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Promoting Biofuels in India: Assessing Land Use Shifts Using Econometric Acreage Response Models

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Abstract**—**Acreage response function are modeled taking account of expected harvest prices, weather related variables and other non-price variables allowing for partial adjustment possibility. At the outset, based on the literature on price expectation formation, we explored suitable formulations for estimating the farmer's expected prices. Assuming that farmers form expectations rationally, the prices of food and biofuel crops are modeled using time-series methods for possible ARCH/GARCH effects to account for volatility. The prices projected on the basis of the models are then inserted to proxy for the expected prices in the acreage response functions. Food crop acreages in different growing states are found sensitive to their prices relative to those of one or more of the biofuel crops considered. The required percentage improvement in food crop yields is worked to offset the acreage loss.

Keywords**—**Acreage response function, biofuel, food security, sustainable development

I. Introduction

BIOFUELS have emerged as an alternative and greener source of energy worldwide and promoting biofuels for energy security is one among the energy policy choices in India. While meeting energy needs for transportation and other developmental works creates an option for large scale production of biofuels, the prospect of producing biofuels from farm-generated feedstock as an alternative energy source to blend with fossil fuel must be weighed against possible trade-offs like land diversion from food. Promotion of biofuel may contribute to sustainable growth, agricultural development and to higher farm income. On the other hand, it will affect both, oil market and food production by providing substitutes. The country still has to formulate a final action plan yet to deal with the increasing energy needs but bio based fuels as a means to fulfill energy needs will be acceptable only if they do not undermine the food security of the country. In India, food security is a basic development policy concern and feeding the large population is policy priority.

If India promotes biofuel crop cultivation to reduce the burden of importing fossil fuel and curb GHG emission, the biofuel crops are likely to compete for the limited agricultural land available for supporting food crops unless crop yield rates are substantially improved. As a result of acreage shift across crops any price increase in energy market will affect food production in the country. The paper analyzes the impact of large scale production of biofuel from three field crops, namely sugarcane, maize and soybean, on acreage under food-grains, cereals, pulses and oilseeds due to possible agricultural land diversion at the aggregate country level. In the initial part of work, the importance of prices in farmer's decision making is discussed. The estimation of expected harvest prices is made assuming rationality of farmers. Using these estimated prices, acreage response functions are estimated econometrically. Finally, the marginal effects on acreage of food crops due to unit price increase of a substitute potential biofuel crop are calculated.

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II. Food vs Energy Security

To achieve a planned transition to sustainable energy sources, decisions about production of food crops as biofuel inevitable raise the issue of food security. The substitution of land and product use patterns may have direct impact on prices of food crops. The use of potential biofuel crops as feedstock can further reduce food availability as they are alternative sources of human and animal nutrition and are essential in human diet. India has a population of about 1.25 billion with 269.3 million living under the poverty line in 2011-12, as estimated by Tendulkar committee using Mixed Reference Period method [1] and the demand for food grains by year 2020 to 2021 is varying around 253.2 to 296.6 million tonnes in various studies [2]-[5]. As a leading developing economy, the country's energy demand has increased in order to achieve the desired growth. The government's work plans to protect the domestic food security can be well supported through promotional programmes to enhance crop productivity and extension of farm mechanization in underdeveloped and hill states.

Developing countries like India face the challenges of meeting energy demand for powering high economic growth. The growth should be sustainable while complying with international norms and minimizing natural hazards that global warming may cause. Fossil fuels are the exhaustible and fast depleting sources of energy and presently fulfilling about 87% of world's total energy requirements. Research in various discipline has is started placing increased focus on options other than fossil fuels variously described by 'alternative', 'non-conventional' and 'renewable' energy. The energy consumption in India is only 613 kg. of oil equivalent per capita in year 2011 which is less than one-third to china and nearly one-twelfth to USA. Promoting biofuels as one among the available renewable alternatives can serve to strengthen growth as well as to address the environmental concerns. For the emerging economies already constrained by their access to energy, a further challenge came from the Kyoto Protocol signed in Japan and adopted in 1997 to reduce Green House Gases [GHG] emissions from economic activities. At the same time promotion of bio-energy feedstock can also potentially create new markets for agro-commodities that in turn will generate more employment in agriculture and agro-processing and enhance farm incomes.

III.Effect of Prices on Food Acreage

India being one of the major producer countries for many of the food crops and also a large consumer, its agricultural policy and resultant production levels have direct impacts on the world food market prices. Shifts in production, domestic demand, trade and public procurement policies influence movement of prices. The prices of energy and biofuels, population trends, grain stocks, commodity markets and weather effects also contribute to high prices and volatility [6]. The nature of food crop prices can be understood through its past behavior and can be predicted in terms of their expected values from a predictive model and the deviation around the dynamic mean that comes out as the expected volatility. Crop prices help in farmer's decision making in sowing crop area but their expectations about the prices actually play a role in farmer's rational expectations because the harvest period prices are usually unknown at sowing times. The prices for different crops also fluctuate due to dynamic forces in the economy. For rational farmers, expectations may be based on past experience combined with current news.

IV.Data and Methodology

Econometric acreage response functions are modeled to identify the crops the acreage of which will be sensitive to the promotion of sugarcane, maize and soybean as biofuel crops. The present study Consider major kharif crops – rice as food-grain, great millet, pearl millet and finger millet as cereals, pigeon pea, green gram and black gram as pulses and groundnut as oilseed in the analysis.

A.Data Use

Wholesale prices as the average of the major markets in producer states of India are used to estimate prices for the period 1975 to the latest year 2013 for each of the food as well as biofuel crops. Major producer states are selected based on the average share in the crop area during 2001 to 2010 for each selected crop. Data with monthly frequency is preferred as crop prices often vary with season and each crop has different harvesting cycles. The exogenous variables include the price index of high speed diesel (HSD) used to capture the role of an extraneous source of inflation. Crop specific policy dummy variables are used to work out the effect of government policies in the price variation. Promotion of production through technology diffusion indicated as TMO - Technology Mission on Oilseeds initiated in 1980, TMOP- Technology Mission on Oilseeds and Pulses initiated in 1990, ISOPOM- Integrated Scheme on Pulses, Oilseeds and Maize initiated in 1995 and AMDP-Accelerated Maize development Programme initiated in 2001 is considered. The month dummies are used to find the effect of seasonality on price and price volatility of months. The effect of time trend and the crop-wise dummies for future trading -started since 2003 onwards is also utilized in all the price equations.

For the acreage response function estimation, annual time series data is collected for selected food crops for the period 1985 to 2013. The major producer states are considered for each selected crop in which positive effect of prices is reported on acreage of crops. The wholesale price of food crops is deflated by the substitute biofuel crop price prevalent during the harvesting period. Minimum Support Prices (MSP) is also considered if the government procures the crop. Revenue of crop from a hectare of land is alternatively considered to account for yield dynamics due to technology. Monthly rainfall, usually for June and July months, or average rainfall of these months, irrigation use by type, fertilizer use, month wise minimum and maximum temperature, if significantly affects crop, are also used as exogenous variables wherever found significant.

B.Data Sources

Wholesale prices are taken from- Agricultural Prices in India and Agricultural Situation in India, both, are published by Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture (MoA), Government of India (GoI). It also provides data for MSP. Computation of data for the missing month/year is performed using wholesale price index, a database of the Office of the Economic Adviser, Ministry of Commerce & Industry, GoI. Data for crop area and yield is taken from Official sources such as Area and Production of Principal crops in India, MoA, and from Agricultural Statistics at a Glance. Data on fertilizer is collected from Fertilizer statistics a database of The Fertilizer Association of India and from Water and related statistics. Data on temperature is collected from Indian Meteorological Department and India Water Portal. Indian Meteorological Department also provides data on met-wise rainfall which is converted to state-wise rainfall using net sown area as weights.

V.Price and Acreage Estimation

A.Price Estimation

A list of models is available in literature to deal with time series data, starting with the simple time-trend models and its decomposition from seasonal and cyclical components to further development of the ARMA-ARIMA type models of the Box-Jenkins family. Keeping in view the importance of analyzing volatility patterns in price data and its implications in economy, model based time series methods based GARCH/ ARCH is preferred in estimation and for forecasting the agricultural prices. The ARCH models were introduced by R.F. Engle in 1982 [7] and further generalized as GARCH (Generalized ARCH) by Bollerslev in 1986 [8]. Widely preferred in econometrics, many variations of the model distinguish between positive and negative past shocks in which conditional variance tends to respond asymmetrically the use of dummy variables [9]-[12]. Some higher order GARCH (q, p) models or the Exponential-GARCH (EGARCH) model allowing non-linearity, asymmetry and a restriction on the estimated conditional variance to be positive [8], [13], [14]. Among various time series models ARIMA and GARCH methods are also popularly used to measure time varying inflation expectations [15]. The variability in commodity prices has been linked with their traded volumes [16], [17] and whether signing of WTO agreement has made prices of food and commercial crop more variable has drawn interest [12].

The GARCH (q, p) model has a general notation as (1) and (2) where i and j are lags up to m and n

$$Y_t = \sum \alpha_i Y_{t-i} + \sum \beta_j Z_{t-j} + \varepsilon_t \ldots \quad (1)$$

$$\sigma_t^2 = m + \sum_{i=1}^{q} a_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} b_j \sigma_{t-j}^2 + \sum \gamma_i Z_i \ldots \quad (2)$$

where Y_t is the dependent variable is a function of its own lagged values, the exogenous variable Z and an error term ε. The conditional variance equation of the model as a function of three terms, the mean (m), news about volatility from the previous period, measured as the lag of the squared residual from the mean equation: ε_{t-1}^2 (the ARCH term) and last period's forecast variance: σ_{t-1}^2 (the GARCH term). Based on above specifications the model used for price estimation is:

$$P_t = f\,(P_{t-l}, Dm, t, D_{HS}, D_P, D_D, D_{FT}, e_t) \ldots \quad (3)$$

where P_t is the monthly price (t=1, 2,…n, where n is sample size), differenced if necessary to obtain stationarity, P_{t-l} is the lagged price of lth lag, i.e. l=1,2,…,m, and Z is any exogenous or dummy variable includes Dm, represents the month dummies (i.e. m = 1, 2, …, 11) with December month as base, t, the time trend (t = 1, 2,…., n replicates n months of the sample period), D_{HS} being high speed diesel price index series based on 2004-05 base differenced according with the dependent variable being explained and the D_P representing the policy dummies used for crop specific cases. The drought effect is considered by D_D for years 1979, 1987, 2002, 2009 and 2012. D_{FT} is future trade dummy used for the specific crop for which future trading is initiated and e_t is the error term.

Initially, the price data is checked for stationary. To check the presence of trend and intercept while choosing the specifications and to obtain the order of differencing the ADF test is adopted. The lag lengths are decided with reference to the Akaike information criterion (AIC) and the Schwarz based criterion (SBC). We estimated the model for period 1975 to 2013 and the final model specification is selected as GARCH/ARCH or Least Square Method, whatever specifications suggested based on diagnostic checks for the significance of the relevant statistics such as z-statistics, S.E. of regression, AIC, SBC, Durbin-Watson statistics. The model is also checked for its in-sample errors in estimation and post-sample forecast accuracy.

B.Acreage Response

Expected harvest month prices or revenue estimated by price model equations (3) are used in acreage equations. We adopted the Nerlovian approach using the lagged area as a dynamic effect. The Nerlovian framework incorporating the adaptive expectations hypothesis and partial adjustment of acreage [18] has been most dominant influence in the literature. Methodological developments further enriched the subject [19]-[25] providing alternative ways of modeling supply and price and merging theoretical and empirical methods. These empirical models varied in their specifications of exogenous variables and assumptions about expectation families. Applications of supply modeling are found in Indian agriculture [24], [25]. The estimated prices are substituted in the crop specific area equations as an expected economic variable along with other possible exogenous effects.

The structural model for the acreage response is given as:

$$A_t = f\,(A_{t-1}, P_t^e, Rf, I, F, D_t, e_t) \ldots \quad (4)$$

where A_t is area under the crop as dependent variable, A_{t-1} is the lag area, P_t^e is expected price is unknown and requires presumptive specification, Rf is the rainfall for significant months or average of significant month rainfall, I is the irrigation by type i.e. well, tank, canal, total (NIA). D_t is dummy for month wise temperature for unusually high min. and max. temperature compared to long term normal and e_t is the residual effect. Interaction of rainfall and irrigation is also used as variable if have any significant effect. The time period of analysis is 1985 to 2013. Likewise, in price estimation, the specification for the model is selected on the basis of diagnostic checks such as standard errors of regression, AIC, SBC, test of t-statistics and the coefficients are further diagnosed for the signs and significance. Constrains such as non-negativity of the price coefficient and robustness across sample sizes are also checked for satisfaction of required conditions to the model and normality test of the residuals is performed. The price coefficients from the estimated state-wise acreage response equations (4) for food crops in the selected states using three alternates as potential biofuels are presented in Tables I-III.

The effect of price increase is found significant impact on food crop acreages, more dominantly on pulses and oilseeds. Rice acreages in states are also affected by price increase of biofuel crops, although in % term less impact is noticed. The impact of prices coefficients is found less for cereal crops. Prices increase of substitute biofuel crops maize and soybean have less impact on cereals finger millet and pearl millet whereas relative price coefficients of great millet and finger millet are also not much significant for substitute biofuel sugarcane. Sugarcane and maize are not found to significantly substitute any of the crops grown in state Uttar Pradesh. Similar effect is noticed in Rajasthan except pulses crop green gram is found significant impact due to maize and oilseeds groundnut for sugarcane. The production of soybean in India is concentrated to few major states only.

TABLE I
COEFFICIENT OF RELATIVE PRICE: MAIZE AS SUBSTITUTE BIOFUEL

	Food grain and cereals			
States	Rice	Great millet	Finger millet	Pearl millet
Andhra P.	140.8***		11.8*	
Bihar	407.9**			
Gujarat	51.0*			102.3*
Haryana	91.1**			1505.5
Karnataka	35.0***	88.3***	170.8**	139.8*
Madhya P.	323.0*	330.0***		
Maharasht	279.2***	276.6**	33.4	
Orissa	527.1***			
Punjab	52.9**			
Rajasthan				839.8
Tamil Nadu	586.6**	133.4***	14.4*	
Uttar P.	225.6**		10.5	
West Bengal	352.3***			
		Pulses		Oilseed
States	Pigeon pea	Green gram	Black gram	Groundnut
Andhra P.	178.2**	15.7*	7.4***	99.8*
Bihar	23.4**		8.6*	
Gujarat	21.5**	24.0*	12.8***	40.1
Haryana				
Karnataka	68.0**	85.9*	11.0***	113.2*
Madhya P.	62.4***	3.3***	45.3***	36.5***
Maharasht	78.3***	85.4*	19.2**	17.7**
Orissa	5.7**	23.1*	39.0*	
Punjab				
Rajasthan		101.9***	24.3*	25.0*
Tamil Nadu				15.9*
Uttar P.	22.6*		37.0*	
West Bengal				

Note: ***, ** and * indicates significance of t-statistics under 1%, 5% and 10%.

TABLE II
COEFFICIENT OF RELATIVE PRICE: SOYBEAN AS SUBSTITUTE BIOFUEL

	Food grain and cereals			
States	Rice	Great millet	Finger millet	Pearl millet
Madhya P.		222.6*		
Maharashtra	16.2**	251.9*	11.9	
Rajasthan		357.7**		1098.2
		Pulses		Oilseed
States	Pigeon pea	Green gram	Black gram	Groundnut
Madhya P.	60.0**	7.2*	74.6***	27.3*
Maharashtra	73.2**	42.4	29.8**	9.0*
Rajasthan		186.7**	61.9**	

Note: ***, ** and * indicates significance of t-statistics under 1%, 5% and 10%.

C.Marginal Effects on Food Crop Acreages

The marginal effects on food crop acreage are calculated using the coefficients of relative price or revenue, as specified, in the acreage response equations (4) and then the aggregate marginal effect on area in the selected states, as an indicative effect at all India level is calculated. The net effect on particular food crop area $\boldsymbol{A_i^F}$ (i = 1, 2, …, m; m = no. of food crops) with price $\boldsymbol{P_i^F}$ grown in major producer states S_j (j = 1, 2,…, n; n = no. of food crop producer states) for a price rise in particular substitute biofuel crop with price $\boldsymbol{P_k^B}$ (k = 1, 2, 3; k = considered three potential biofuels) is given as:

$$\Delta A_i^F = \sum_{S_j=1}^{n}\left\{(-)\alpha_{ik}.\left(\frac{P_i^F}{P_k^{B^2}}\right)\Delta(P_k^B)\right\}\ldots \qquad (5)$$

In which α_{ik} is the coefficient of relative price variable (P_i^F/P_k^B) with respect to k[th] substitute potential biofuel. When the relative price is reported in terms of relative revenue the net marginal effect is derived as:

$$\Delta A_{F_i} = \sum_{S_j=1}^{n}\left\{(-)\alpha_{ik}.\left(\frac{P_i^F}{P_k^{B^2}}\right).\left(\frac{Y_i^F}{Y_k^B}\right).\Delta(P_k^B)\right\}\ldots(6)$$

The aggregate level effect, sum of the states included in analysis, on acreage of food crops simulated for the year 2013 due to unit price increase of potential biofuels is reported in Table IV.

TABLE III
COEFFICIENT OF RELATIVE PRICE: SUGARCANE AS SUBSTITUTE BIOFUEL

	Food grain and cereals			
States	Rice	Great millet	Finger millet	Pearl millet
Andhra P.	15310.6**		21	
Bihar	568.9			
Gujarat	8.0*			26.7*
Haryana	521.0***			341.6**
Karnataka	4.9**	102.2*	24.5**	200.1**
Madhya P.	42.9*	3565		
Maharashtra		346.0*	31.8*	
Orissa	208.3**			
Punjab	310.1*			
Rajasthan		376.2		33.2
Tamil Nadu			4.9*	
Uttar P.	1112.3		37	
		Pulses		Oilseed
States	Pigeon pea	Green gram	Black gram	Groundnut
Andhra P.	8213.2**	36.2**	0.8***	434.1*
Bihar	2.5*		480.1**	
Gujarat	74.6***	198.6**	1336.1*	378.8**
Haryana				
Karnataka	167.6***	71.2	15.5***	22.6***
Madhya P.	8.7***	7.4***	75.8***	40.5*
Maharashtra	7.3*	7.5***	3.1***	1.1*
Orissa	11.0*	141.3*	340.4***	
Punjab				
Rajasthan		166.9	3231.4*	119.4***
Tamil Nadu				3.8*
Uttar P.	1.2		3.9	

Note: ***, ** and * indicates significance of t-statistics under 1%, 5% and 10%.

VI.RESULTS AND CONCLUSION

Aggregation at the national level indicates that the effect on acreage of food grain–rice is less than 1%, due to price increases of maize crop and it is about 2%, due to sugarcane price increases but in terms of actual area declines. It may be significant because the gross cropped area of crop is significantly high compare to that of selected other food crops. Area under cereal is affected by 2% to 5% due to maize price hike and impact of sugarcane price rise is found dominantly high, especially on the cereal crop finger millet by nearly 14%. Acreage of protein crops (pulses) is affected strongly by price induced shifts towards biofuel crop sugarcane by 4.5% to 5.5%. India, already lacking in production of pulses and the current need is fulfilled through import. Acreage of oilseed crop -groundnut due to price rise of sugarcane is expected to affect by above 7%. Maize prices has less effect on food crop acreage compared to that of sugarcane and effect of its price increase is concentrate to cereals acreage, about 2% to 5%. Production of soybean in concentrated to three major states, namely Madhya Pradesh, Maharashtra and Rajasthan, together they constitute above 90 % of crop area, so the effect due to increase in prices of soybean is less than 1 % at aggregate level majorly on pulses and cereals.

TABLE IV
EFFECT ON ACREAGE OF FOOD CROPS DUE TO INCREASE IN SUBSTITUTE BIOFUEL CROP PRICES BY RS.1000/TONNE

Crop	Adjusted aggregate acreage (ml. h.)	Marginal effect on acreage (ml. h.)	Decline in acreage (%)	Decline inprod. (%)	Yield required (offsetting area loss) (%)
Substitute biofuel crop: Maize					
Rice	36.17	0.26	0.72	0.7	0.73
Great millet	1.17	0.06	4.79	4.93	5.03
Pearl millet	5.63	0.18	3.13	4.91	3.23
Fingr millet	1.02	0.02	2.35	2.27	2.4
Pigeon pea	3.76	0.07	1.86	1.87	1.89
Green gram	2.17	0.05	2.17	2.07	2.21
Black gram	2.12	0.04	1.77	1.76	1.8
Groundnut	4.42	0.05	1.08	0.72	1.09
Substitute biofuel crop: Sugarcane					
Rice	28.5	0.61	2.1	2.21	2.14
Great millet	1.61	0.01	0.71	0.71	0.71
Pearl millet	5.64	0.17	2.99	3.68	3.09
Fingr millet	0.9	0.14	13.84	14.7	16.06
Pigeon pea	3.63	0.21	5.37	5.48	5.67
Green gram	2.12	0.1	4.62	5.25	4.84
Black gram	2.06	0.1	4.52	4.76	4.74
Groundnut	4.15	0.32	7.16	4.74	7.71
Substitute biofuel crop: Soybean					
Rice	1.51	0.0005	0.03	0.03	0.03
Great millet	1.45	0.011	0.76	0.76	0.77
Pearl millet	4.42	0.013	0.28	0.28	0.28
Fingr millet	0.1	0.001	0.5	0.5	0.5
Pigeon pea	1.65	0.006	0.34	0.32	0.34
Green gram	1.54	0.01	0.68	0.65	0.68
Black gram	1.2	0.006	0.46	0.45	0.46
Groundnut	0.47	0.002	0.35	0.34	0.36

Note: Adjusted aggregate acreage is total area cropped under selected crop (sum of area under all selected states under study) – marginal area (sum of crop area declined due to unit price increase of potential biofuel crops in selected states). adjusted aggregate acreage varying for different substitute biofuels because selected states under the crop are also varying based on signs and significance of price or revenue relatives.

Results at aggregate level indicate that nearly identical amount of yield is required to increase, nearly equals to the % loss of food crop acreage, to maintain the same level of production of food crops due to promotion of biofuel crops. The aggregate yield at country level is calculated as the weighted average of state level results. Area under different food crops is found responsive to their prices relative to the biofuel crops considered under study. If India promotes biofuels it may affect production of cereals, pulses and oilseeds in the country.

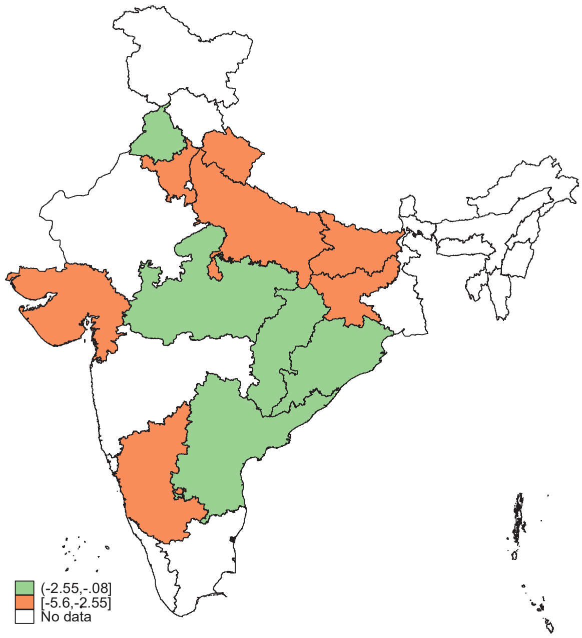

Fig. 1 (a) Rice – Acreage loss

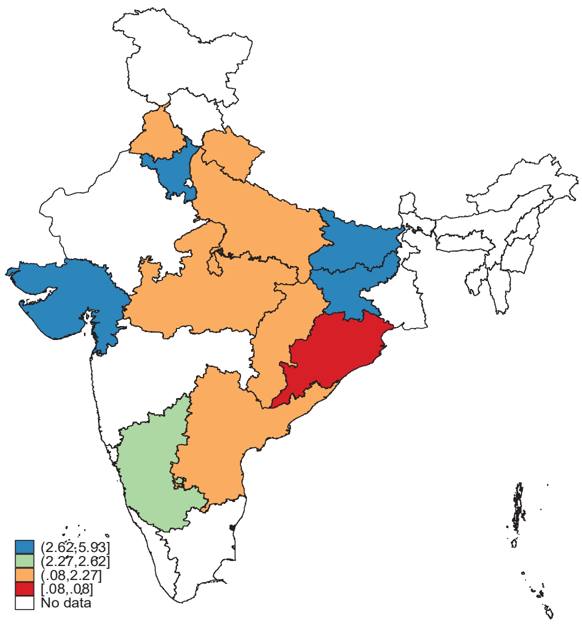

Fig. 1 (b) Rice – desired yield improvement

Fig. 1 Acreage loss of food crop and required yield improvement (in %) to offset production loss due to unit price increase of sugarcane

APPENDIX

TABLE V
REGRESSION RESULTS (COEFFICIENTS) FOOD CROPS: SUBSTITUTE BIOFUEL CROPS ARE MAIZE AND SUGARCANE

Crop	State	Constant	A(-1)	Pri//Rev	rf1	rf2
Potential biofuel crop maize as substitute crop						
Rice	TamilN.	-1346***	-0.1	586.6**	26***	-0.2**
Finger m	Mahara.	127***	0.3*	33.4	0.1***	0.4
Blakk gr	Rajasth.	82.1**	0.4**	24.3*	0.5**	
Groundn	Karnat.	127.7	0.5***	113.2*	0.6	0.5***
Potential biofuel crop sugarcane as substitute crop						
Rice	Haryana	-389.7***	1.1***	521.0***	0.5***	
Finger m	Karnat.	981***	0.1	24.5**	-0.8*	
Black gr	Orissa	148***	-0.7***	340.4***	-0.3***	
Groundn	Karnat.	61.6	0.2**	22.6***	1.2***	0.5***
Crop	**State**	**Irrig.**	**Int1**	**Int2**	**Trend**	**AR**
Potential biofuel crop maize as substitute crop						
Rice	Tamil N.	2.8***	-0.02**	0.002*		
Finger m	Mahara.		-0.01**		-3***	
Black gr	Rajast.	-0.03	-.01***			-.6***
Groundn	Karnat.		-0.01**	-0.01***		-0.3**
Potential biofuel crop sugarcane as substitute crop						
Rice	Haryana		0.001**			
Finger mil	Karnat.	-0.3***	0.01***			
Black gr	Orissa	0.5***				
Groundn	Karnat.		-.01***			

Note: A(-1) is area lag term, Rel. Pri./Rev. is Relative prices and revenue and chosen based on significance (price of crop is either harvest price or the MSP), rf1and rf2 indicates different months or monthly average combinations of rainfall, Irrig. is irrigation used by type of source and Int1 and Int2 indicates interaction terms for different combinations of monthly (current as well as lag) or average seasonal rainfalls and irrigation (by type) terms. ***, ** and * indicates significance of t-statistics under 1%, 5% and 10% level.

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