However, in terms of significance of individual coefficients, this is not a better fit as compared with the rice equation. The rural literacy rate turned out to be a significant variable explaining yield variation. Perhaps Punjab's high yield and better literacy rate partly explain this. Kumar and Rosegrant's (1997) estimates of wheat give a low elasticity of 0.06 in the short run and 0.23 in the long run. In Gulati and Kelley'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 and mustard display better response to price than groundnut (Tables 8 and 9). However, the rapeseed and mustard is a winter crop and predominantly irrigated, whereas groundnut is rainfed, and hence subject to more variation in yield. Gulati's result for groundnut indicated that, in the two large groundnut-growing regions, acreage response was poor. Across zones, the elasticity varied between 0.05 and 0.52. His estimates pertained to the pre-reform period. For sugarcane, Gulati obtained negative elasticities. His study led to the conclusion that, own price plays a less important role in acreage decisions than non-price factors.

Statistical tests for significant differences between pre-reform and post-reform estimates provided few rejections of the hypothesis of equality of coefficients. Significant differencs were obtained only in yield responses for rice and wheat. There is no clear evidence to support the view that the response increased post reforms.

The response coefficient for coarse cereals is around 0.12. It is very similar to the estimates obtained by Kumar and Rosegrant (1997). For cotton, both area and yield response coefficients are significant, but area adjustment is slow.

Table 8—Results of acreage and yield response equations for Wheat, Rapeseed & mustard, and grams
Price variable: Ratio of output prices of own-crop to substitute-crop

Variables	Area	Yield
Lagged dependent	0.723*	0.074*
Wheat—output price—pre-reform	.066	.083[1]
Wheat—output price—post-reform	.071	.097*
Rapeseed and mustard—output price—pre-reform	.258*	.171
Rapeseed and mustard—output price—post-reform	.252*	.161
Grams—output price—pre-reform	.211	.013
Grams—output price—post-reform	.216	.041
Rainfall		.002*
Percent of irrigated area	.008*	
Rural literacy rate		.021*
Period dummy	-.012*	-.028*
Crop dummy—rapeseed and mustard	.005	.008
Crop dummy—grams	-.012	-.011
Constant	-.034*	-.067*

Notes: All variables except the dummy variable are in logarithmic form.
Sample size = 528.
Period of analysis is 1970-71 to 2004-05.
Tests for price coefficients between pre- and post-reforms yielded significant differences only in yield response for wheat. *Significant at the 5-percent level.

Table 9—Results of acreage and yield response equations for Cotton and Groundnut
Price variable: Ratio of output prices of own-crop to substitute-crop

Variables	Area	Yield
Lagged dependent—one period	.620*	.064*
Lagged dependent—two periods	.150*	.095*
Cotton—output price pre-reform	.119*	.109*
Cotton—output price post-reform	.121*	.106*
Groundnuts—output price—pre-reform	.089	.108
Groundnuts—output price—post-reform	.082	.109
Rainfall		.041
Absolute deviation from normal rainfall	-.002	
Percent of irrigated area		.090*
Period dummy	-.0065*	-.012*
Crop dummy—groundnuts	.0035	-.009
Irrigated crop regional dummy	.0017	-.0074*
Constant	-.0012*	.0145*

Notes: All variables except the dummy variable are in logarithmic form.
Sample size = 445.
Period of analysis is 1970-71 to 2004-05.
*Significant at the 5-percent level.

The supply elasticities were derived by adding area and yield elasticities, and the results are presented in Table 10. Comparison of various estimates indicates that the long run supply elasticity is greater than unity only for sugarcane and rapeseed & mustard.

For oilseeds, trade liberalization is likely to have more effect on domestic price since the proportion of imports in the total supply is higher. After the mid-1990s, the prices of oilseeds relative to other crops have been declining. Pandey et al. (2005) conducted an analysis of supply response of oilseeds to see if domestic price fluctuations had negative effects on oilseeds production. For oilseed crops such as groundnut, rapeseed & mustard, soybeans, and sunflowers, the study confirmed that oilseeds production respond to expected prices and price risk reflected in fluctuations in the domestic market price due to increasing imports.

Table 10—Short run and long run price elasticity
Price variable: Ratio of output prices of own-crop to substitute-crop
Period of analysis: 1970-71 to 2004-05

Particulars	**Pre-reform**			**Post-reform**		
Rice:						
	Area	**Yield**	**Supply**	**Area**	**Yield**	**Supply**
Short run	0.075	0.164	0.239	0.078	0.198	0.276
Long run	.424	.216	.640	.441	.261	.702
Wheat:						
Short run	.066	.083	.149	.071	.097	.168
Long run	.238	.090	.328	.256	.105	.361
Grams:						
Short run	.211	.013	.224	.216	.041	.257

Long run	.762	.014	.776	.780	.044	.824
Cotton:						
Short run	.119	.109	.228	.121	.106	.227
Long run	.517	.130	.647	.526	.126	.652
Sugarcane:						
Short run	.267	.102	.369	.268	.100	.368
Long run	1.510	.135	1.645	1.514	.132	1.646
Groundnut:						
Short run	.089	.108	.197	.082	.109	.191
Long run	.234	.115	.349	.216	.116	.332
Rapeseed and mustard:						
Short run	.258	.171	.429	.252	.161	.413
Long run	.931	.185	1.116	.910	.174	1.084

A comparison of the pre- and post-reform periods indicates that for food grains, the post-reform acreage elasticity is not significantly different from the pre-reform estimate. However, the yield response is greater than the acreage response and significantly higher in the post-reform period. Among nonfood grains, rapeseed and mustard had the largest response. Cotton and groundnuts revealed poor response. Our efforts to include a risk variable did not work in this version. In the alternative version (Analysis 2), we obtained a significant result for the yield risk variable.

Analysis 2: Price Variable is Ratio of Output Price to Average Variable Cost

This section reports the results obtained based on the same methodology as above, but with the price variable adjusted for variable cost and measured as a ratio of output price to variable cost per quintal. The period of analysis is 1980-81 to 2004-05. We also incorporated a yield risk variable for cotton-groundnut regression as mentioned earlier. Grams were not included in this analysis due to data gaps. The results are given in Tables 11 to 14.

Table 11— Results of acreage and yield response equations for Rice and Sugarcane
Price variable: Ratio of output price to average variable cost

Variables	Area	Yield
Lagged dependent	0.732*	0.515*
Rice—output price—pre-reform	.065*	-.099
Rice—output price—post-reform	.082*	.100
Sugarcane—output price—pre-reform	.194*	.099*
Sugarcane—output price—post-reform	.211*	.106
Rainfall	.024	.043*
Percent of irrigated area		.977*
Rural literacy rate		.324*
Period dummy	-.0053*	-.062*
Crop dummy—rice	-.0013	
Irrigated crop regional dummy		.0097
Constant	.0054*	-.0012*

Notes: All variables except the dummy variable are in logarithmic form.
Sample size = 184.
Period of analysis is 1980-81 to 2004-05.
Tests for price coefficients between pre- and post-reform gave significant differences in yield for rice.
*Significant at the 5-percent level.

Table 12—Results of acreage and yield response equations for Wheat and Rapeseed & Mustard Price variable: Ratio of output price to average variable cost

Variables	Area	Yield
Lagged dependent	0.594*	0.131*
Wheat—output price—pre-reform	.016	.027
Wheat—output price—post-reform	.076	.087
Rapeseed and mustard—output price—pre-reform	.194*	.103
Rapeseed and mustard—output price—post-reform	.284*	.118
Rural literacy rate	.093	.043
Percent of irrigated area	.024*	.241*
Period dummy	-.006*	-.020*
Crop dummy—rapeseed and mustard	.014*	.0018
Constant	-.1062*	.0315

Notes: All variables except the dummy variable are in logarithmic form. Sample size = 184.
Period of analysis is 1980-81 to 2004-05.
Tests for price coefficients between pre-and post-reform produced significant difference for both crops for area and yield
*Significant at the 5 percent level.

Overall, we have found that the yield responses are greater than acreage responses for rice, wheat, and cotton after the reforms. When input costs are taken into account, acreage elasticities are significantly different after the reforms for rice, wheat, rapeseed &

mustard and cotton. For cotton, post-reform elasticity declined. The post-reform yield response is negative for groundnut. However, yield risk, as measured by standard deviation of the past 3 years' yield, turned out be a significant variable in cotton-groundnut regression. As mentioned earlier, cotton and groundnut experience large year-to-year fluctuations in yields.

Table 13—Results of acreage and yield response equations for Cotton and Groundnut Price variable: Ratio of output price to average variable cost

Variables	**Area**	**Yield**
Lagged dependent—one period	.655*	0.041*
Cotton—output price pre-reform	.147*	.234*
Cotton—output price post-reform	.085*	.222*
Groundnut—output price—pre-reform	.159	-.083
Groundnut—output price—post-reform	.117	-.069*
Percent of irrigated area		.389*
Yield risk (STD$ of past 3 years)	-.0163*	-.022*
Period dummy	-.0050*	-.0005*
Crop dummy—groundnuts	-.0072*	-.014*
Irrigated crop regional dummy	.0034*	-.0073
Constant	.0086*	.021*

Notes: All variables except the dummy variable are in logarithmic form.
Sample size = 248. $ STD refers to standard deviation
Period of analysis is 1980-81 to 2004-05.
Tests for price coefficients between pre- and post-reform produced significant difference in area response for both cotton and groundnut.
*Significant at the 5-percent level.

The long run elasticity is greater than unity only for sugarcane (Table 14). Among the two main cereals, long run supply elasticity is higher for rice than wheat. Groundnut recorded a low response among all the crops.

Table 14 —Short run and long run price elasticity
Price variable: Ratio of output price to average variable cost
Period of analysis: 1980-81 to 2004-05

Crop	Pre-reform			Post-reform		
	Area	**Yield**	**Supply**	**Area**	**Yield**	**Supply**
Rice:						
Short run	0.065	-0.099	-0.034	0.082	0.100	0.182
Long run	.243	-.204	.039	.306	.206	.512
Wheat:						
Short run	.016	.027	.043	.076	.087	.163
Long run	.039	.031	.070	.187	.100	.287
Cotton:						
Short run	.147	.234	.381	.085	.222	.307
Long run	.426	.244	.670	.246	.231	.477
Sugarcane:						
Short run	.194	.099	.293	.211	.106	.317
Long run	.724	.204	.928	.787	.219	1.006
Groundnut:						
Short run	.159	-.083	.076	.117	-.069	.048
Long run	.460	-.087	.373	.339	-.072	.267
Rapeseed and mustard:						
Short run	.194	.103	.297	.284	.118	.402
Long run	.478	.119	.597	.700	.136	.836

Conclusion

This study supports the findings of the available literature that farmers' responses to price are low in the short run, and their adjustment of actual area toward desired level is slow, particularly for food grains. This study hypothesized that farmers do respond by adjusting application of non-acreage inputs since the flexibility to shift acreage could be restricted. This is particularly true for the main cereals, rice and wheat. Using panel data models, the study rejected the hypothesis that economic liberalization enhanced the acreage response for the crops cotton, groundnut, and sugarcane.

This study specified a yield response function with respect to output price to analyze farmers' responses regarding use of inputs other than land. The findings confirmed that yield response improved significantly for rice and wheat. This supports our hypothesis that farmers respond to prices by intensive application of other inputs (other than land), and this point was not considered in many earlier studies. Discussions on the supply response theme in the academic literature and in the policy arena pointed out that removing some of the physical infrastructure constraints as well as credit constraints would strengthen the supply response. This study could not incorporate infrastructure variables other than irrigation due to paucity of long time series data. Production risk due to adverse weather is likewise an important factor, influencing farmers' responses, particularly for cotton and groundnut, which are subject to large year-to-year fluctuations in yield. This study has included risk variable and found significant impact.

Mere reforms will not contribute to the strengthening of response unless they are adequately supported by infrastructure facilities and risk-reducing instruments. Further analysis is needed to construct infrastructure variable in a meaningful way and to explicitly incorporate risk in the modeling stage to ascertain the impact of these variables on response parameters.

References

Ahn, S.C., and P. Schmidt. (1995) "Efficient Estimation of Models for Dynamic Panel Data," *Journal of Econometrics*, Vol. 68, No. 1, pp. 5-28.

Anderson, T.W., and C. Hsiao. (1981). "Estimation of Dynamic Models With Error Components," *Journal of the American Statistical Association,* Vol. 76, pp. 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, pp. 277-297.

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

Behrman, J.R. (1966) "Price Elasticity of the Marketed Surplus of a Subsistence Crop," *Journal of Farm Economics*, Vol. 48, pp. 875-893.

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.

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

Brauw, Alan de, J. Huang, and S. Rozelle. (2002) "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." University of California, Department of Agricultural and Resource Economics, Davis Working Paper No. 02-005.

Chamberlain, G. (1984) "Panel Data," *Handbook of Econometrics,* Z. Griliches and M.D. Intriligator, (Eds), Elsevier Science, Vol. II.

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

Epstein, L. (1981) "Duality Theory and Functional Forms for Dynamic Factor Demands," *Review of Economic Studies*, Vol. 48, pp. 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 Nonlinear, Implicit Equations," *Journal of Econometrics, Vol.* 5, pp. 71-88.

Greene, W.H. (2006) *Econometric Analysis,* Fifth Edition, Pearson Education, Upper Saddle River, NJ.

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

Hausman, J., and W. Taylor. (1981) "Panel Data and Unobservable Individual Effects," *Econometrica*, Vol. 49, pp. 1,377-1,398.

Kanwar, S. (2004) "Price Incentives, Nonprice Factors and Crop Supply Response: The Indian Cash Crops," Working Paper No. 132, Centre for Development Economics, Delhi School of Economics, India, November.

Krishna, Raj. (1962) "A Note on the Elasticity of the Marketable Surplus of a Subsistence Crop," *Indian Journal of Agricultural Economics*, Vol. 17, pp. 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 P. Kumar. (2000) "Literacy, Technology Adoption Factor Demand and Productivity: An Econometric Analysis," *Indian Journal of Agricultural Marketing*, Vol. 55, No. 3, pp. 490-499.

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

Narain, Dharm. (1965) *The Impact of Price Movements on Areas Under Selected Crops in India 1900-1939,* Cambridge University Press, United Kingdom.

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 No. 81-1, Vol. 35, International Institute for Applied Systems Analysis.

Narayana, N.S.S., and M.M. Shah. (1984) "Farm Supply Response in Kenya: Acreage Allocation Model," Working Paper No. 82-103, International Institute for Applied Systems Analysis, Oxford University Press, United Kingdom.

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

Nerlove, M. (1971) "Further Evidence on the Estimation of Dynamic Economic Relations from a Time Series of Cross Sections," *Econometrica,* Vol. 39, pp. 359-382.

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

Nowshirvani, V.F. (1971) "Land Allocation Under Uncertainty in Subsistence Agriculture," *Oxford Economic Papers,* Oxford University Press, United Kingdom, Vol. 23, No. 3, pp. 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*, February 15, pp. 615-620.

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

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

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

Appendix - Model to Determine Own- and Cross-Price Elasticities

A system of equations has been specified for own and competing crops as follows:

$$Y = \alpha + \alpha_1 D_{reform} + \gamma_{11} P_{t-1}^{own} D_{pre} + \gamma_{12} P_{t-1}^{own} D_{reform} + \gamma_{21} P_{t-1}^{sub} D_{pre} + \gamma_{22} P_{t-1}^{sub} D_{reform} + \ldots\ldots\ldots$$

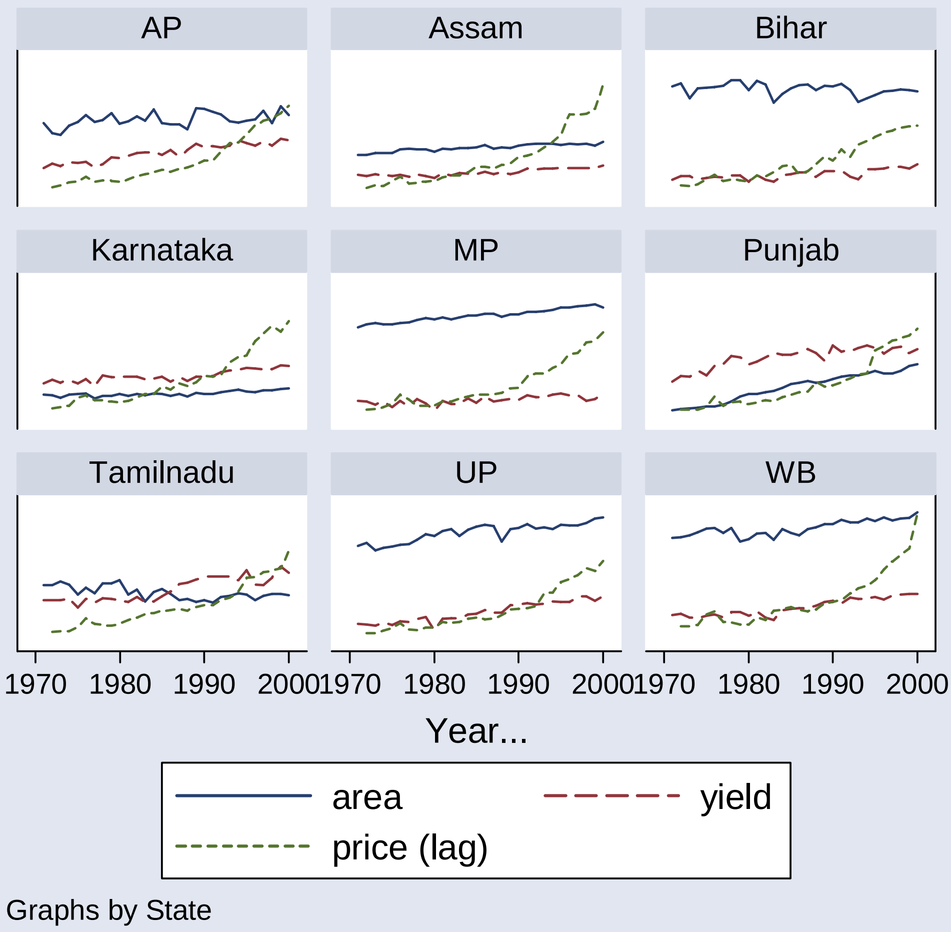
After imposing symmetry restrictions, both area and yield equations were estimated.

Appendix Table A1–Own-price and cross-price elasticities
Price variable: Ratio of output price over variable cost per quintal

Crops	**price elasticity Area**		**price elasticity Yield**	
Own price elasticity				
	Pre-reform	Post-reform	Pre-reform	Post-reform
Rice	-0.027	0.164*	-0.013	0.142*
Sugarcane	.237*	.223*	.081*	.066*
Wheat	.002	.164*	.157*	.084*
Rapeseed & mustard	.167*	.187*	.040	.241*
Cotton	.519*	.021	.417*	.203*
Groundnut	.041	-.010	.014	.238
Cross-price elasticity				
Rice and sugarcane	-.083	.014	-.031	.051
Wheat and rapeseed & mustard	-.326	-.136	-.222	-.420*
Cotton and groundnut	-.209	.120	.078	.053

* significant at 5% level

Figure 1
Rice Area, Yield and Price over Time



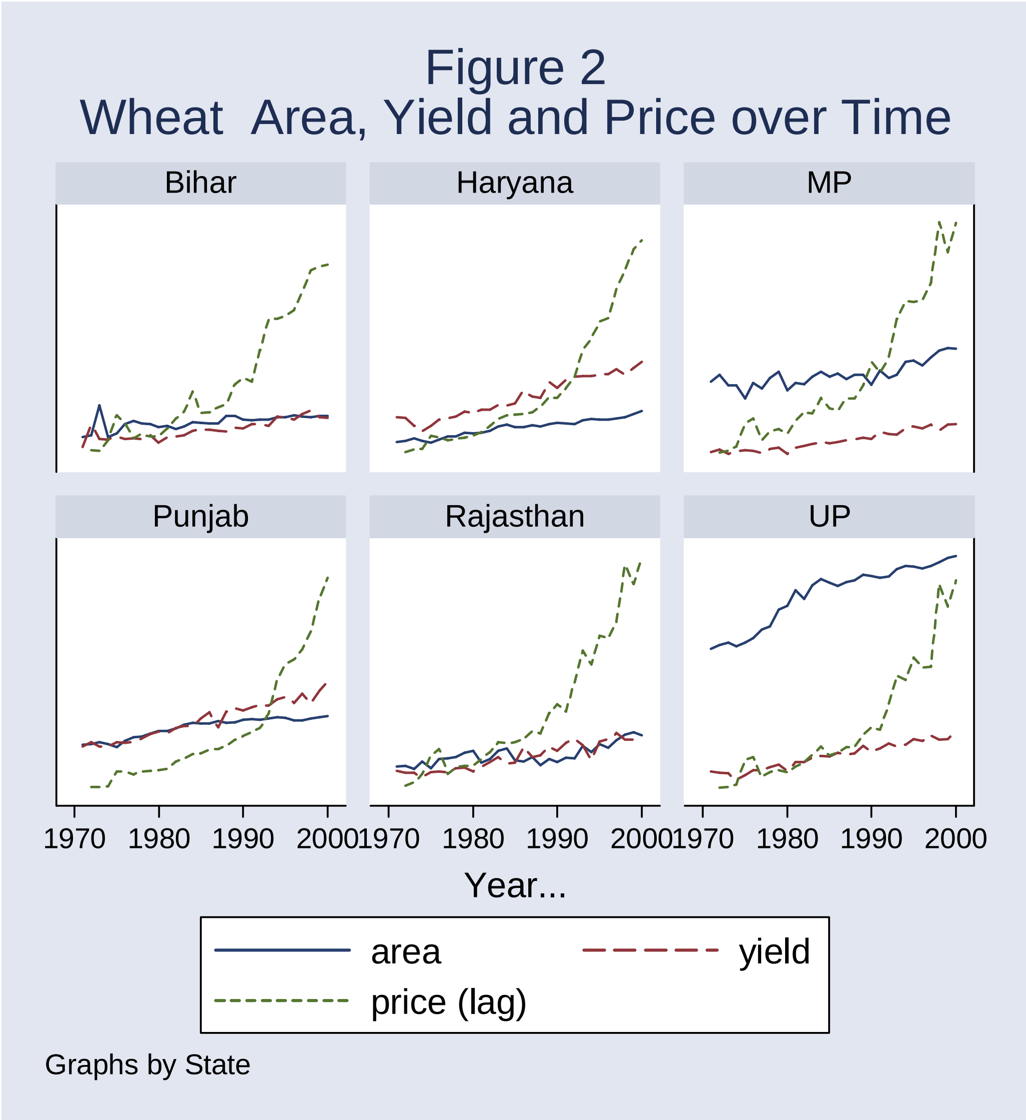


Figure 2
Wheat Area, Yield and Price over Time
Bihar
Haryana
MP
Punjab
Rajasthan
UP
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

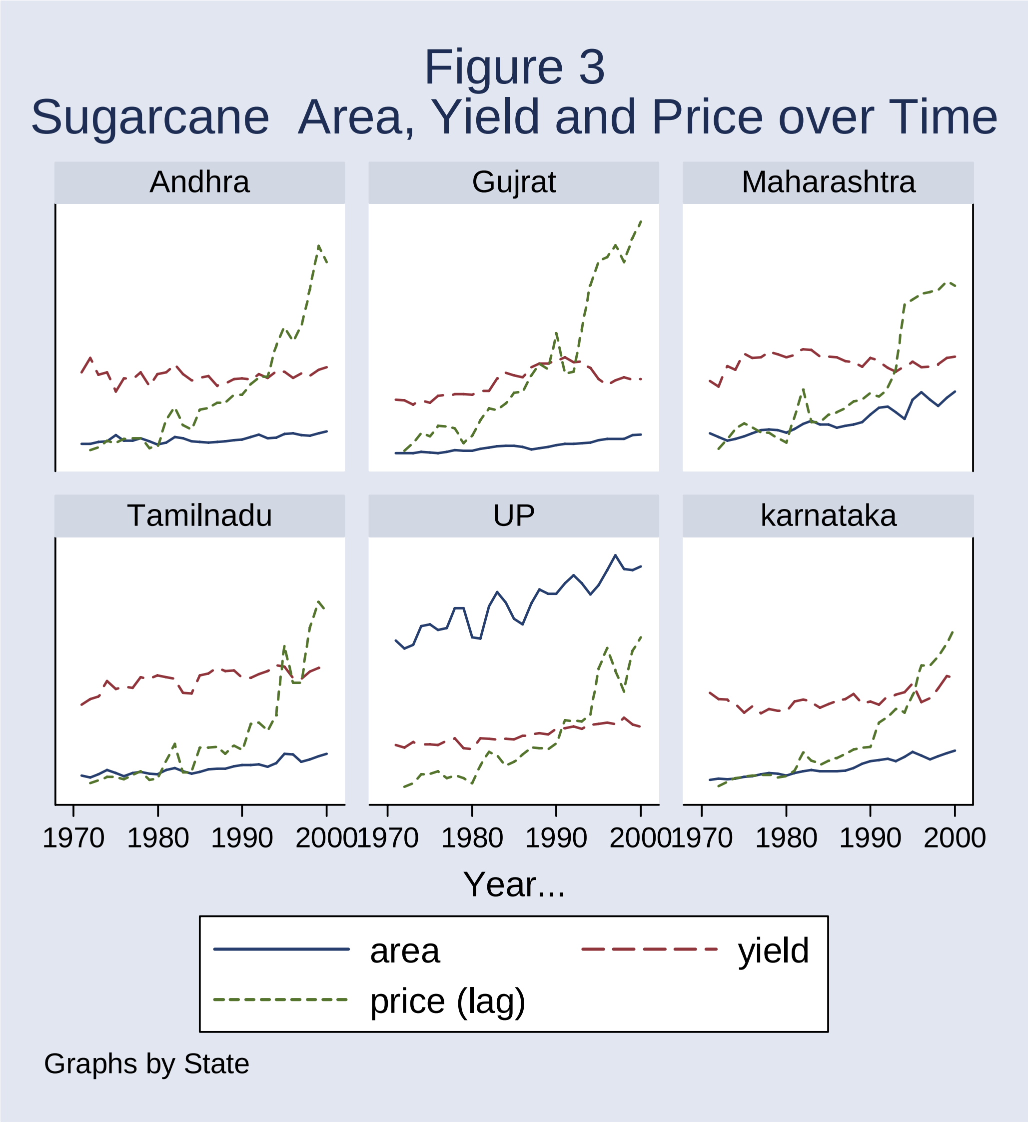
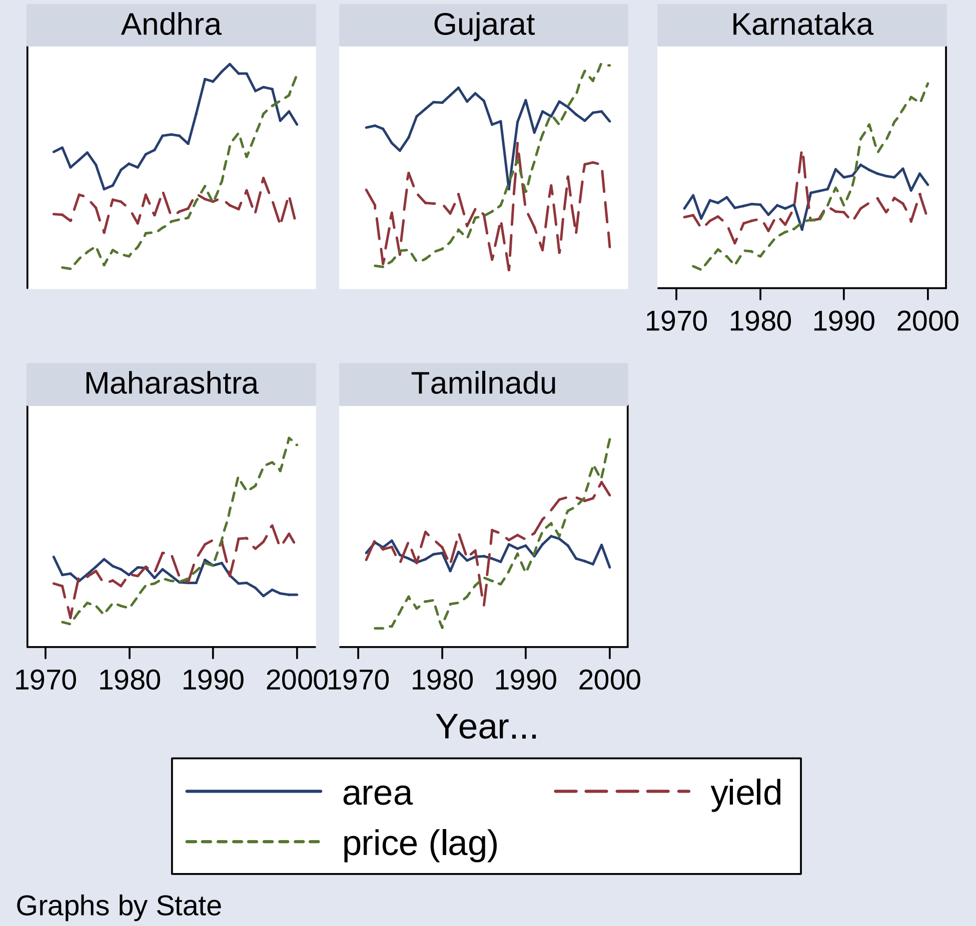


Figure 3
Sugarcane Area, Yield and Price over Time
Andhra
Gujrat
Maharashtra
Tamilnadu
UP
karnataka
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

Figure 4
Groundnut Area, Yield and Price over Time



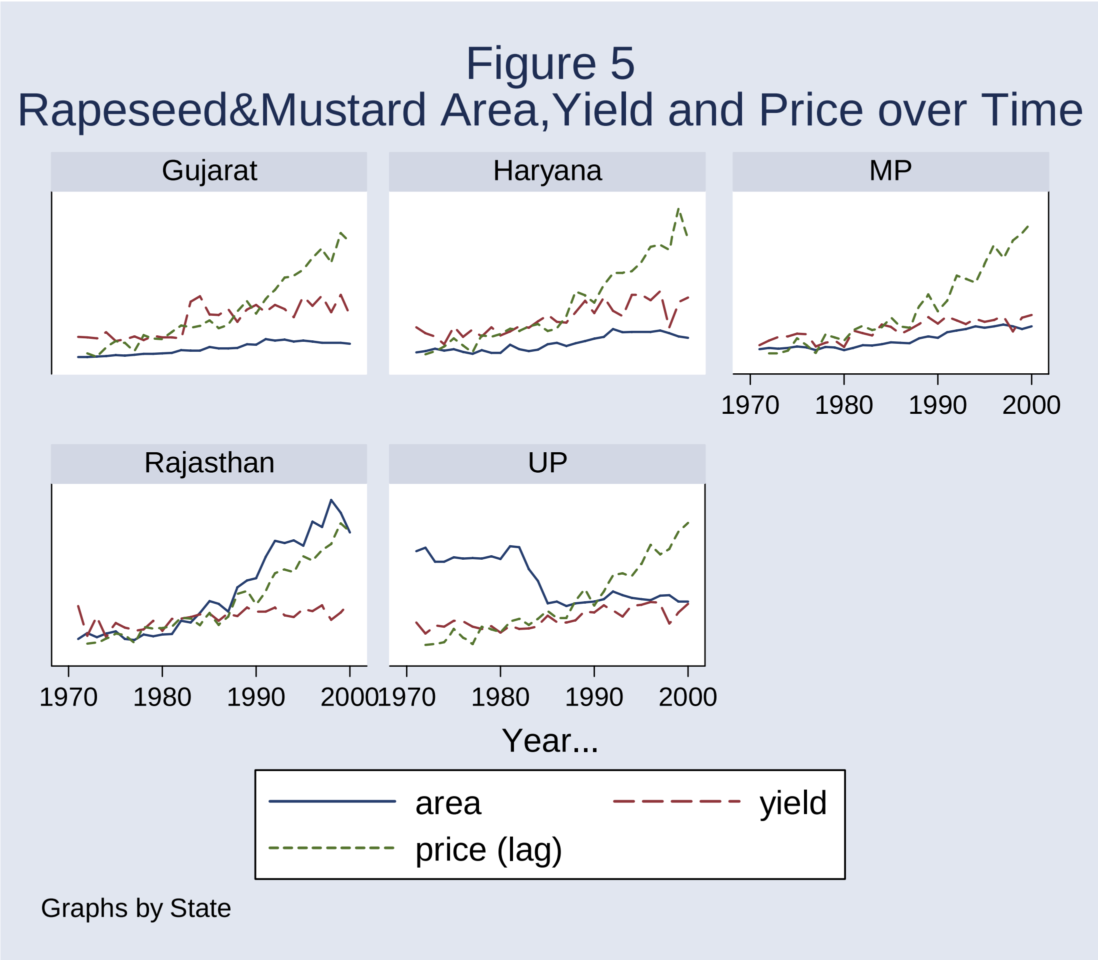


Figure 5
Rapeseed&Mustard Area,Yield and Price over Time
Gujarat
Haryana
MP
Rajasthan
UP
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State

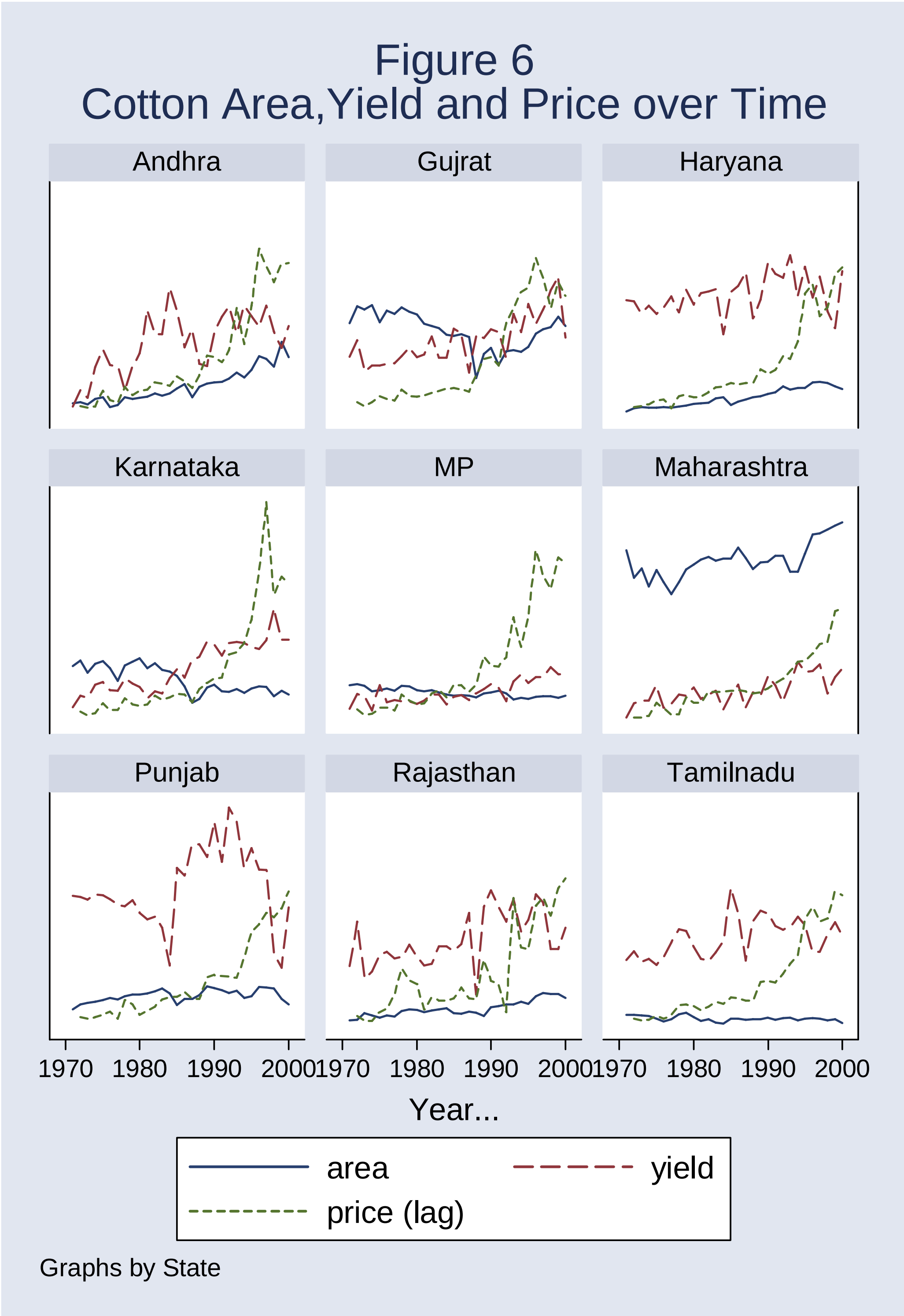


Figure 6
Cotton Area,Yield and Price over Time
Andhra
Gujrat
Haryana
Karnataka
MP
Maharashtra
Punjab
Rajasthan
Tamilnadu
1970
1980
1990
2000
Year...
area
yield
price (lag)
Graphs by State