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Price Incentives, Nonprice factors, and Crop Supply Response: The Indian Cash Crops

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Abstract

Agriculture as a source of growth was sorely neglected in the early development strategies of the currently developing countries. Realisation of this shortcoming prompted public policy in these countries to encourage agriculture by various means. The success of these policies depends, however, on how farmers respond to the incentives provided. Using panel data pertaining to Indian agriculture for the period 1967-68/1999-00, covering 7 major 'annual' cash crops cultivated across 16 major states, we provide estimates of area, yield and output elasticities w.r.t price and nonprice variables. Our results suggest that the preferred policy ought to be to enhance irrigation and encourage the use of fertiliser and HYVs, if long-run agricultural growth is to be achieved.

Keywords: Incentives, supply response, deprivation

JEL Classification: O13, Q11

1. Introduction

Agriculture as a source of growth was sorely neglected in the early strategies of economic development, particularly in the 1950s and 1960s, when the currently developing countries embarked on their processes of modern economic growth. Although a host of arguments were used to justify this neglect, it was realised even by the early development theorists, that "economies in which agriculture is stagnant do not show industrial development" (Lewis 1954). One of the more obvious benefits of a dynamic agriculture would be its positive role in easing the wage-goods constraint which, if binding, could bring the entire growth process of a developing country to a pre-mature halt (Harris and Todaro, 1970). A host of policy instruments were used, therefore, to encourage developing country agriculture.

In the Indian context, various instruments of public policy such as output price supports, government procurement operations, input price subsidies etc., have been used to enhance the production and productivity of individual crops since the mid-1960s (Rao, 2001). In the process tens of billions of rupees are spent by the government agencies annually, in providing price and nonprice incentives to Indian farmers (Ramaswami, 2002; Gulati and Narayanan, 2003). It is no surprise, therefore, that there has been a continuing debate in India on various aspects of these incentives.

The success of public policy in this sphere hinges, inter alia, on how strongly farmers respond to the various incentives provided (Nerlove, 1979). Thus, are the price and nonprice elasticities of acreage/output significantly large? For if they are not, then obviously other instruments may have to be employed. Second, are the price elasticities of acreage/output larger or smaller than the nonprice elasticities? For if they are smaller, nonprice instruments may be relatively effective in raising agricultural performance; although that need not imply that the price instrument is ineffective (Nerlove, 1979). Third, are the short-run elasticities of acreage/output (both price and nonprice) significantly smaller then the long-run elasticities? For if they are, that may indicate various constraints on farmers' responses in the short-run, so that policy could be more effective by removing these constraints and not necessarily raising prices inordinately period after period. To address these questions[1] we need information on the acreage and yield responsiveness of individual crops (as opposed to the supply response of agriculture as a whole), with respect to price and various nonprice factors.

We observe, however, that the studies in this area relating to Indian agriculture are mostly dated, using data till only the mid-1970s or earlier (Krishna, 1963; Madhavan, 1972; Cummings, 1975; Ray, 1980; Krishna and Roychoudhury, 1980; and Narayana and Parikh, 1981), and/or very narrow in terms of state or crop coverage (Krishna, 1963; Madhavan, 1972; Krishna and Roychoudhury, 1980; Lahiri and Roy, 1985; Gulati and Sharma, 1990), and/or technically deficient. With regard to the latter-most observation, Krishna (1963) and Madhavan (1972) assume naive price expectations for their samples of farmers, which is not very appealing. Cummings (1975) frequently finds price-expectations and area-adjustment parameters to be larger than unity, but does not explain the rationale behind the persistent overadjustment in the context of resource-constrained farmers. Ray (1980) reports long-run elasticities *smaller* than short-run elasticities! As in the case of Cummings above, this does not seem plausible behaviour for the poor, cash-strapped Indian peasants that he is modelling. Krishna and Roychoudhury (1980) curiously define the price variable in their output response functions as the ratio of *lagged* wholesale price to the *current* input price index; and the wheat equation dispenses with a lagged dependent variable term. Lahiri and Roy (1985) report static price expectations and full area adjustment for rice, the former being especially surprising in a period of rising prices. Gulati and Sharma (1990) implicitly assume naive price expectations, and do not correct for autocorrelation.[2] Although Behrman (1968) was amongst the first to introduce risk variables into his analysis of Thai agriculture, none of the Indian studies appear to follow suit (see Just, 1974; Pope, 1982; Pope and Just, 1991; and Chavas and Holt, 1996, for alternative risk specifications). This paper attempts to correct for some or all of these deficiencies in the context of the Indian annual cash crops.

We should clarify, that in this study we focus on supply response rather than marketed surplus response because the former encompasses all farmers, whereas the latter is concerned mostly with large farmers. It is conceivable that policies benefitting marketed surplus response – price incentives, for instance – are more likely to benefit large farmers than the small farmers who do not have much to sell; on the other hand, policies benefitting supply response may well benefit both the small and the large farmers. The difference between supply response and marketed surplus response is likely to be small, however, given that the self-consumption of cash crops by farmers is very small. Section 2 outlines the model used in this study, and the estimation methodology adopted. Section 3 provides a description of the data used. Section 4 presents the estimation results; and, finally, Section 5 underlines the important conclusions and policy implications.

2. The Model and Methodology used in this Study

The Economic Model

It may be argued that the representative agent, the farmer, determines the desired or long-run area under crop i in response to relative expected profit,[3] production risk, and various enabling factors. We may specify this relationship as

$$A_{it}^{d} = \alpha_0 + \alpha_1 \Pi_{it}^{re} + \alpha_2 Z_{it} + \varepsilon_{1it} \quad (1)$$

where, for crop i, A_{it}^{d} is the desired supply for period t, Π_{it}^{re} is the relative expected profit in period t, and Z_{it} is the vector of risk variables and enabling factors (such as price risk, yield risk, irrigation, and rainfall) in period t.[4] This relationship is not deterministic, and is affected by random shocks as captured by the error term ε_{1it} ~ (0, $\sigma_{\varepsilon_1}^{2}$). The relative expected profit is defined as $\Pi_{it}^{re} = \Pi_{it}^{e}/0.5(\Pi_{jt}^{e} + \Pi_{kt}^{e})$, i.e. the expected profit of the crop in question (i) relative to the average expected profit of the two most important competing crops (j and k).

In a developing country (particularly Asian) context, however, adjusting the actual acreage towards the desired level need not be possible in a single time-period. Farmer response may be constrained by very small acreages combined with the need to diversify production to spread risks, credit constraints, lack of availability of inputs etc. To allow for this possibility we hypothesize, in the Nerlovian tradition (Nerlove, 1958), that the change in acreage between periods occurs in proportion to the difference between the desired acreage for the current period and the actual acreage in the previous period. This may be expressed as

$$A_{it} = A_{i(t-1)} + \gamma(A^{d}_{it} - A_{i(t-1)}) + \varepsilon_{2it} \qquad 0 < \gamma \leq 1 \qquad (2)$$

where, for crop i, A_{it} is the actual acreage in period t, $A_{i(t-1)}$ is the actual acreage in period t-1, and A^{d}_{it} is the desired acreage for period t. As above, the error term $\varepsilon_{2it} \sim (0, \sigma^2_{\varepsilon_2})$ allows for the possibility that this adjustment may be subject to random shocks. The adjustment parameter γ must lie between 0 and 2 for the adjustment to converge over time, but γ > 1 implies persistent overadjustment, and does not appear plausible in a developing country context as noted above. So we limit γ to lie between 0 and 1.

The structural form equations (1) and (2) yield the reduced form

$$A_{it} = \theta_0 + \theta_1 A_{i(t-1)} + \theta_2 \Pi^{e}_{it} + \theta_3 Z_{it} + \nu_{it} \qquad (3)$$

where

$$\theta_0 = \gamma\alpha_0$$

$$\theta_1 = 1 - \gamma$$

$$\theta_2 = \gamma\alpha_1$$

$$\theta_3 = \gamma\alpha_2$$

$$\nu_{it} = \gamma\varepsilon_{1it} + \varepsilon_{2it} \qquad (4)$$

The presence of the lagged dependent variable term introduces (first-order) autocorrelation in the error term. This model, however, is not estimable because of the unobservable variable Π^{e}_{it}.

In the Nerlovian tradition, this problem would be resolved by hypothesizing that expectations are up-dated between periods in proportion to the discrepancy between the actual and expected levels of profits in the previous period. That is

$$\Pi^{e}_{it} = \Pi^{e}_{i(t-1)} + \beta(\Pi_{i(t-1)} - \Pi^{e}_{i(t-1)}) + \varepsilon_{3it} \qquad 0 < \beta \leq 1 \qquad (5)$$

where, for crop i, Π^{e}_{it} is the profit expectation for period t, $\Pi^{e}_{i(t-1)}$ is the profit expectation for period t-1, $\Pi_{i(t-1)}$ is the actual profit in period t-1, the expectations parameter β may be constrained to lie between 0 and 1, and the error term $\varepsilon_{3it} \sim (0, \sigma^2_{\varepsilon_3})$. Substitution of (5) in (3), and some algebraic manipulation, then yields the estimable reduced form[5]

$$A_{it} = \delta_0 + \delta_1 \Pi_{i(t-1)} + \delta_2 A_{i(t-1)} + \delta_3 A_{i(t-2)} + \delta_4 Z_{it} + \delta_5 Z_{i(t-1)} + \eta_{it} \qquad (6)$$

where

$\delta_0 = \gamma\beta\alpha_0$

$\delta_1 = \gamma\beta\alpha_1$

$\delta_2 = (1-\beta) + (1-\gamma)$

$\delta_3 = (1-\beta)(1-\gamma)$

$\delta_4 = \gamma\alpha_2$

$\delta_5 = \gamma(1-\beta)\alpha_2$, and

$$\eta_{it} = \gamma\alpha_1\varepsilon_{1it} + \gamma\varepsilon_{2it} - \gamma(1-\beta)\varepsilon_{2i(t-1)} + \gamma\varepsilon_{3it} - \gamma(1-\beta)\varepsilon_{3i(t-1)} \qquad (7)$$

Estimating (6), and using the relations in (7), we can derive unique estimates of α_0 and α_1, but not those of α_2 (see Nerlove, 1958, who notes the inherent identification problem). To derive unique estimates of α_2, we require (unique) estimates of γ and, therefore, β. However, we can only obtain $\hat{\beta}+\hat{\gamma} = 2-\hat{\delta}_2$ and $\hat{\beta}\hat{\gamma} = 1+|\hat{\delta}_3|-\hat{\delta}_2$, which yield (non-unique) estimates of β and γ only if $(\hat{\beta}+\hat{\gamma})^2 \geq 4\beta\gamma$. But if this condition fails to hold, then no estimates are obtainable. Further, although the terms in Z_t and Z_{t-1} in equation (4) allow us to derive yet another set of estimates of β and γ this, however, merely compounds the non-uniqueness problem noted above. In other words, while we can derive estimates of the long-run elasticity of supply w.r.t (expected) profit, this model either does not yield unique estimates of the long-run supply elasticities w.r.t the 'nonprice' variables, or else does not yield the long-run nonprice elasticities at all. Finally, note that for every variable Z included in the structural form, there appear two variables (current and lagged) in the reduced form, which is too restrictive. To circumvent these numerous problems we do *not* estimate (6), and instead, adopt the following approach.

The Profit or 'Price Variable'

Instead of using (5) directly to eliminate the unobservable variable in (3), we approximate the latter as follows (Carvalho, 1972; Nerlove, Grether and Carvalho, 1979; Narayana and Parikh, 1981; Nerlove and Fornari, 1998; Nerlove and Bessler, 2001). For any crop i, the adaptive profit expectation hypothesis

$$\Pi^*_{it} = \Pi^*_{i(t-1)} + \beta'(\Pi_{i(t-1)} - \Pi^*_{i(t-1)}) \qquad 0 < \beta \leq 1 \tag{8}$$

may be expressed as an infinite-order AR process

$$\Pi^*_{it} = \Sigma^{\infty}_{\tau=0} \ \beta'(1 - \beta')^{\tau} \ \Pi_{i(t-1-\tau)} \tag{9}$$

This can then be rewritten as an ARMA(p,q) process, under conditions of stationarity and invertibility (Judge et.al. 1985), i.e.

$$\Pi^*_{it} = b_1\Pi_{i(t-1)} + b_2\Pi_{i(t-2)} + ... + b_p\Pi_{i(t-p)} + \mu_{it} + c_1\mu_{i(t-1)} + ... + c_q\mu_{i(t-q)} \tag{10}$$

where μ_{it} are white noise errors. More generally, if Π_{it} is integrated of order d, we can estimate an ARIMA process of order (p,d,q) as follows

$$\Pi_{it} = b_1\Pi_{i(t-1)} + b_2\Pi_{i(t-2)} + ... + b_p\Pi_{i(t-p)} + \mu_{it} + c_1\mu_{i(t-1)} + ... + c_q\mu_{i(t-q)} \tag{11}$$

and use $\hat{\Pi}_{it}$ in lieu of Π^*_{it} for a given crop i.[6] In the literature cited above, (9) is referred to as 'quasi-rational expectations'. We would like to emphasize, however, that while (9) may be a representation of quasi-rational expectations (insofar as price expectations are based on prices in the previous periods), *we use it as a re-expression of the adaptive expectations hypothesis*. In other words, while we recognize that the adaptive expectations and quasi-rational expectations hypotheses are observationally equivalent when expressed as (9), that need not imply dropping the former expectations formation hypothesis in place of the latter.

Equations (10) and (11) are, then, merely practical ways of estimating the adaptive expectations hypothesis re-written as (9).

Estimation of (11), however, requires specification of p, d and q. Allowing d = {0, 1, 2}, p = {1, 2} and q = {1, 2}, we choose the best combination (p,d,q) by considering various stationarity tests, the invertibility criterion, the significance of the ARMA terms, the Schwarz criterion, the Ljung-Box-Pierce test and various error properties. Repeating this process for the two most important competing crops j and k, we estimate $\hat{\Pi}^{re}_{it} = \hat{\Pi}_{it}/0.5(\hat{\Pi}_{jt} + \hat{\Pi}_{kt})$. Substituting $\hat{\Pi}^{re}_{it}$ for Π^{re}_{it} in (3), allows us to estimate the reduced form parameters (4); which, in turn, provide estimates of the adjustment parameter, and the structural form parameters in (1), for each crop i.

It may be possible to improve the estimates of the profit expectations derived above by allowing for the possibility, that the error term in the ARIMA process need not have a constant variance. For if it doesn't, it would be preferable to estimate an ARCH model (Green, 2003). To jump ahead for a moment, conducting tests of ARCH(1) effects we find, however, that the assumption of conditionally homoscedastic errors cannot be rejected for any of the crops in our sample.

The Other Regressors

Having discussed the 'price variable'[7] $\hat{\Pi}^{re}_{it}$, we now briefly discuss the other regressors Z_{it} in our model. One of the most important inputs into agrarian production in the Indian context happens to be water. We capture this in terms of two variables – the irrigated area under the crop (I_{it}), and the total rainfall (in mm) for the current period (R_{it}).[8] A higher irrigated area is likely to have a positive effect on the area planted to that crop, insofar as it implies a greater availability of (assured) water. Similarly, rainfall is also expected to have a positive effect on area allocation, particularly in the case of rainfed agriculture.

The poor resource base of the bulk of the Indian farmers, particularly the fact that even today only about 40% of the cultivated area is irrigated (Government of India, 2003), makes for high production risk Of course, years in which output moves in a certain direction, prices tend to move in the opposite direction, so that our concern is with revenue risk. We represent this by two variables – price risk and yield risk. Price risk is defined as the coefficient of variation of prices over the current and two previous periods ($\mathbf{CVP_{it}}$). In measuring yield risk, however, we must be mindful of the fact, that yield variation is endogenous to the extent that it is influenced by variations in input-use by farmers. Therefore, because yield risk is supposed to reflect that part of yield variation which is *not* within the farmer's control, we proxy it by the coefficient of variation of rainfall over the current and two previous periods ($\mathbf{CVR_{it}}$).[9] The higher the price risk or yield risk associated with the production of a crop, the smaller would we expect the area allocation in favour of that crop to be.

Rural public investment – specifically in the areas of irrigation, soil and water conservation, agricultural research and education, and food storage and warehousing – may also be expected to encourage acreage under a crop. Given that capital stock figures are non-existent, we proxy this by using capital expenditures figures. Thus, the public investment variable ($\mathbf{PUBINV_{it}}$) is estimated as $[E_t+(1-d)E_{t-1}]$/CFD, where E_t is rural capital expenditure in the current period, E_{t-1} is rural capital expenditure lagged one period, d is the annualized rate of depreciation of the capital stock in question, and *CFD* is the capital formation deflator. Although d = 0.025 is assumed for the calculations, alternative assumptions about the life of the capital stock do not appear to matter.[10]

Acreage, Yield, and Output Elasticities

Although we have set out our model in terms of area response (leading to the derivation of the short-run and long-run *area* elasticities), farmers respond to various stimuli not just by adjusting area, but also by adjusting the other inputs into production (such as water, fertilizer etc.). Indeed, in land-scarce countries such as India the latter response, leading to yield (or output per unit land) increases, is likely to dominate the area response (as is borne out by numerous studies, e.g. Vaidyanathan, 1994). To capture the full supply response, therefore, we also estimate a yield response model, i.e. with yield ($\mathbf{Y_{it}}$) in place of acreage ($\mathbf{A_{it}}$) in equations (1), (2) and (3)

$$Y^d_{it} = \alpha'_0 + \alpha'_1 \Pi^{me}_{it} + \alpha'_2 Z_{it} + \epsilon'_{1it} \tag{1a}$$

$$Y_{it} = Y_{i(t-1)} + \gamma'(Y^d_{it} - Y_{i(t-1)}) + \epsilon'_{2it} \qquad 0 < \gamma' \leq 1 \tag{2a}$$

$$Y_{it} = \theta'_0 + \theta'_1 Y_{i(t-1)} + \theta'_2 \Pi^{me}_{it} + \theta'_3 Z_{it} + \nu'_{it} \tag{3a}$$

where all the regressors are as defined above,[11] and we use $\hat{\Pi}^{me}_{it}$ in lieu of Π^{me}_{it} (3a) as before. It is possible, however, for γ' to exceed 1 on occasion. insofar as yield is subject to the weather and not totally within the farmer's control. Of course, for stability it is sufficient that γ' lie between 0 and 2. In contrast to the area response model, two additional regressors that we include in the yield response model are fertilizer input per hectare ($FERT_{it}$) and high-yielding variety seeds (HYV_{it}), for chemical fertilizers and improved seeds are considered to be the most important yield-augmenting inputs after water.[12] (See the data section below for further details on the latter variable.) The yield response model gives us the short-run and long-run *yield* elasticities. Adding together the area and yield elasticities, we can derive the *output* elasticities.

3. The Data Set and Methodology

The Data Set

We estimate the models specified above for the Indian annual cash crops, for the period 1967-68 to 1999-2000.[13] The study focuses on 7 crops – the oilseeds Groundnuts, Rapeseed/Mustard, and Sesamum; and the commercial crops Cotton, Jute, Sugarcane, and Tobacco.

Unlike previous studies (specifically in the Indian context), instead of using aggregate time series data for these crops, we use panel data, where the cross-section units are the different states growing a given crop. This allows for cross-sectional or state-specific variation in all the variables included, as compared to all-India data which would reduce such variation by aggregating some variables and averaging others (as in the case of, for example, Gulati and Sharma, 1990, Lahiri and Roy, 1985, and Narayana and Parikh, 1981). To select the 'important' states growing a given crop, we first computed the average output of each state growing that crop for the triennium centred on 1965-66, 1970-71, 1980-81, 1990-91 and 1999-00. We then included only those states which produced at least 3% of the all-India output of that crop in the above-mentioned triennia. For example, in the case of Jute the states of Assam, Bihar and West Bengal each accounted for at least 3% of the total Jute production for the triennia mentioned above. Therefore, these 3 states were taken to constitute the 'Jute sample' (see Appendix 1). Of course, having chosen the sample of states for a given crop, data for the entire period 1967-68/1999-00 were employed in estimating the area and yield regressions for this sample.

Furthermore, panel estimation allows us to incorporate sources of variation which cannot be incorporated otherwise. Thus, for any given crop, the competing crops need not be the same in each state; and, in fact, this was our experience for some crops. All these advantages of panel estimation increase the efficiency of the sample estimates, and render the results more representative of the constituent cross-sections.

As regards the price data used, we prefer to use farm harvest prices for computing the relative profitability[14] of the different crops rather than wholesale prices, contrary to the practice in the received literature. Since most Indian farmers have very limited storage facilities, and a large proportion in any case have rather small surpluses to sell, the predominant bulk of the crops are marketed soon after the harvest, and the prices farmers receive are the farm harvest prices. Wholesale prices, on the other hand, are yearly averages of the prices prevailing in the wholesale markets. While these prices tend to be close to farm harvest prices around harvest time, during the rest of the year they can rule substantially higher, and do not necessarily reflect the prices farmers receive.[15]

All the data were available from various sources in the public domain. In the case of Jute, lack of availability of some price data for the state of Orissa forced us to drop this state from the Jute sample. This isn't a problem, however, because the remaining three states in the Jute sample (Assam, Bihar and West Bengal) still account for about 96% of the total Jute production. Further, irrigation data were not available for the Jute crop for any of the sample states, forcing us to use the respective state-specific averages in lieu of this variable in the Jute estimations. As it turns out, dropping this proxy from the regressions does not alter the other results.

With regard to the improved seeds variable, it needs to be pointed out that data on the area under HYVs were never collected for our sample of crops. The spread of improved seeds in the context of the Green Revolution in India was initially restricted to just Rice and Wheat. The Technology Mission on Oilseeds was established in 1986, so that the oilseeds benefited from improved seeds only by the 1990s. For the commercial crops, such benefits were less dramatic. Thus, the Technology Mission on Cotton was established as late as 2000, although intensive development programmes were initiated earlier. The Central Tobacco Research Institute was established as early as 1947, but it concentrated more on cultural practices. The Sugar Technology Mission was established in 1993 (and its benefits to Sugarcane are only indirect), whereas the Technology Mission on Jute is yet to take off. Keeping all this in mind, we define the improved seeds variable as a dummy, where HYV_{it} = 1 for t > 1989, and 0 for the earlier years.

The samples of states for each of the crops considered are given in Appendix 1. The definitions of the different variables used are provided in Appendix 2. The different data sources drawn upon are reported in Appendix 3; and the means and standard deviations of the (untransformed) variables, for each of the crops, are reported in Appendix 4.

The Methodology

For estimating the acreage and yield equations (3) and (3a) (with $\hat{\Pi}^{re}_{it}$ in place of Π^{re}_{it}) for a given crop, we pool the panel data using a random effects model. A growing body of literature (Nerlove, 1967, 1971; Maddala, 1971; Nickell, 1981) shows, that this technique is superior to alternative techniques such as fixed effects or OLS estimation, for the latter may imply a significant loss of degrees of freedom and/or completely ignore the information emanating from 'between group' variation. Further, this literature argues, individual (cross-section) effects reflect our ignorance just as much as the normal residuals in the estimating equations and, therefore, there is no reason to treat the former any differently from the latter. An added consideration in our context is the presence of a lagged dependent variable amongst the set of regressors. In such specifications, the above-mentioned literature points out, random effects estimation provides consistent estimators.

Let *s = 1, ..., S* represent the cross-section units (the states), and *t = 1, ..., T* the observations on each cross-section unit. Suppressing the crop index i (because we estimate the same econometric model for each crop), the econometric model that we employ may be stated as

$$y_{st} = \bar{\beta}_1 + \Sigma_{k=2}^{K} \beta_k x_{kst} + \mu_s + e_{st} \qquad s = 1, ..., S; \quad t = 1, ..., T_s \qquad (12)$$

where $\mu_s \sim (0, \sigma_\mu^2)$

$$e_{st} = \rho e_{s(t-1)} + \psi_{st} \qquad |\rho| < 1$$

$$\psi_{st} \sim (0, \sigma_\psi^2)$$

$$E(\mu_s \mu_r) = 0 \qquad s \neq r$$

$$E(\mu_s e_{rt}) = 0 \qquad s \neq r \qquad (13)$$

The dependent variable y_{st} refers to area in equation (3) and yield in equation (3a). Variables x_{kst} denote the set of regressors discussed above. All variables – regressand and regressors – are in natural logs (excepting the improved seeds dummy). Estimation leads to GLS estimates of the reduced form model parameters.[16] Using these results, the structural form estimates are easily derivable. The estimation results are presented in Tables 1, 2 and 3, and discussed in the following section. An important assumption of random effects estimation, however, is that μ_s is independent of the regressors – an assumption which may not always hold, and which is *not* required for the consistency of *fixed* effects estimation. Keeping this in mind, for purposes of comparison we also present the estimation results of fixed effects estimation, in Appendix 5.

4. Estimation Results

For the area as well as the yield equations (Tables 1 and 2), the hypotheses that changes in area or yield occurred randomly over time were very strongly rejected in the case of all crops

– the associated Wald χ^2 statistics reported in the tables turn out to be large, and have P-values of 0 without exception. The sign and magnitude of the coefficient of the lagged dependent variable (lagged area in the area equation, and lagged yield in the yield equation), which have implications for the dynamic stability of the models, are as per expectations in all cases. Only in very few cases was a regressor found to have the wrong sign *and* turned out to be significant.

The Area Response

Considering the area equations first (Table 1), by far the most important variable determining area allocations over time appears to be rainfall. Rainfall has a very strong positive influence on the area planted under the different crops, and the associated long-run elasticities (with the sole exception of sugarcane) are also the highest (Table 3).[17] Sugarcane turns out to be a bit of an exception probably because it has, on average, the highest percentage area irrigated amongst all the crops (Table A1, Appendix 4).

The irrigation variable turned out to have a strong positive and significant effect in the case of all crops, except Groundnuts. The long-run area elasticities w.r.t irrigation vary quite considerably, ranging between approximately 0.1 and 0.5, except for Groundnuts for which it is very small, Perhaps this result can be better understood by allowing for the fact that, with the exception of sugarcane, most of these crops (particularly the oilseeds) are grown under primarily rainfed conditions. In other words, rather small percentages of their cultivated areas have access to assured irrigation, and these percentages do not exhibit substantial variation over time.

The 'price variable', or relative (gross) profits, is found to have a strong positive influence on area allocations in the case of Groundnuts and Tobacco, and a somewhat weaker effect in the case of Cotton and Sesamum (although only using a one-tail test for the latter). Barring Groundnuts and Tobacco, however, the associated long-run area elasticities are very small, usually less than 0.1.

Both risk variables – price risk as represented by the coefficient of variation of price, as well as yield risk as proxied by the coefficient of variation of rainfall – are consistently insignificant. So also is the public investment variable. The area adjustment coefficient γ (Table 3) ranges from about 0.3 for Sesamum to about 0.7 for Jute, suggesting an average of about 0.5; which is what it approximately is for the other five crops. This implies, that for most of these crops it would take about two years for the 'complete' area response to occur. This is contrary to the results reported by Ray (1980), who found the short-run elasticities to *exceed* the long-run elasticities (i.e. $\gamma > 1$) – a result we feel is quite implausible given the constraints Indian farmers operate under. Our results for the Indian annual cash crops (which appear to imply an 'average' adjustment time closer to 2 years), compare very well with the estimate of 2 years reported by Vasavada and Chambers (1986) for U.S. agriculture. At another level, however, one can argue that a 'significantly' higher adjustment time of over 3 years for Sesamum and over 2.5 years for Cotton and Sugarcane (rather than 2), points towards the presence of various constraints such as lack of access to inputs and credit, which inhibit farmer response to stimuli.

A similar value of γ, though, for two different crops need not result from the same set of factors. Thus, for Sugarcane, a (relatively) small γ (0.37) is probably the result of the fact that it is already the second largest crop in terms of area cultivated. Given the competing demands for other crops, crop-diversification as a risk-coping measure etc., further area allocation in favour of Sugarcane tends to be small. A small γ (0.31) for Sesamum, on the other hand, has more to do with the fact, that till recently, it was grown by 'small-scale, subsistence oriented farmers' with not much access to land and non-land inputs. Unfortunately, a formal regression analysis of the relationship between the area adjustment coefficient and its determinants is not possible, because of the lack of a time series on the coefficient *by crop*.

The Yield Response

Coming to the yield equations (Table 2), once again rainfall turns out to be an important factor determining variations in yield over time; although decidedly not so important as it is in determining crop area. It has a strong positive effect on the yield of all crops, albeit using a one-tail test for Cotton. The only exception appears to be Tobacco, where rainfall turns out to have a significantly negative effect on yield. We find this aberration quite inexplicable, and feel that it ought to be discounted; especially in view of the fact that it is *not* supported by the fixed effects estimation results (Table A5.2, Appendix 5), which are otherwise generally supportive of all the random effects estimation results discussed in this section. The associated long-run yield elasticities are, compared to those of the other regressors, amongst the highest (Table 3).

The irrigation variable has a strong positive effect on the yield variations of all crops. The long-run yield elasticities w.r.t irrigation are quite substantial and, in fact, even larger than the yield-elasticities w.r.t rainfall for several crops. A notable exception appears to be Sesamum, which has to do with the fact that only a very small proportion of the Sesamum acreage has access to assured irrigation (Table A1, Appendix 4), so that changes in this proportion have rather small incremental effects on production and yield.

In addition to the availability of water, two other important yield-enhancing inputs are fertiliser and high-yielding variety seeds. Fertiliser applications have the expected positive sign in the case of all crops, and this effect is significant in the case of Cotton, Sugarcane, Rapeseed/Mustard and Tobacco.[18] The associated long-run elasticities of yield, however, are rather small for all three oilseeds, although relatively substantial for the other cash crops. Apparently this is due to the very small percentage areas fertilised in the case of the oilseeds, so that higher fertiliser use intensity does not have much impact on total production and yield. Similarly, the use of HYVs has a significant positive influence on the yields of our sample crops, barring Cotton and Sugarcane. Unfortunately, the associated long-run elasticities of yield w.r.t this variable are not available, because the HYV variable is a dummy variable.

The 'price variable' (relative gross profit) has a significant positive influence on the yields of Cotton and Tobacco, but turns out to be unimportant for the other crops. This implies, that after controlling for the use of yield-enhancing inputs such as water (irrigation and rainfall), fertiliser, and improved seeds, increases in expected profits (which make possible purchases in such inputs), do not lead to any further intensification of cultivation for crops other than Cotton and Tobacco. The two risk variables do not have any significant effect on the yield variations of any of the crops, barring price risk vis-a-vis Sesamum. The same observation holds for public investment.

The Total Output Response

Putting the area and yield responses together, we obtain the total output responses of the different crops to the regressors used. Of particular interest are the long-run elasticities of output of the crops, and we attempt to discern any patterns that may emerge from the elasticity estimates. From Table 3[19] we find, first, that the largest output elasticities for all crops excepting Sugarcane (and possibly Tobacco),[20] are those w.r.t rainfall. Barring Sugarcane and Tobacco these elasticities exceed 2/3, hovering close to unity for Sesamum, Jute and Rapeseed. Our result differs from those reported in the received literature on Indian agriculture – for example, Narayana and Parikh (1981) – which find the elasticities of supply w.r.t irrigation to be the largest, even exceeding those for rainfall.

Second, the output elasticities w.r.t the irrigation variable are positive and relatively large for all the crops, ranging from a low of 0.13 for Sesamum to a high of 0.73 for Sugarcane. On average, these elasticities are higher for the commercial crops than for the oilseeds.

Third, the output elasticities w.r.t the 'price variable' or relative gross profits, are close to zero for Rapeseed/Mustard and Jute, and rather small for Sugarcane. The 'price' elasticities of output for these crops may, therefore, be ignored from the policy viewpoint. For the remaining crops – Groundnuts, Sesamum, Cotton, and Tobacco – the 'price' elasticities of output are all reasonably large, ranging between 0.10 for Sesamum and 0.36 for Tobacco. (It may be worth noting, that in the fixed effects estimation results in Table A5.3, Appendix 5, this is true for Jute as well.)

Fourth, the output elasticities w.r.t the risk variables – the coefficient of variation of price and the coefficient of variation of rainfall – are close to zero in virtually all cases and may, hence, be ignored. The same observation holds for the public investment variable. In other words, price risk and output risk are not likely to be important instruments in effecting variations in area and yield over time, at least for this sample of crops. By implication, emphasizing commodity stabilization schemes is not likely to be useful *from the production viewpoint*. Further, it is not so much the variation in water availability as the level of water use that appears relevant for production.

5. Conclusions and Policy Implications

From the above analysis it is apparent, that the supply response of Indian agriculture is influenced by the weather, input availability (specifically irrigation, and possibly fertiliser and HYVs), and prices, in that order. Rainfall appears to be the single most important factor determining area response, and the second most important factor determining yield response, even today; and exhibits the largest elasticities of output. In other words, even after several decades of initiating massive irrigation projects, Indian agriculture continues to be weather-dependent. The only exception to this observation, we find, holds for Sugarcane. Of course, this merely reflects the fact that the bulk of the Sugarcane crop is cultivated on irrigated land, unlike the other crops which are grown under rainfed conditions, particularly the oilseeds.

Next in importance to the weather appears to be the availability of irrigation – the irrigation elasticities of all crops being positive and quite substantial in magnitude. As revealed by our results, irrigation is particularly instrumental in raising yields rather than the area cultivated. Taken together with the result noted in the previous paragraph, it is apparent that the most important policy variable from the viewpoint of long-run output response, is the water input.[21] Given that rainfall cannot be manipulated, the irrigation variable is the obvious one that policy can impinge upon.

Evaluating the importance of the other two inputs – fertiliser and 'modern' seeds – is rendered difficult by the fact, that although the latter turned out to be unambiguously important, we do not have access to the corresponding elasticity estimates. Subject to this limitation, one may conjecture that, after water, it is these inputs that are the next most important determinants of variations in output; with the possible exception of Tobacco.

The above observations do not, however, imply that the price variable is not important as a policy instrument. Barring Rapeseed/Mustard and, to a lesser extent, Sugarcane, the price variable may also be used to encourage the production of these crops. Particularly so in the case of Tobacco, Cotton and Groundnuts. That relative profit should be important in motivating the producers of cash crops is not at all surprising.

These results lead us to opine, that the authorities need to concentrate on the increased provision of assured irrigation, fertiliser and improved seeds if a substantial increase in the long-run output of the sample crops is to be achieved. Not only will increased irrigation have a direct positive impact on supply, it will also have an indirect impact insofar as access to irrigation serves to reduce the negative influence of rainfall variation (although we found the magnitude of this effect to be small and not worth bothering about per se).

While this prescription does not rule out the importance of the price instrument, at the same time nor can we pronounce on whether it is the price or the nonprice variables that are the more important of the two. In the case of the price variable it must be well-understood, that the price instrument refers to prices (substantially) exceeding cost of production, *coupled with government purchase*; so that the government agencies would also have to reckon with not only the cost of running such a scheme, but also work out how best to dispose off what they procure. Both decisions, as the Indian experience amply shows, can be very expensive and inefficient (Ramaswami, 2002).

This is not to imply that similar inefficiencies do not also exist in the case of the irrigation variable, for instance. But how large these costs are, will probably depend upon the manner in which the increased irrigation is secured. An increase in the percentage area irrigated need not involve any large-scale public investments. *Given the extant irrigation infrastructure* (and, hence, the amount of water available for irrigation), an increase in the percentage area irrigated can still be brought about simply by switching to superior irrigation technologies. This could be achieved, for instance, by private investment in sprinkler irrigation (as opposed to the current practice of 'flooding the furrows'), aided by subsidized credit. The inefficiency costs of such schemes should be a lot less than those of entirely government-administered schemes providing producer subsidies (and off-loading the grain procured to the consumers). In general, then, a choice between the price and nonprice instruments will depend upon the relative costs of a 1% increase in these instruments. We are not aware, however, of any studies which provide such cost comparisons, and are consequently not in a position to pronounce on whether it is the price variable or the nonprice variables that are the more cost-effective in raising output.[22] Despite this caveat, one cannot disagree with the fact, that incentive prices prove an incentive only to those farmers whose output is actually procured; and these are the larger, relatively well-off farmers. Provision of irrigation, fertiliser and improved seeds, on the other hand, is likely to benefit both large and small farmers.

Appendix 1

Sample Crops and the Sample States

Cotton – Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan.

Groundnuts – Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu.

Jute – Assam, Bihar, West Bengal.

Rapeseed/Mustard – Assam, Gujarat, Haryana, Madhya Pradesh, Rajasthan, Uttar Pradesh, West Bengal.

Sesamum – Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh.

Sugarcane – Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh.

Tobacco – Andhra Pradesh, Gujarat, Karnataka, Uttar Pradesh.

Appendix 2

Definitions of Variables

A_{it} – Area under crop i in period t ('000 hectares)

Y_{it} – Yield of crop i in period t (tons/hectare)

$A_{i(t-1)}$ – Area under crop i in period t–1 ('000 hectares)

$Y_{i(t-1)}$ – Yield of crop i in period t–1 (tons/hectare)

$\hat{\Pi}_{it}^{re}$ – Estimated Relative gross profit of crop i in period t (number)

CVP_{it} – Coefficient of Variation of (Farm Harvest) Price (number)

CVR_{it} – Coefficient of Variation of Rainfall (number)

HYV_{it} – Dummy equal to 1 for t > 1989, and 0 otherwise

$FERT_{it}$ – Fertiliser consumption (of NPK) as a proportion of cultivated area for crop i in period t (tons/hectare)

$PUBINV_{it}$ – Public investment in agriculture in period t (Rs. million)

I_{it} – Irrigated area as a proportion of cultivated area for crop i in period t (ratio)

R_{it} – Rainfall for crop i in period t (mm)

Appendix 3

Data Sources

A_{it} – Government of India (a)

Y_{it} – Government of India (a)

$\hat{\Pi}^{e}_{it}$ – Computed from data in Government of India (a), (b) and (2001)

CVP_{it} – Computed from data in Government of India (b)

CVR_{it} – Computed from data in India Meteorological Department (2004)

HYV_{it} – Fertiliser Association of India

$FERT_{it}$ – Fertiliser Association of India

$PUBINV_{it}$ – Reserve Bank of India

I_{it} – Computed from data in Government of India (a), (c) and (d)

R_{it} – India Meteorological Department (2004)

Appendix 4

Table A4 Means and Standard Deviations of Variables 1967-68/1999-00

Variable	Units	Groundnuts	Rapeseed/Mustard	Sesamum	Cotton	Jute	Sugarcane	Tobacco
Area	'000 hectares	1088.844	591.825	226.947	858.712	243.882	327.524	86.871
		(587.653)	(680.010)	(155.904)	(749.176)	(183.919)	(459.727)	(68.615)
Yield	tons/hectare	0.869	0.672	0.260	1.334	7.873	65.647	1.502
		(0.332)	(0.278)	(0.179)	(1.043)	(2.062)	(20.905)	(1.339)
Relative Profit	ratio	8.240	2.945	0.485	0.301	0.588	15.204	0.384
		(6.170)	(9.881)	(0.785)	(0.340)	(0.344)	(16.975)	(0.354)
Price Risk	number	0.144	0.140	0.127	0.159	0.191	0.188	0.194
		(0.110)	(0.088)	(0.088)	(0.102)	(0.149)	(0.165)	(0.115)
Yield Risk	number	0.173	0.209	0.180	0.201	0.133	0.200	0.199
		(0.112)	(0.147)	(0.120)	(0.137)	(0.074)	(0.149)	(0.154)
Public Investment	Rs. millions	5631.412	4066.892	5489.863	4641.115	2618.926	5585.604	6510.919
		(4509.340)	(4275.697)	(4791.162)	(4171.599)	(2674.716)	(5123.385)	(5107.844)
Fertilizer	tons/hectare	0.060	0.029	0.019	0.071	0.021	0.204	na
		(0.097)	(0.034)	(0.019)	(0.074)	(0.024)	(0.163)	
Irrigated area	ratio	0.141	0.420	0.057	0.441	na	0.919	na
(per hectare)		(0.116)	(0.337)	(0.098)	(0.386)		(0.308)	
Rainfall	mm	224.237	85.788	34.508	176.486	102.474	56.598	18.147
		(145.031)	(78.822)	(23.770)	(225.613)	(90.930)	(71.728)	(13.519)

Note: Standard deviations reported in parentheses, below the corresponding means;
na – denotes data not available; Rs. – denotes 'Rupees';

Table A5.1 Fixed Effects Estimation – GLS Reduced Form Coefficient Estimates: Dependent Variable – Area (A_{it})

Regressors	Groundnuts	Rapeseed/Mustard	Sesamum	Cotton	Jute	Sugarcane	Tobacco
$A_{i(t-1)}$	0.341	0.390	0.485	0.515	0.175	0.315	0.322
	(5.86)	(10.77)	(15.13)	(13.47)	(2.06)	(7.92)	(4.65)
$\hat{\Pi}_{it}^{re}$	0.032	0.002	0.022	0.015	0.012	0.034	0.095
	(2.11)	(0.23)	(1.71)	(0.70)	(0.26)	(1.78)	(3.63)
CVP_{it}	−0.013	−0.025	0.001	0.004	−0.007	−0.015	−0.006
	(−0.92)	(−1.54)	(0.08)	(0.42)	(−0.43)	(−1.94)	(−0.35)
CVR_{it}	−0.019	0.009	dd	dd	−0.024	−0.003	−0.007
	(−1.11)	(0.50)			(−1.18)	(−0.37)	(−0.39)
$PUBINV_{it}$	0.009	−0.013	0.027	−0.004	0.026	−0.005	0.027
	(0.76)	(−0,30)	(1.99)	(−0.36)	(0.82)	(−0.51)	(1.82)
I_{it}	−0.004	0.107	0.067	0.045	0.006	0.404	0.053
	(−0.25)	(5.65)	(3.99)	(2.70)	(0.14)	(10.43)	(1.49)
R_{it}	0.344	0.390	0.422	0.316	0.443	0.135	0.332
	(10.82)	(12.85)	(16.62)	(13.20)	(8.38)	(5.88)	(8.18)

Table A5.1 contd.

Intercept	2.543	1.628	0.979	1.566	2.125	1.002	1.651
	(8.76)	(5.77)	(5.56)	(5.43)	(4.06)	(7.43)	(5.85)
N	198	231	297	297	99	297	132
Wald χ^2 ($\beta_k = 0$)	34.99	206.93	258.38	215.48	17.78	248.96	47.45
R^2	0.8526	0.8680	0.7266	0.9388	0.8906	0.9202	0.9607

Note: All variables are in (natural) logs; Asymptotic t-values are in parentheses

dd – regressor dropped because it had the wrong sign and was significant

Table A5.2 Fixed Effects Estimation – GLS Reduced Form Coefficient Estimates: Dependent Variable – Yield (Y_{it})

Regressors	Groundnuts	Rapeseed/Mustard	Sesamum	Cotton	Jute	Sugarcane	Tobacco
$Y_{i(t-1)}$	−0.303	0.218	0.105	0.182	−0.090	0.525	0.673
	(−4.77)	(3.21)	(1.72)	(3.00)	(−0.76)	(10.47)	(8.63)
$\hat{\Pi}_{it}^{re}$	0.052	0.003	0.062	0.139	0.105	−0.010	0.105
	(1.57)	(0.35)	(1.59)	(2.56)	(0.26)	(−0.55)	(2.47)
CVP_{it}	−0.056	−0.022	−0.068	0.010	dd	−0.001	0.005
	(−1.79)	(−0.94)	(−1.54)	(0.39)		(−0.14)	(0.21)
CVR_{it}	0.014	−0.006	−0.025	−0.029	−0.021	0.003	0.004
	(0.37)	(−0.22)	(−0.58)	(−0.96)	(−0.54)	(0.27)	(0.16)
$PUBINV_{it}$	−0.033	−0.020	−0.057	−0.015	−0.039	−0.005	0.004
	(−1.21)	(−0.31)	(−1.42)	(−0.48)	(−0.63)	(−0.47)	(0,22)
HYV_{it}	0.099	0.100	0.223	−0.012	0.141	0.047	0.116
	(1.46)	(1.80)	(2.60)	(−0.19)	(1.54)	(2.25)	(2.08)
$FERT_{it}$	−0.050	0.042	0.063	0.132	0.088	0.041	nd
	(−1.40)	(0.90)	(1.26)	(3.78)	(1.80)	(2.58)	

Table A5.2 contd.

I_{it}	0.289	0.112	−0.070	0.078	0.163	0.133	0.039
	(6.76)	(3.54)	(−1.16)	(1.64)	(0.77)	(2.71)	(0.73)
R_{it}	0.528	0.160	0.282	0.069	−0.109	0.004	−0.034
	(7.46)	(4.40)	(4.15)	(1.14)	(−1.06)	(0.18)	(−0.73)
Intercept	−2.364	−0.438	−1.650	0.556	3.256	1.633	0.133
	(−6.15)	(−0.78)	(−3.43)	(1.37)	(4.10)	(7.45)	(0.90)
N	198	231	297	297	99	297	132
Wald χ^2 ($\beta_k = 0$)	14.23	24.65	6.65	20.65	4.19	23.51	35.33
R^2	0.0309	0.5465	0.0812	0.6165	0.0024	0.8459	0.8952

Note: All variables are in (natural) logs; Asymptotic t-values are in parentheses

dd – regressor dropped because it had the wrong sign and was significant

nd – regressor dropped because no data were available on this variable

Table A5.3 Structural Form Estimates

Crop	Area Adj. Coeff. (γ)	Regressors	Structural Form Elasticity Area (A_{it})	Yield (Y_{it})	Elasticity of Output[††]
Groundnuts	0.66	$\hat{\Pi}^{me}_{it}$	0.049	0.040	0.089
		CVP_{it}	−0.019	−0.043	−0.062
		CVR_{it}	−0.029	0.010	−0.018
		$PUBINV_{it}$	0.014	−0.025	−0.012
		HYV_{it}	nr	0.076	0.076
		$FERT_{it}$	nr	−0.039	−0.039
		I_{it}	−0.006	0.221	0.216
		R_{it}	0.522	0.405	0.927
Rapeseed	0.61	$\hat{\Pi}^{me}_{it}$	0.003	0.004	0.007
		CVP_{it}	−0.041	−0.027	−0.068
		CVR_{it}	0.016	−0.017	0.008
		$PUBINV_{it}$	−0.021	−0.026	−0.047
		HYV_{it}	nr	0.127	0.127
		$FERT_{it}$	nr	0.054	0.054
		I_{it}	0.176	0.143	0.319
		R_{it}	0.641	0.205	0.845
Sesamum	0.52	$\hat{\Pi}^{me}_{it}$	0.043	0.069	0.112
		CVP_{it}	0.002	−0.076	−0.073
		CVR_{it}	na	−0.028	na
		$PUBINV_{it}$	0.052	−0.064	−0.012
		HYV_{it}	nr	0.249	0.249
		$FERT_{it}$	nr	0.071	0.071
		I_{it}	0.130	−0.078	0.052
		R_{it}	0.819	0.315	1.134
Cotton	0.48	$\hat{\Pi}^{me}_{it}$	0.032	0.169	0.201
		CVP_{it}	0.009	0.012	0.020
		CVR_{it}	na	−0.035	na
		$PUBINV_{it}$	−0.009	−0.018	−0.027
		HYV_{it}	nr	−0.014	−0.014
		$FERT_{it}$	nr	0.161	0.161
		I_{it}	0.093	0.096	0.188
		R_{it}	0.653	0.085	0.737

Table A5.3 contd. Structural Form Estimates

Crop	Area Adj. Coeff. (γ)	Regressors	Structural Form Elasticity Area (A_{it})	Yield (Y_{it})	Elasticity of Output††
Jute	0.83	$\hat{\Pi}^{me}_{it}$	0.014	0.096	0.111
		CVP_{it}	−0.009	na	na
		CVR_{it}	−0.029	−0.019	−0.048
		$PUBINV_{it}$	0.032	−0.035	−0.004
		HYV_{it}	nr	0.129	0.129
		$FERT_{it}$	nr	0.081	0.081
		I_{it}	0.007	0.149	0.156
		R_{it}	0.537	−0.100	0.437
Sugarcane	0.68	$\hat{\Pi}^{me}_{it}$	0.050	−0.021	0.029
		CVP_{it}	−0.022	−0.003	−0.025
		CVR_{it}	−0.005	0.006	0.001
		$PUBINV_{it}$	−0.008	−0.011	−0.019
		HYV_{it}	nr	0.099	0.099
		$FERT_{it}$	nr	0.086	0.086
		I_{it}	0.590	0.279	0.869
		R_{it}	0.198	0.008	0.206
Tobacco	0.68	$\hat{\Pi}^{me}_{it}$	0.140	0.321	0.462
		CVP_{it}	−0.010	0.016	0.007
		CVR_{it}	−0.011	0.013	0.002
		$PUBINV_{it}$	0.040	0.012	0.052
		HYV_{it}	nr	0.353	0.353
		$FERT_{it}$	nd	nd	nd
		I_{it}	0.078	0.119	0.197
		R_{it}	0.489	−0.105	0.384

Note: Elasticities w.r.t the lagged dependent variables are not reported here

†† – Elasticity of output is the sum of the structural form elasticities of area and yield;

na – denotes 'not available' (because the corresponding regressor was dropped from the corresponding reduced form equation)

nr – denotes 'not relevant' in the corresponding equation

nd – no data on this variable, hence no elasticity

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Table 1 **Random Effects Estimation – GLS Reduced Form Coefficient Estimates: Dependent Variable – Area (A_{it})**

Regressors	**Groundnuts**	**Rapeseed/Mustard**	**Sesamum**	**Cotton**	**Jute**	**Sugarcane**	**Tobacco**
$A_{i(t-1)}$	0.529	0.509	0.692	0.600	0.292	0.629	0.518
	(11.38)	(14.12)	(24.09)	(18.14)	(4.38)	(19.68)	(10.12)
$\hat{\Pi}_{it}^{re}$	0.052	−0.007	0.016	0.031	−0.001	0.008	0.054
	(3.54)	(−0.91)	(1.47)	(1.70)	(−0.02)	(0.88)	(2.26)
CVP_{it}	−0.013	−0.025	0.015	0.012	−0.014	−0.012	−0.009
	(−0.91)	(−1.39)	(0.95)	(1.17)	(−0.83)	(−1.42)	(−0.45)
CVR_{it}	−0.001	0.016	dd	dd	−0.013	−0.006	0.013
	(−0.05)	(0.78)			(−0.64)	(−0.53)	(0.67)
$PUBINV_{it}$	0.002	0.018	0.023	−0.005	0.026	−0.014	0.009
	(0.15)	(0.38)	(1.47)	(−0.40)	(0.82)	(−1.17)	(0.61)
I_{it}	0.014	0.109	0.025	0.043	0.065	0.184	0.129
	(1.10)	(6.16)	(1.99)	(2.95)	(8.84)	(7.91)	(7.74)
R_{it}	0.280	0.320	0.273	0.246	0.485	0.133	0.323
	(9.48)	(10.79)	(11.31)	(12.37)	(11.11)	(6,48)	(9.67)

Table 1 contd.

Intercept	1.561	0.934	0.505	1.383	1.080	0.644	0.823
	(5.40)	(2.09)	(2.61)	(6.05)	(3.02)	(4.83)	(4.01)
N	198	231	297	297	99	297	132
Wald χ^2 ($\beta_k = 0$)	594.05	1604.91	1550.26	2632.23	2853.98	4066.05	6266.56
R^2	0.9075	0.9158	0.8677	0.9548	0.9702	0.9725	0.9816

Note: All variables are in (natural) logs; Asymptotic t-values are in parentheses

dd – regressor dropped because it had the wrong sign and was significant

Table 2 **Random Effects Estimation – GLS Reduced Form Coefficient Estimates: Dependent Variable – Yield (Y_{it})**

Regressors	Groundnuts	Rapeseed/Mustard	Sesamum	Cotton	Jute	Sugarcane	Tobacco
$Y_{i(t-1)}$	−0.243	0.317	0.288	0.384	−0.024	0.724	0.763
	(−3.44)	(5.07)	(5.01)	(7.06)	(−0.20)	(19.45)	(12.60)
$\hat{\Pi}_{it}^{re}$	0.019	−0.003	0.033	0.074	−0.002	0.007	0.059
	(0.58)	(−0.30)	(1.13)	(2.10)	(−0.02)	(0.91)	(1.84)
CVP_{it}	−0.030	−0.019	−0.080	−0.008	dd	0.006	0.005
	(−0.87)	(−0.84)	(−1.81)	(−0.32)		(0.69)	(0.19)
CVR_{it}	−0.008	0.010	−0.022	−0.007	−0.0028	0.001	0.012
	(−0.19)	(0.40)	(−0.51)	(−0.23)	(−0.06)	(0.14)	(0.50)
$PUBINV_{it}$	−0.038	−0.003	−0.060	−0.038	−0.041	−0.003	0.0003
	(−1.22)	(−0.05)	(−1.54)	(−1.16)	(−0.65)	(−0.30)	(0,02)
HYV_{it}	0.147	0.100	0.153	−0.042	0.221	0.004	0.088
	(1.95)	(1.92)	(1.94)	(−0.71)	(2.43)	(0.18)	(1.83)
$FERT_{it}$	0.018	0.043	0.040	0.093	0.021	0.045	nd
	(0.53)	(1.70)	(1.01)	(3.54)	(0.62)	(3.17)	

Table 2 contd.

I_{it}	0.127	0.115	0.035	0.180	0.173	0.065	0.061
	(3.58)	(4.31)	(1.86)	(5.19)	(1.92)	(2.66)	(2.21)
R_{it}	0.103	0.105	0.194	0.052	0.214	0.023	−0.079
	(2.01)	(3.59)	(3.30)	(1.62)	(4.46)	(2.06)	(−2.43)
Intercept	−0.225	−0.437	−1.241	0.808	1.695	1.194	0.383
	(−0.57)	(−0.74)	(−2.46)	(2.36)	(2.46)	(6.26)	(1.97)
N	198	231	297	297	99	297	132
Wald χ^2 ($\beta_k = 0$)	55.78	272.14	74.10	459.66	65.66	895.17	750.99
R^2	0.1000	0.6503	0.3845	0.7292	0.4422	0.8761	0.9366

Note: All variables are in (natural) logs; Asymptotic t-values are in parentheses

dd – regressor dropped because it had the wrong sign and was significant

nd – regressor dropped because no data were available on this variable

Table 3 Structural Form Estimates

Crop	Area Adj. Coeff. (γ)	Regressors	Structural Form Elasticity Area (A_{it})	Structural Form Elasticity Yield (Y_{it})	Elasticity of Output††
Groundnuts	0.47	$\hat{\Pi}^{me}_{it}$	0.110	0.016	0.126
		CVP_{it}	−0.029	−0.024	−0.053
		CVR_{it}	−0.002	−0.006	−0.008
		$PUBINV_{it}$	0.004	−0.031	−0.027
		HYV_{it}	nr	0.118	0.118
		$FERT_{it}$	nr	0.015	0.015
		I_{it}	0.030	0.102	0.132
		R_{it}	0.595	0.083	0.678
Rapeseed	0.49	$\hat{\Pi}^{me}_{it}$	−0.014	−0.004	−0.017
		CVP_{it}	−0.050	−0.028	−0.079
		CVR_{it}	0.033	0.014	0.047
		$PUBINV_{it}$	0.037	−0.005	0.032
		HYV_{it}	nr	0.146	0.146
		$FERT_{it}$	nr	0.063	0.063
		I_{it}	0.222	0.169	0.391
		R_{it}	0.652	0.154	0.806
Sesamum	0.31	$\hat{\Pi}^{me}_{it}$	0.050	0.047	0.097
		CVP_{it}	0.050	−0.112	−0.063
		CVR_{it}	na	−0.031	na
		$PUBINV_{it}$	0.073	−0.091	−0.018
		HYV_{it}	nr	0.216	0.216
		$FERT_{it}$	nr	0.057	0.057
		I_{it}	0.082	0.049	0.131
		R_{it}	0.886	0.273	1.159
Cotton	0.40	$\hat{\Pi}^{me}_{it}$	0.077	0.120	0.198
		CVP_{it}	0.030	−0.013	0.016
		CVR_{it}	na	−0.011	na
		$PUBINV_{it}$	−0.013	−0.061	−0.074
		HYV_{it}	nr	−0.069	−0.069
		$FERT_{it}$	nr	0.150	0.150
		I_{it}	0.106	0.293	0.399
		R_{it}	0.616	0.085	0.701

Table 3 contd. Structural Form Estimates

Crop	Area Adj. Coeff. (γ)	Regressors	Structural Form Elasticity Area (A_{it})	Structural Form Elasticity Yield (Y_{it})	Elasticity of Output[††]
Jute	0.71	$\hat{\Pi}^{me}_{it}$	−0.001	−0.002	−0.003
		CVP_{it}	−0.020	na	na
		CVR_{it}	−0.019	−0.002	−0.021
		$PUBINV_{it}$	0.037	−0.040	−0.003
		HYV_{it}	nr	0.216	0.216
		$FERT_{it}$	nr	0.021	0.021
		I_{it}	0.091	0.169	0.260
		R_{it}	0.685	0.209	0.894
Sugarcane	0.37	$\hat{\Pi}^{me}_{it}$	0.021	0.026	0.047
		CVP_{it}	−0.033	0.021	−0.012
		CVR_{it}	−0.015	0.005	−0.010
		$PUBINV_{it}$	−0.037	−0.012	−0.050
		HYV_{it}	nr	0.013	0.013
		$FERT_{it}$	nr	0.164	0.164
		I_{it}	0.496	0.236	0.732
		R_{it}	0.360	0.082	0.443
Tobacco	0.48	$\hat{\Pi}^{me}_{it}$	0.111	0.248	0.360
		CVP_{it}	−0.018	0.020	0.002
		CVR_{it}	0.027	0.053	0.079
		$PUBINV_{it}$	0.019	0.001	0.020
		HYV_{it}	nr	0.373	0.373
		$FERT_{it}$	nd	nd	nd
		I_{it}	0.267	0.256	0.524
		R_{it}	0.671	−0.334	0.337

Note: Elasticities w.r.t the lagged dependent variables are not reported here

[††] – Elasticity of output is the sum of the structural form elasticities of area and yield;

na – denotes 'not available' (because the corresponding regressor was dropped from the corresponding reduced from equation)

nr – denotes 'not relevant' in the corresponding equation

nd – no data on this variable, hence no elasticity

Notes

1. In addition, some earlier researchers have also used supply response behaviour to address the issue of 'farmer rationality' in developing countries. Thus, Krishna (1963) observes that the positive acreage response to prices that he finds, proves that Indian farmers are rational agents. However, this is no longer an issue today – in fact, equating negative price response with irrationality would be much too simplistic. The new development economics literature has amply shown that if peasants do not respond positively to prices, that could be because of various constraints on their behaviour; in other words, it could be because of the importance of other determinants of behaviour (see Basu, 1997, for numerous models of credit and interlinkage which substantiate this point).

2. Moreover, there is no consistency in the way they define the price variable – in some equations it relates to wholesale prices, in some to revenues, in some the deflator is an index of commodity prices, in some it is an index of fertilizer prices.

3. Parikh (1972) considered relative price and relative yield, but not relative profit per se, in his set of regressors. Barten and Vanloot (1996), and Holt (1999) consider absolute, and not relative, profit as the relevant regressor. Narayana and Parikh (1981) consider relative gross profit as the appropriate regressor. See also Rosegrant et.al. (1998) where the theoretical model is set up in terms of profit, but the empirical models include only prices.

4. The profit function approach would require data on input prices. Improved seeds, (irrigation) water and fertiliser are considered the three most important yield-enhancing inputs in the context of the Green Revolution. Data on neither seed prices nor irrigation water charges, however, are available in the Indian context. Further, canal water (which is only one source of irrigation) is provided by public agencies, and its user charges are administered prices which do not reflect the scarcity value of this resource. Even these user charges data are virtually non-existent. Moreover, depending on political expediency, some state administrations make water (and electricity) available to farmers free of cost! Finally, input prices would not vary across crops and states for a given year, negating the advantages of panel estimation.

5. Although observationally equivalent reduced forms may be derivable from alternative structural hypotheses (e.g. Fisher and Temin, 1970).

6. Narayana and Parikh (1981) argue, that given $\Pi_t = \Pi_t^* + \mu_t$ where μ_t is the random component, the Nerlovian expectation specification (9) amounts to placing equal weights on the expected and random components of profits. To remedy this, they prefer specification (10). It stands to reason, however, that not only should the weights on the expected and random components of profits be different, the weight on the former should exceed that on the latter. But there is nothing in specification (10) per se to ensure that – a fact that is borne out by many of the results reported in *their* Table 2 (p. 16; Narayana and Parikh, 1981). Therefore, we prefer to use specification (10) strictly as a statistical approximation.

7. The price variable that we have derived above serves to indicate the return on marketed produce for those who have a surplus. But for small farmers, who consume most of what they produce and don't have much to market, it indicates the opportunity cost of the resources that go into the production of that crop. If the relative price of the crop declines, that would imply higher prices for the competing crop(s). A rational farmer would then be better off producing more of the competing crop(s), selling some (or all) of that output, and using the proceeds to purchase (more of) the subsistence crop in question. Thus, a lower (relative) price for the crop in question would lead to a decline in the area allocated to it, just as it would for the 'large' farmer with a surplus.

8. The irrigation variable is not measured as a proportion of cropped area, as that would introduce a negative bias into the relationship between the regressand (acreage) and the irrigation variable so defined. Thus, an increase in the regressand would imply a smaller percentage area irrigated, downwardly biasing the relationship between acreage and the irrigation variable.

9. Alternatively, we could proxy yield risk by the absolute rainfall deviation, i.e. the absolute deviation of the rainfall in period t from 'normal' rainfall in period t. The meteorological department measures normal rainfall in a given period as the average of the previous thirty years. The results using this alternative definition were, however, no different.

10. We were prevented from considering other relevant regressors, such as credit, due to the lack of data availability at the individual crop level. Even the aggregate data were available for only part of our sample period.

11. Except that we now measure the irrigation variable as a proportion of the cropped area.

12. Ideally we would like to include at least one other regressor in the yield equation - namely,

mechanisation. However, data on this variable are not available in a form that can be meaningfully used here. Although some data on the yearly stock of tractors are available, these are obviously not crop-specific. For that we would require data on the number of machine-hours of labour used, which do not exist.

13. 1967-68 is considered the first normal year after the onset of the green revolution in 1965, the previous two years 1965-66 and 1966-67 being drought years.

14. Since cost of production data were not available for our complete sample period, and were in any case patchy, we were forced to measure (expected) profits in terms of gross profits.

15. One could derive more accurate estimates of supply response if one had information on which farmers have a surplus, which have a deficit, and which are self-sufficient (Key, Sadoulet and de Janvry, 2000), but we do not have household-specific data.

16. While the disturbances in the area and yield equations for a given crop and, indeed, all crops, may be correlated, this cannot be presently handled in the context of random effects estimation by either the STATA (2003) or the SHAZAM (Whistler et.al., 2001) econometrics packages. This was confirmed in personal communications from the STATA and SHAZAM support teams.

17. The elasticities being referred to here, and in the discussion below, are the long-run (or structural) elasticities, unless specifically stated otherwise.

18. As noted in the data section, fertiliser application data are not available for Tobacco. This observation, therefore, is based on the result of the HYV dummy in the Tobacco yield regression, which is probably picking up (part of) the effect of the omitted fertiliser variable.

19. The long-run elasticity estimates w.r.t the lagged dependent variables are omitted from Table 3, because they do not appear to be of any apparent interest.

20. For Tobacco the long-run elasticity of output w.r.t rainfall turns out to be smaller than what it might have been, because of the significant *negative* effect of rainfall on yield. This result, as we pointed out above, is quite inexplicable, and ought to be discounted. Thus, the fixed effects estimation results in Table A5.2 do *not* support this result, and the elasticity estimates in Table A5.3 show that the yield elasticity w.r.t rainfall is indeed the highest even for Tobacco.

21. Adding the rainfall and irrigation elasticities of output, though technically admissible, is not informative; for what would, say, a 5% increase in the composite rainfall-irrigation variable mean?

While it would refer to an increase in rainfall in millimetres, it would refer to an increase in irrigated area in hectares (relative to the cultivated area), changes that are not directly comparable.

22. Note that cost estimates in terms of what the Indian government spends on achieving a 1% increase in prices versus a 1% increase in percentage area irrigated, would help but not quite settle the issue. Since private markets for providing irrigation and producer subsidies do not exist, the government expenditure outlays on these instruments would not necessarily reflect the opportunity costs of the resources involved.

* Complete list of working papers is available at the CDE website:
http://www.cdedse.org/worklist.pdf