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Did technological intervention help to spare land from agriculture: evidence from post liberalisation India

India has witnessed fairly high economic growth since economic liberalisation started in 1991. However, agriculture has remained excluded from the growth experienced in other economic sectors. This growth paradox has serious implications for the agricultural land use pattern. This study uses the Environmental Kuznets Curve hypothesis to examine the impact of agricultural technology and economic development on agricultural land expansion in India. Panel data regression is performed on an unbalanced sample covering information from 25 Indian states for the period 1990 to 2008. Our results suggest a nonlinear (N shaped) relationship between agricultural land expansion and Net State Domestic Product (NSDP) per capita. Two incomes turning points, showing the level of NSDP per capita at which inflection between agricultural land expansion and NSDP per capita takes place, occur at INR 20986.14 and INR 42855.10 respectively. We find mixed results as far as the impact of technological variables on agricultural land expansion is concerned. The study concludes that rapid economic growth in the post liberalisation period has failed to reverse agricultural land expansion in India.

Keywords: EKC, Agricultural technology, Javon's Paradox

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Introduction

One of the secondary consequences of economic transition of a country is a change in its land use pattern. A number of studies analysed *land use change* to identify the factors explaining it. These studies imputed population (Cropper and Griffith, 1994), agricultural technology (Kumar and Agarwal, 2003), law and governance (Barbier, 2004), international trade (Barbier, 2001), urbanisation (Hasse and Lathrop, 2003), economic growth (Dinda, 2004) and climate change (Lambin *et al*., 2001) as major factors explaining land use change. Agricultural land expansion remains an important factor determining land use change across countries. Given the fixed supply of land, agricultural land expansion comes at the cost of a declining area under forests, pastures and other natural habitats. It is widely believed that technology and economic development help to reverse agriculture-driven land use change (see Barbier *et al*., 2010). However, declining quality of agricultural resources due to increased intensification (Maston *et al*., 1997; Tilman *et al*., 2002) and climate change (Lambin *et al*., 2001) are environmental forces that can limit the potential of technology to reverse agricultural land expansion.

Assuming forest and agriculture to be competing land use activities, Barbier (2001) extended the Environmental Kuznets Curve (EKC) hypothesis[1] to study agricultural land expansion and factors explaining it. The changing structure of economic activities (Dinda, 2004), in general, and technological intervention in agriculture (Cropper and Griffith, 1994; Kumar and Agarwal, 2003), in particular, are two factors in any economy that can justify considering the EKC as the basis for agricultural land expansion. However, the dynamics between agricultural land expansion and development depend on complex interactions between agricultural technology and other complementary (environment, policies, institutions) factors (Figure 1). Policies and institutions play major roles in determining the impact of technology on agricultural land expansion. Lewandrowski *et al*. (1997), using information from European and Asian countries, showed that agricultural pricing policies had significant impacts on agricultural land expansion. Studying the determinants of agricultural land expansion in tropical countries, Barbier (2004) found institutions and governance playing major roles in explaining agricultural land expansion.

From the literature it can be argued that the shape of the EKC for agricultural land expansion will change with changing technological and institutional possibilities (Figure 1). The uppermost curve represents the shape of the EKC for agricultural expansion under traditional agriculture. Low yield and long fallows which are attributes of traditional agriculture force farmers to bring additional land into agriculture. However, technological inputs, by increasing crop yield, help to reverse agricultural land expansion at relatively low levels of economic development (curve 2). Furthermore, agricultural technology, by augmenting land, also minimises the extent of agricultural land expansion. This phenomenon is reflected by the lowering of the EKC peak in Figure 1. Furthermore, adequate institutional support and resource conservation policies further help farmers to adopt technology in a proper way. This scenario is represented by curve 3 in Figure 1.

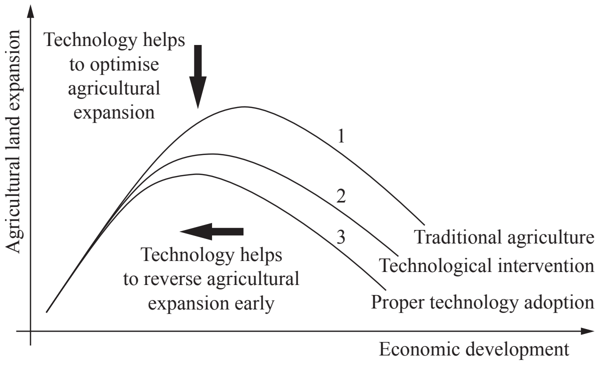

Figure 1: EKC for agricultural land expansion under various technological scenarios.

Source: own composition

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[1] EKC hypothesis suggests that in the initial phase of development, environmental quality deteriorates but after attaining a certain threshold level of per capita income, environmental quality starts to improve.

Table 1: Growth rate of land use categories in India (1950-51 to 2008-09) (per cent per year).

Land use	1950-51 to 1965-66	1966-67 to 1979-80	1980-81 to 1989-90	1990-91 to 1999-00	1996-97 to 2008-09	2000-01 to 2008-09
Forest	1.98 (7.42)**	0.51 (8.99)**	-0.04 (-0.73)	0.27 (10.3)**	0.08 (5.66)**	0.02 (1.97)*
Pasture	4.51 (7.97)**	-0.99 (11.20)**	-0.53 (5.36)**	-0.53 (5.83)**	11.8 (5.02)**	18.10 (3.80)**
Net cultivated area	0.94 (11.67)**	0.17 (1.94)**	-0.12 (-0.59)	-0.05 (-1.06)	-0.14 (-0.87)	0.18 (0.50)
Gross cultivated area	1.17 (10.48)**	0.61 (5.52)**	0.37 (1.61)	0.39 (4.12)**	0.21 (0.90)	0.92 (2.19)*
Cropping intensity	0.23 (6.07)**	0.45 (14.20)**	0.49 (7.53)**	0.44 (8.44)**	0.35 (4.01)**	0.74 (8.96)**
Net irrigated area	1.73 (31.90)**	2.73 (26.4)**	1.77 (7.64)**	2.02 (20.9)**	1.13 (3.98)**	2.20 (5.46)**

Notes: Compound annual growth rates are computed using a log linear model. t test is used to examine statistical significance of slope coefficient of trend line fit over data. Figures in parenthesis are t values. *P<0.05 and **P<0.01.
Source: DES (2011).

Heterogeneous policy and institutional environments across countries make it difficult to use the EKC hypothesis as a policy tool to study agricultural land expansion. In view of the lack of information on policy and institutions across countries, it is appropriate to apply the EKC hypothesis for studying agricultural land expansion in a region with homogenous agricultural policy and institutional structure. India possesses the world's second largest agricultural sector in terms of land area. It adopted agricultural technology in the mid 1960s and became a signatory of GATT in 1991. Despite liberalisation of other economic activities, agriculture in India is still highly regulated by government agencies. Governmental regulation of agriculture creates a homogenous policy environment across Indian states. This aspect of Indian agriculture provides an ideal environment for using EKC hypothesis to study agricultural land expansion across Indian states.

Unlike in tropical countries, agricultural (net cultivated area) expansion in India took place at the cost of other rural lands instead of forests (Table 1)[2]. Prior to technological intervention in agriculture, popularly known as the *Green Revolution* (1965-66), net cultivated area in India grew at a rate of 0.94 per cent per annum. The rate of growth in net cultivated area declined during 1966-67 to 1979-80 to a moderate 0.17 per cent per year, and was insignificant after 1980-81.

Technological intervention in agriculture, by increasing the yield per hectare of food grains, played an important role in restricting the growth of the net cultivated area in India. The contribution of land (area effect) in food grain production became irrelevant in the period from 1979-80 to 1989-90 (Table 2). It revived marginally during the years 1989-90 to 1999-2000 but again vanished for the rest of the period. This evidence suggests that technology (irrigation, fertilisers and high yielding varieties, HYV) facilitated land use diversification[3] without causing further expansion of net cultivated area.

The GDP growth rate in India gained momentum after the liberalisation of the economy started in 1991. However, apart from a short period of time (1990-91 to 1996-97) agricultural growth failed to attain any momentum. During the period from 1990-91 to 1996-1997, the Indian economy grew at a rate of 5.84 per cent per year. After the structural adjustment programme (SAP) ended, the growth rate of the economy further increased and reached 7.12 per cent per year during the period from 1997-98 to 2008-09. For the same reference periods, growth rate of agriculture was 3.58 and 2.21 per cent per year (Table 3). These statistics indicate that technology supported land diversification in agriculture went hand in hand with overall economic growth in post liberalisation India. However, whether agricultural technology and rapid economic growth succeeded in reversing agricultural land expansion in post reform India is still an unexplored research question. This study is an attempt to answer this question by examining the impact of economic development

Table 2: Sources of food grain production growth in India (million tonnes, 1950-51 to 2008-09).

Period	Change in production	Yield effect	Area effect	Interaction effect
1950-51 to 1965-66	21.53	10.35 (48.09)	9.28 (43.12)	1.89 (8.78)
1966-67 to 1979-80	35.47	26.78 (75.52)	6.38 (17.98)	2.30 (6.49)
1980-81 to 1989-90	41.45	41.31 (99.67)	0.10 (0.24)	0.032 (0.078)
1990-91 to 1999-00	33.41	41.44 (124.20)	-6.54 (-19.59)	-1.53 (-4.60)
1999-00 to 2008-09	37.66	34.23 (90.96)	2.89 (7.69)	0.50 (1.33)
1997-98 to 2008-09	42.21	44.14 (104.60)	-1.57 (-3.74)	-0.36 (-0.85)

Notes: The formula used for decomposition is $(P_1-P_0)=A_0(Y_1-Y_0)+Y_0(A_1-A_0)+(Y_1-Y_0)(A_1-A_0)$, where (P_1-P_0) is change in production. The first term on the right hand side shows yield effect, second term shows area effect and the last one is interaction of yield and area change on food grain production. Figures in parentheses are contributions in percentage.
Source: DES (2010).

Table 3: Growth of Gross Domestic Product (GDP) in India (per cent per year).

Period	GDP	GDP agriculture and allied activities	GDP agriculture
1950-51 to 1965-66	3.84 (-35.56)	2.27 (-10.46)	2.33 (-8.82)
1966-67 to 1979-80	3.59 (-17.6)	2.43 (-6.1)	2.61 (-5.95)
1980-81 to 1989-90	5.17 (-25.6)	2.97 (-6.82)	3.09 (-6.67)
1990-91 to 1996-97	5.84 (-14.1)	3.58 (-7.15)	3.58 (-6.68)
1997-98 to 2009-10	7.12 (-25.73)	3.08 (-6.4)	2.21 (-3.77)
2000-01 to 2009-10	7.98 (-26.83)	4.02 (-5.3)	2.95 (2.90*)

Notes: Compound annual growth rates are computed using a log linear model. t test is used to examine statistical significance of slope coefficient of trend line fit over data. Figures in parenthesis are t statistic values. All t values except one are significant at P<0.01 level. *P<0.05.
Source: RBI (2012)

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[2] The Indian land use classification system considers 'pasture' and 'agricultural land' as two different land use categories. Agricultural land includes net cultivated area, cultivable waste land and land under miscellaneous tree crops. Net cultivated (sown) area, the largest and actively growing component in agricultural land category, includes land under crops and orchards. Net cultivated area being the active component is the subject of our interest in this study.

[3] Land diversification, here, indicates increasing area under non food grain crops.

and technology on agricultural land expansion in post liberalisation India[4].

EKC for agricultural land expansion: a theoretical interpretation

We use the decomposition framework given in Angelson (2010) to derive the relationship between agricultural land, development and technology. We start by assuming an economy producing a homogenous agricultural output called ‘food’. Food demand (Q^d_{it}) in any country i at time t will be equal to its supply (Q^S_{it}),

$$Q^d_{it} = Q^S_{it} \tag{1}$$

For country i year t, supply of food can be defined as the sum of domestic production (Q^p_{it}) and net exports (Q^T_{it}) of food from the country.

$$Q^c_{it} = Q^p_{it} \pm Q^T_{it} \tag{2}$$

Food consumption in country i at time t can be given by multiplying per capita consumption of food (q^c_{it}) with the population (M_{it}) of the country.

$$Q^c_{it} = q^c_{it} M_{it} \tag{3}$$

Using back substitution, we can expand Q^c_{it} in following manner,

$$Q^c_{it} = \frac{Q^c_{it}}{Q^p_{it}} \times \frac{Q^p_{it}}{L^g_{it}} \times \frac{L^g_{it}}{L^n_{it}} \times L^n_{it} \tag{4}$$

where L^g_{it} is *effective agricultural land* (gross cultivated area) and L^n_{it} is agricultural land[5].

The ratio of total production and effective agricultural land $\left(\frac{Q^p_{it}}{L^g_{it}}\right)$ gives food production per unit of effective agricultural land (yield), a measure of the state of technology. Similarly $\left(\frac{L^g_{it}}{L^n_{it}}\right)$ is another technology variable that measures technology supported *land augmentation* (cropping intensity). Transferring equation (3) into equation (4) gives:

$$q^c_{it} \times M_{it} = \frac{Q^p_{it} \pm Q^T_{it}}{Q^p_{it}} \times y_{it} \times I_{it} \times L^n_{it} \tag{5}$$

where y_{it} and I_{it} stands for yield and cropping intensity. The term $\left(\frac{Q^p_{it} \pm Q^T_{it}}{Q^p_{it}}\right)$ on the right hand side gives the extent of trade T_{it} that is necessary to fulfil the food demand in a country. Taking the log of equation (5) and rearranging it in terms of agricultural land gives:

$$\log L^n_{it} = \log q^c_{it} + \log M_{it} \mp \log T_{it} - \log y_{it} - \log I_{it} \tag{6}$$

Differentiating equation (6) with respect to time we get:

$$\hat{L}^n_{it} = \hat{q}^c_{it} + \hat{M}_{it} \mp \hat{T}^A_{it} - \hat{y}_{it} - \hat{I}_{it} \tag{7}$$

In equation (7) each term is expressed in terms of annual change. Equation (7) suggests determinants of change in net cultivated area with their expected signs in an ideal framework. However; the expected direction of these variables in determining change in agricultural land depends on the nature of economic development in a region. Applying Engel’s income-consumption hypothesis, we can write per capita food consumption as a function of per capita income (z).

$$q^c_{it} = f(z_{it}) \tag{8}$$

Per capita income has a derived impact on agricultural inputs through demand for agricultural commodities (Lewandrowski *et al.*, 1997). Engel’s hypothesis suggests that the share of expenditure on food items starts to decline after reaching an income threshold. Joining the two statements, we can hypothesise that, keeping other factors constant, agricultural land expansion has a nonlinear relationship with income per capita. Economic growth is an equally important factor as it helps to absorb an increasing labour force and reduces the population pressure from agriculture. We have considered Net State Domestic Product (NSDP) per capita and growth in NSDP as proxies for per capita income and economic growth respectively.

Population is another factor that affects agricultural land expansion (Cropper and Griffith, 1994; Lewandrowski *et al.*, 1997; Barbier, 2001, 2003, 2004). Rapid population growth shifts the food demand curve upwards and causes price rise in the economy. Increasing prices of agricultural commodities along with subsidised inputs induces agricultural land expansion. The side effects of population growth on agriculture may be more severe if other sectors of the economy fail to provide employment to the growing labour force. We consider growth in population as an explanatory variable for econometric analysis.

Modern agricultural technology has twin effects on agricultural production. The introduction of HYV seeds increases crop yields and the external supply of nutrients and water ensures the multiple use of agricultural land in a crop year (land augmentation). Two variables, cropping intensity and growth in cereal yields, are included in the regression analysis to capture the effect of technology on agricultural land use. Increasing cropping intensity can help to relieve land from agriculture by increasing the supply of effective land. On the other hand, increasing cropping intensity and crop yield can be incentives for farmers to expand agricultural operations on new lands if agricultural inputs are subsidised and terms of trade are favourable to agriculture[6]. Assuming subsidised inputs as normal good, input subsidies induce reallocation of resources from subsidised inputs to other

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[4] We consider net cultivated area as a proxy for agricultural land. Hereafter, we use net cultivated area and agricultural land interchangeably.

[5] Effective agricultural land is defined as area under cultivation that can be used for growing more than one crop in a crop year i.e. gross cultivated area.

[6] This argument has quiet resemblance with ‘the Jevons paradox’. Jevons (1866) observed that technological improvements in 19th century England increased the efficiency of coal use. Owing to this gain in efficiency, consumption of coal in England increased instead of decreased.

inputs (price effect). In such a case subsidised technology, in general, increases the area under agricultural operations, especially in favour of those crops that are more profitable. However, the latter effect will not sustain in the long run as more farmers start producing these commodities and prices will eventually fall.

Rapid growth in yields under a free trade framework does not guarantee the release of land from agriculture. Rather, high growth in crop yields under a free trade arrangement provides farmers with an incentive to increase agricultural land to reap more income by exporting. In this case, annual change in yield (yield growth) should be positively related with agricultural land expansion. However, this conclusion is fairly simplistic and prices of agricultural commodities (Barbier and Burgess, 1992) also play a role in determining the impact of yield on agricultural land expansion. If prices of agricultural commodities are regulated in the domestic economy then agricultural expansion may or may not take place given the trade policy of the Government for food and related commodities.

In addition, there is an employment side of agricultural technology. If employment elasticity in the other sectors of the economy is low then increasing yields added with input subsidies provide an opportunity to increase income by expanding agricultural operations in new areas. EKC studies on land use change have incorporated yield as an explanatory variable to explain both deforestation (Koop and Tole, 1999) and agricultural land expansion (Barbier, 2001, 2004).

Methodology

We use secondary data compiled from various sources for studying agricultural land expansion (Table 4). The sample made for the EKC estimation includes information from 25 Indian states covering the period from 1991 to 2008. Contrary to Barbier (2004), who followed the World Bank's definition, we have considered net cultivated area as a proxy for agricultural land; however, we accepted Barbier's approach to defining agricultural land expansion. This choice of proxy suits our objective to study the response of farmers to technology and economic development. A three year moving average of net cultivated area is computed before constructing the dependent variable. This exercise helps us to remove wild yearly fluctuations in the data (Arahata, 2003). Regression analysis in the study employs panel data estimation methods using a reduced form specification of the EKC (equation 9) (see Stern, 2004).

On the basis of the discussion above, the following econometric specification of the EKC will be estimated:

$$
\begin{aligned}
AGEXP_{it} = \alpha_i + \beta_1 NSDPPC_{it} + \beta_2 NSDPPC_{it}^2 + \\
\beta_3 NSDPPC_{it}^3 + \beta_4 AGEXP_{i(t-1)} + \beta_5 EG_{it} + \\
\beta_6 POPG_{it} + \beta_7 CI_{it} + \beta_8 CI_{it}^2 + \beta_9 YLDG_{it} + \varepsilon_{it}
\end{aligned}
\tag{9}
$$

In the regression model given by equation (9), α is the time invariant intercept and ε is an error term, subscripts i and t stands for state and year. The definition and construction of variables in equation (9) is provided in Table 4.

Table 4: Definition and construction of the variables used in the econometric specification of the Environmental Kuznets Curve.

Variable	Notation	Definition	Data source
Agriculture expansion	AGEXP	$[\{A_{it} - A_{i\,(t-1)}\}/A_{it}]*100$ where, A_{it} is net cultivated area in state i at time t	CMIE (2012a)
Net State Domestic Product per capita	NSDPPC	in constant 1999-00 INR	RBI (2012)
Economic growth	EG	$[\{Y_{it} - Y_{i(t-1)}\}/Y_{i(t-1)}]*100$ where, Y_{it} is net state domestic product in state i at time t	RBI (2012)
Population growth	POPG	$[\{P_{it} - P_{i(t-1)}\}/P_{i(t-1)}]*100$ where, P_{it} is population in state i at time t	CMIE (2012b)
Cropping intensity	CI	(Gross cultivated area/ Net cultivated area)*100	CMIE (2012a)
Growth in cereals yield	YLDG	$[\{C_{it} - C_{i(t-1)}\}/C_{i(t-1)}]*100$ where, C_{it} is yield in state i at time t	CMIE (2012a)

Results

We start by exploring the summary statistics of the variables. The total sample size is 323 consisting of observations from 25 Indian states. Table 5 suggests very big differences among states for various development parameters used in the analysis. The correlation matrix (Table 6) shows that correlation among the right hand side variables is within tolerance limits.

Table 5: Summary statistics of the variables used in the econometric specification of the Environmental Kuznets Curve (323 observations).

Variable	Mean	Standard Deviation	Minimum	Maximum
AGEXP	0.38	1.21	-3.92	4.20
NSDPPC	18157	7315	6117	56021
EG	6.27	5.82	-12.01	32.18
POPG	1.96	1.15	-0.68	12.04
CI	139	23	104	189
YLDG	0.01	0.17	-0.71	0.69

Note: For abbreviations of the variables, see Table 4

Table 6: Correlation matrix of the variables used in the econometric specification of the Environmental Kuznets Curve.

	NSDPPC	EG	POPG	CI	YLDG
NSDPPC	1				
EG	0.189	1			
POPG	-0.176	-0.035	1		
CI	0.181	-0.05	-0.139	1	
YLDG	0.028	-0.284	0.003	-0.003	1

Note: For abbreviations of the variables, see Table 4

Regression results of the EKC for agricultural land expansion are given in Table 7. The estimates are based on the model given in equation (9). After getting pooled OLS estimates, we test for presence of heteroscedasticity in the data. We fail to reject the null hypothesis of homoscedasticity. The F test is used to test presence of panel effect in data. A statistically significant F test allows us to reject pooled

Table 7: Determinants of agricultural land expansion.

Independent variable	OLS	Fixed Effects	Random Effects
$NSDPPC/10^3$	0.29 (2.94**)	0.39 (2.98**)	0.29 (2.94**)
$(NSDPPC)^2/10^6$	-0.01 (-2.79**)	-0.01 (-2.86**)	-0.01 (-2.79**)
$(NSDPPC)^3/10^9$	0.0001 (2.70**)	0.0001 (2.67**)	0.0001 (2.70**)
LAGEXP	0.37 (6.87**)	0.22 (3.91**)	0.37 (6.87**)
EG	-0.002 (-0.19)	-0.01 (-0.75)	-0.002 (-0.19)
POPG	0.11 (2.09*)	0.01 (0.13)	0.11 (2.09*)
CI	0.13 (2.95***)	0.31 (4.01***)	0.13 (2.95**)
CI^2	-0.0004 (-2.80**)	-0.0009 (-3.30**)	-0.0004 (-2.80**)
YLDG	2.18 (5.73**)	1.55 (4.12**)	2.18 (5.73**)
Constant	-11.85 (-3.45**)	-28.04 (-5.11**)	-11.85 (-3.45**)
Adjusted R^2	0.23	within = 0.28 between = 0.07 overall = 0.09	within = 0.20 between = 0.65 overall = 0.25
F test for goodness of fit	11.64 (9,313)**	12.58 (9, 289)**	

Note: (1) *P<0.05 and **P<0.01. (2) For abbreviations of the variables, see Table 4

OLS estimates against panel data models. Further, we use the Hausman test to identify efficient model from fixed and random effects. The χ^2 statistic for the Hausman test has a higher level of statistical significance which supports the fixed effects regression estimates over random effects. Another issue with estimation of EKC is the degree of polynomials in per capita income (see Selden and Song, 1994). In the present case, we find that the inclusion of a cubic term is highly significant so we allow a cubic term of per capita NSDP in the regression model. Following the result of the Hausman test, we are interpreting fixed effects model estimates.

All the structural variables except economic growth and population growth are highly significant (Table 7). The estimated coefficients of level, square and cubic income terms in the model are different from zero with high statistical significance. The positive and negative signs of level and squared income coefficients suggest rejecting the null hypothesis of monotonically increasing agricultural land expansion with NSDP per capita. The significant cubic income coefficient with a positive sign indicates that the relationship between agricultural land expansion and GDP per capita for Indian states is N shaped. This N shaped relationship indicates future rebinding may occur between the two variables. This rebinding may be an outcome of diminishing returns to technology. In this regard, it is important to note that the potential of agricultural technology to satisfy future demand for agricultural commodities in India remains in serious doubt (for an early debate see Bhalla and Hazell, 1998). However, one must be cautious when interpreting predictions based on the EKC results as predictions are not controlled for future developments in technology and related environment. Whether or not a rebinding will happen depends on the future path of economic growth and development in the Indian economy.

To further illustrate the regression results, an enquiry of income turning points may be helpful. The first income turning point for the estimated EKC is approximately at INR 20,986.14 (at constant 1999-00 prices). The mean NSDP per capita of the sample is a standard to measure the distance of the economy from the income level at which income turns may occur. Sample mean for GDP per capita is INR 18157.24, which is below the first turning point of the estimated EKC. This indicates that economic development has failed to reverse agricultural land expansion in post reform India. The second turning point of the EKC falls at INR 42,855.10 (at constant 1999-00 prices) which too is above the mean NSDP per capita in the sample.

Including the lagged value of dependent variable helps us to correct for bias due to presence of endogeneity in the model. Agricultural land expansion is positively related and significant with its lag value of order one i.e. if there was an expansion in agricultural land last year, agricultural land will expand this year too and *vice versa*. It suggests that expectations play a vital role in inclusion or exclusion of land from agricultural operations.

Significant coefficients for the level and square term of cropping intensity suggest an inverted U-shaped relationship between cropping intensity and agricultural land expansion. This suggests that agricultural expansion increases firstly with increasing cropping intensity and then starts reversing at some higher value of cropping intensity. Observed estimates of cropping intensity in the regression model suggest that reversal occurs when cropping intensity reaches 170.80. In other words, agricultural land expansion will start reversing after 70.80 per cent of agricultural land can be used for growing more than one crop in a year. The mean value of cropping intensity in the sample (138.58) is well below this level.

Discussion

NSDP per capita, cropping intensity and cereal yield are factors which explain land expansion in agriculture during the study period. However, the study concludes that the economic development experienced by India in the post liberalisation period failed to reverse agricultural land expansion. The N shaped relationship between agricultural land expansion and per capita NSDP suggests future possibilities of agricultural land expansion after reversal.

The results are justified when we consider the interaction of the socio-economic structure of India with agricultural technology. Technological intervention in Indian agriculture was justified not only for attaining food security but also on employment grounds. Technology in India was promoted by ensuring cheap supply of inputs and making domestic terms of trade favourable to agriculture (Swami and Gulati, 1986; Gulati and Sharma, 1995). These two policies, mixed with employment pressure on the agriculture sector, remain driving forces explaining expansion of agricultural land despite increasing cropping intensity or land augmentation. However, performing agricultural operations on marginal lands is not cost effective in the long term. Hence, after a threshold level, these marginal lands can be withdrawn from production and food requirements will be fulfilled by increasing cropping intensity only.

To explore the impact of land augmentation aspect of agriculture technology, we included cropping intensity as an explanatory variable in the EKC model. This aspect of agricultural technology is completely ignored in previous studies. Our results suggest that land augmentation using technology can help to spare land from agriculture. The growth in cereals yield shows a positive and significant relationship with agricultural land expansion. This positive relationship indicates that cereals are still profitable crops for farmers to grow but not at the cost of non cereal crops.

The positive relationship between the two variables shows that farmers add new lands to their operation when the yield of cereals increases. Similarly, they decrease the area under operation when there is a decline in cereal yield. Cereals being crucial to the public distribution system are covered by a minimum support price (MSP) in India. Ensured by high MSP, farmers perceive less risk in growing these crops which may be one reason for the high responsiveness of agricultural land to cereals yield in India. The positive relationship of growth in cereal yield and cropping intensity with agricultural land expansion supports the Jevon's paradox in the case of Indian agriculture.

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