Economic Growth, Population and Resource use: Examining EKC Hypothesis for Fertilizer and Pesticide use in Post Liberalization India

Paper presented by

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Introduction

❖ Resource use, its importance in economic development and its impact on human environment, constitutes the core of the ongoing debate in environmental economics.

❖ Introduction of chemical inputs in agricultural operations from the mid 20th century helped to increase food production enormously; however, it is now widely believed that intensive use of these chemicals is counterproductive in long run (WCED, 1987)

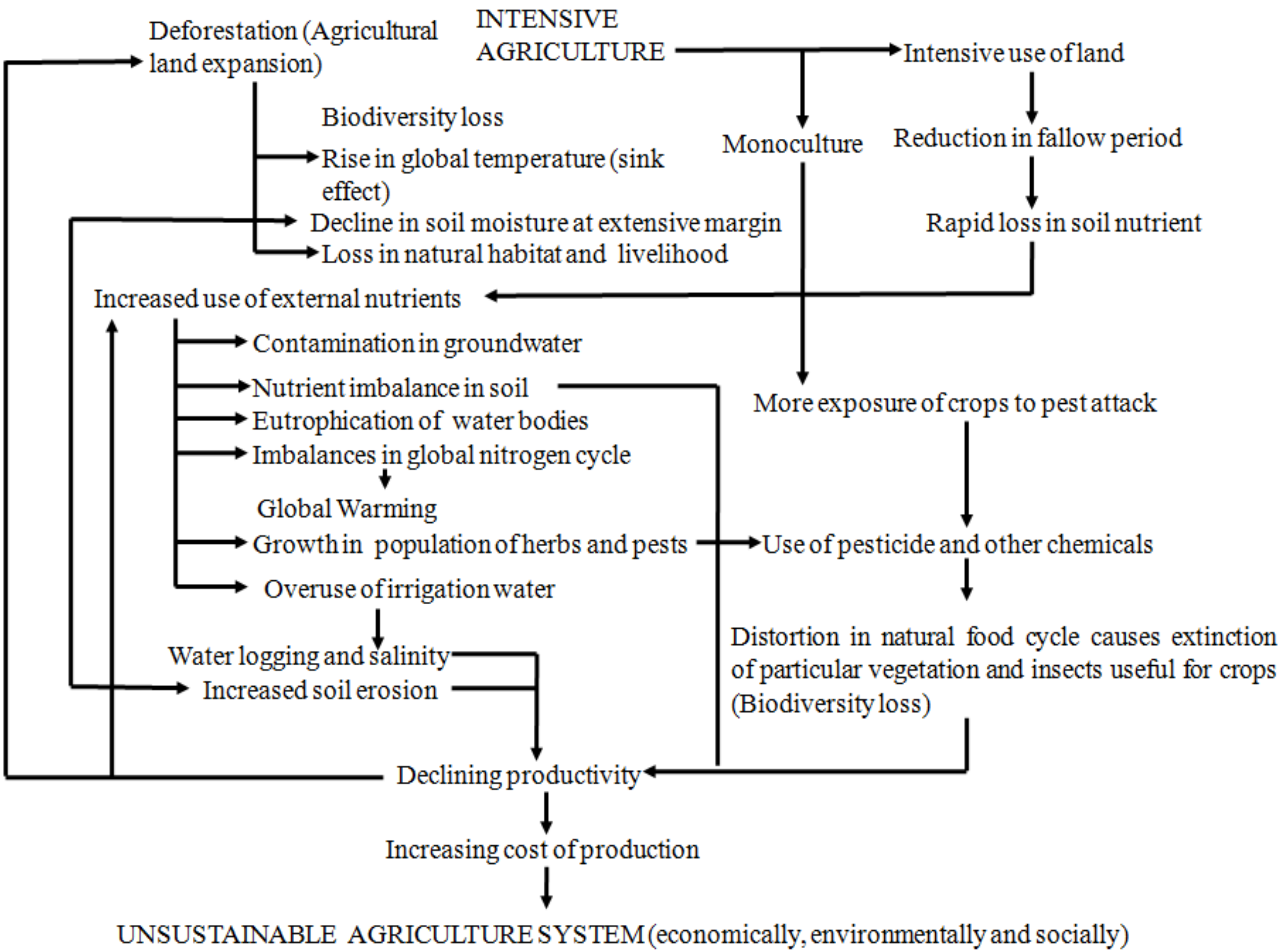
❖ In industrial/technological agricultural systems, resource use forms a vicious cycle forcing producers to apply incremental amounts of these inputs each time to maintain production and profitability.

❖ Two factors are important to explain the working of this vicious cycle-

(a) bias in agriculture development policies against environment due to strategic importance of food security,

(b) resource intensive and selective nature of technology.

Environmental Impact of Agrochemical use



Introduction

❖ Increasing intensity of chemical use (IU) in agriculture when located in broad development-environment debate leads to conflicting views, with some calling for a transition to "**green economy**" (Ruttan; 1971; Commoner, 1972; Bakerman; 1972; WCED, 1987; WDR, 1992; UNEP, 2011), while others argue for a **complete deviation from growth oriented paradigm** of development (Boulding, 1966; Meadows *et* al., 1972; Jackson, 2009; Kallis, 2011).

❖ Decoupling of economic development from resource use can reduce the environmental impacts, and the risk associated with environmental catastrophes can be potentially reduced or mitigated (Bakerman, 1991, Grossman and Kruger, 1995).

❖ Policies and institutions devoted to improve the efficiency of resource use helps in reducing absolute or relative quantity of resources required to serve economic functions (Dasgupta et al., 2000; Dinda, 2004).

Introduction

❖ Traditional approach to study resource use problem goes back to IPAT (Ehlrich and Holdren, 1971) identity which explores causality between resource uses and its drivers in an economy/ society.

❖ Further development in modelling resource use is based on Environment Kuznets Curve (EKC) which hypothesizes an inverted-U relationship between environmental indicators and per capita income.

❖ Applied to resources, the EKC hypothesis implies that the intensity of resource use (IU)-defined as the ratio of physical material use per unit of output-grows rapidly in initial stages of development but eventually falls as income rises further (Malenbaum, 2000).

❖ Alternative EKC formulation for material use can be associated with idea of dematerialization (Wernick et al., 1996; Ausubel and Wagoner, 2002; 2008) of economy.

Why Study India?

❖ With the beginning of economic liberalization in 1991, India witnessed fairly high growth in economic activities; however, agriculture sector in India failed to realize high growth achieved in other economic sectors.

❖ A country level EKC analysis is also methodologically superior as it relieves from accounting policy separately because policies regarding resource use in agriculture remain fairly homogenous within a country.

Composition of Gross Domestic Product in India

Period	1980-81 to 1989-90	1990-91 to 1996-97	1997-98 to 2009-10	2000-01 to 2009-10
GDP	5.17	5.84	7.12	7.98
GDP agriculture and allied activities	2.97	3.58	3.08	4.02
GDP agriculture	3.09	3.58	2.21	2.95

Note: Author's own computations. Source: Statistical Handbook of Indian Economy, Reserve Bank of India, 2012.

Why Study India??

Growth of Fertilizer and Other Non-Land Inputs in Indian Agriculture

Inputs	1980-81 to 1989-90	1990-91 to 1999-00	1990-91 to 1996-97	1997-98 to 2008-09	2000-01 to 2008-09
Consumption of N fertilizers (Kg/GSA)	7.79 (10.01)	4.67 (24.2)	4.67 (12.91)	2.86 (6.27)	4.55 (7.51)
Consumption of P fertilizers (Kg/GSA)	10.30 (16.87)	4.32 (2.58)	-1.70 (-1.3)*	4.63 (6.36)	5.59 (6.83)
Consumption of K fertilizers (Kg/GSA)	6.44 (9.66)	2.79 (1.29)*	-2.99 (-0.9)*	8.23 (11.06)	9.59 (8.71)
Consumption of total fertilizers (Kg/GSA)	8.23 (11.76)	4.40 (7.39)	2.44 (3.39)	3.80 (7.66)	5.36 (8.2)
Consumption of pesticides (Kg/GSA)	5.55 (4.8)	-5.28 (-19.6)	-4.68 (-9.9)	-1.84 (-3.8)	-0.82 (-0.99)*

Note: 1. authors own computation. 2. Figures in parentheses are t values. 3. All t statistic are significant at 1% level of significance. *indicates statistically insignificant t values. Source: Agricultural statistics at a glance, Department of Agriculture and Cooperation, 2010.

Econometric Approach: From IPAT to Environmental Kuznets Curve

- Basic *IPAT* identity suggests that interaction of affluence (*A*), population (*P*) and technology (*T*) determines environmental impact (*I*).

$$I = P \times A \times T$$

- Since, a unit or dimension attaches to every quantity in the identity; therefore, matching dimensionality of driving side and impact side is important while developing any variant of *IPAT* (Chertow, 2001).
- Similarly, a meaningful causality must exist among drivers and impact (Chertow, 2001; Waggoner and Ausubel, 2002).

Econometric Approach: From IPAT to Environmental Kuznets Curve

- To reformulate an *IPAT* for agrochemical use, we use quantity of agrochemicals used per hectare as a measure of impact. For removing any issue related to dimension of impact and driver side, we use back substitution method. We write:

$$\frac{Q}{L} = \frac{Q}{Y} \times \frac{Y}{P} \times \frac{P}{L}$$

where, Q, L, Y and P stands respectively for quantity of agrochemical used in agriculture, land under agriculture, agricultural output and population.

Econometric Approach: From IPAT to Environmental Kuznets Curve

❖ Defining agricultural commodities demanded by population for consumption (C) as sum of domestic agricultural production and trade in agriculture (T), we can rewrite equation 2 as:

$$\frac{Q}{L} = \frac{Q}{Y} \times \left(\frac{C}{P} \pm \frac{T}{P} \right) \times \frac{P}{L}$$

❖ For a densely populated country having large and diverse agricultural system, agricultural trade per capita will be negligible relative to production. Therefore,

$$\frac{Q}{L} = \frac{Q}{Y} \times \frac{C}{P} \times \frac{P}{L}$$

Econometric Approach: From IPAT to Environmental Kuznets Curve

❖ Deitz and Rosa (1997) redefined *IPAT* identity in a stochastic framework in which relative contribution of components can be empirically investigated using econometric methods. Stochastic version of IPAT (STIRPAT) can be given as,

$$\left(\frac{Q}{P}\right)_{it} = \alpha_i \left(\frac{C}{P}\right)_{it}^{\beta} \left(\frac{P}{L}\right)_{it}^{\gamma} \varepsilon_{it}$$

❖ In above formulation, technology (*T*) is modelled as a residual and captures institutional, organizational (socio-political and economic) changes in the economy along with technological change (Deitz and Rosa, 1997).

Econometric Approach: From IPAT to Environmental Kuznets Curve

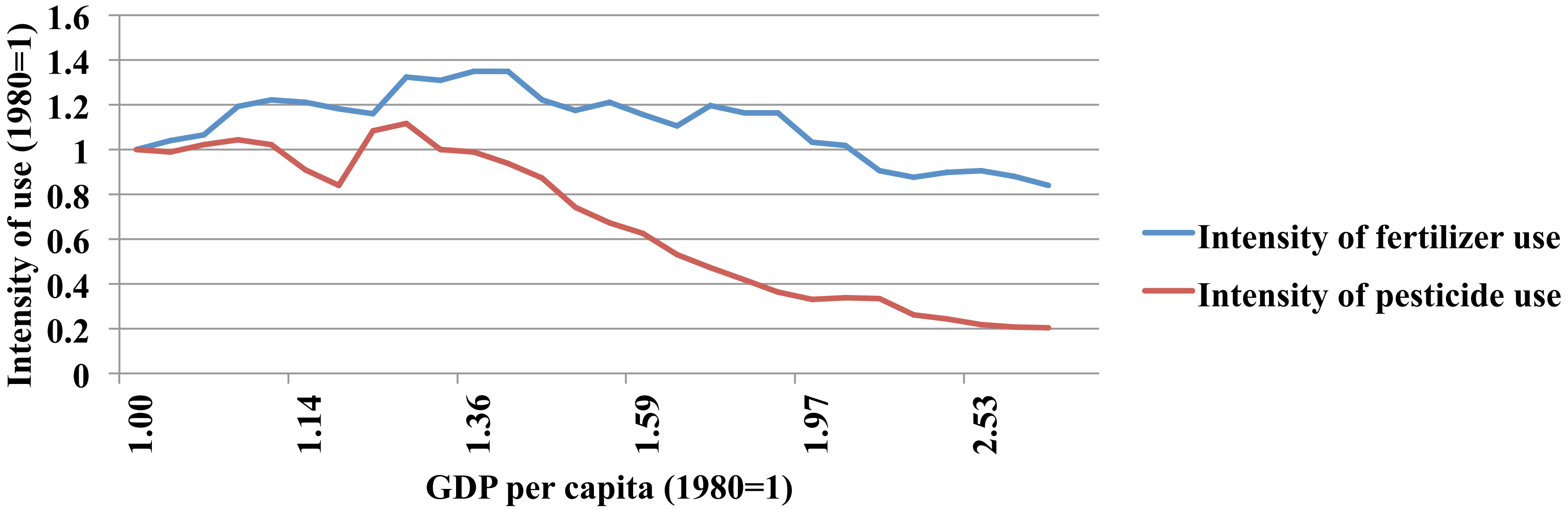
❖ For incorporating nonlinearity between demand for agricultural products and per capita income (Engle's hypothesis), we define a long run income-consumption equation for agricultural commodities as:

$$\ln\left(\frac{C}{P}\right)_{it} = \theta_1(\ln W)_{it} + \theta_2(\ln W)^2_{it}$$

❖ Since demand for agrochemicals is derived from demand for agricultural commodities; therefore, we can write:

$$\ln\left(\frac{Q}{L}\right)_{it} = \ln\alpha_i + \beta_1(\ln W)_{it} + \beta_2(\ln W)^2 + \ln\left(\frac{P}{L}\right)^{\gamma}_{it} + \varepsilon_{it}$$

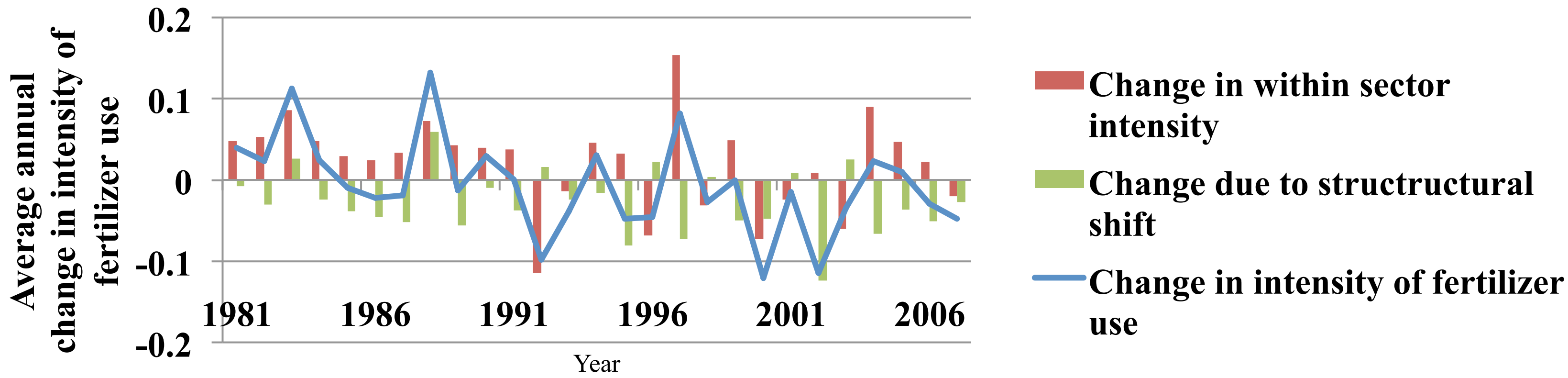
Development of Intensity of Use (IU) and Affluence (GDP per capita) in India

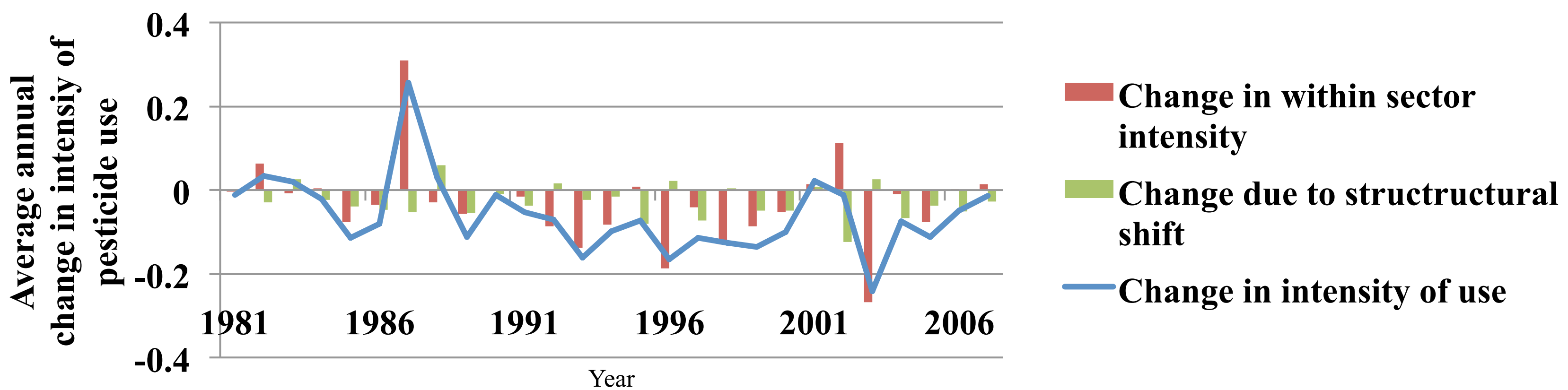


Author's own calculation. **Source:** Handbook of statistics on Indian Economy, RBI (2013)

❖ Decoupling or dematerialization can take place due to structural shift in organization of economic activities. To capture impact of structural shift, change in IU for both inputs is further decomposed into change due to increasing/decreasing efficiency within sector and change due to structural shift in economic activities.

Development of Intensity of Use (IU) and Affluence (GDP per capita) in India





Change in IU **(material use/GDP)** = Change in IU due to within sector dynamics **(material use/agriculture GDP)** + Change in IU due to structural change **(agriculture GDP/GDP)**

Definition of variables

Variable	Notation	Definition	Transformation	Data Source
Fertilizer consumption per hectare	**FERTH**	**(N+P+K) Fertilizer consumption/ Gross cultivated area**	**Logged**	**Harvest Database, CMIE 2012**
Fertilizer consumption per hectare	**PESTH**	**Pesticide consumption/Gross cultivated area**	**Logged**	**Indiastats.com 2012**
Net state domestic product per capita	**NSDPPC**	**in constant 1999-00 Rs**	**Logged**	**Handbook of Indian Economy, 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**	**-**	**Handbook of Indian Economy, RBI 2012**
Population Density	**PD**	**P_{it}/A_i where, P_{it} is mid-year population in state i at time t and A_i is geographical area of state i**	**Logged**	**Indian Intelligence Database, CMIE 2012**
Population Growth	**POPG**	**$[\{P_{it}-P_{i(t-1)}\}/P_{i(t-1)}]*100$ where, P_{it} is mid-year population in state i at time t**	**-**	**Indian Intelligence Database, CMIE 2012**

Summary statistics of variables

Variable	Observations	Mean	Std. Dev.	Min	Max
PESTH	367	0.270	0.263	0.0009	1.099
NPKH	367	72.783	52.745	1.102	215.725
NSDPPC	367	17838.39	7350.217	5994	56021
EG	367	6.372	5.817	-12.013	32.180
PG	367	1.970	1.127	-0.675	12.037
POPD	367	3.226	2.436	0.099	9.884

Correlation Matrix

	NSDPPC	EG	POPG	PD
NSDPPC	1			
EG	0.205	1		
POPG	-0.171	-0.024	1	
PD	0.194	0.007	-0.357	1

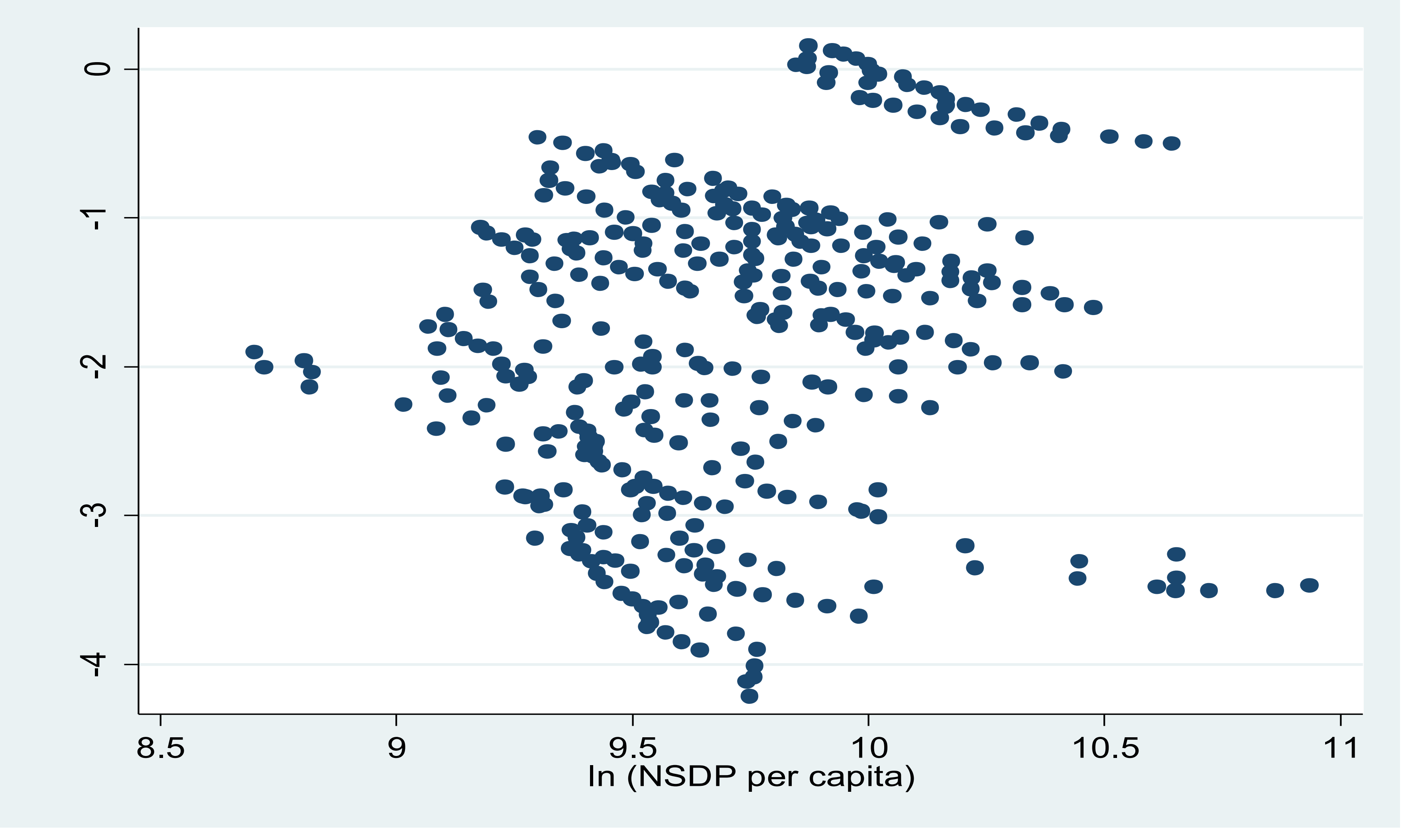
χ^2

Estimation results by panel corrected standard error (PCSE) regression models for pesticide consumption

Model	EKC	Extended EKC
Constant	0.277 (0.191)**	1.430 (0.673)**
ln NSDPPC	-0.326 (0.341)*	-0.443 (0.218)**
$(\ln NSDPPC)^2$	0.295 (0.206)	0.384 (0.211)*
ln PD	-1.664 (0.437)***	-1.519 (0.449)***
EG	-	0.006 (0.002)**
POPG	-	0.0038 (0.032)
R^2	0.687	0.679
Wald chi square	7298.52 (25)***	1412.81 (23)***
Autocorrelation coefficient	0.446	0.467
NSDPPC turning point (in 1999-00 constant prices)	-	29549.21
Autocorrelation type	AR (1) of errors	
State dummies	yes	

Note: Panel corrected standard errors are in parenthesis. *, **, *** refers to significance at 10%, 5%, and 1% level

Pesticides consumption per hectare and NSDP per capita



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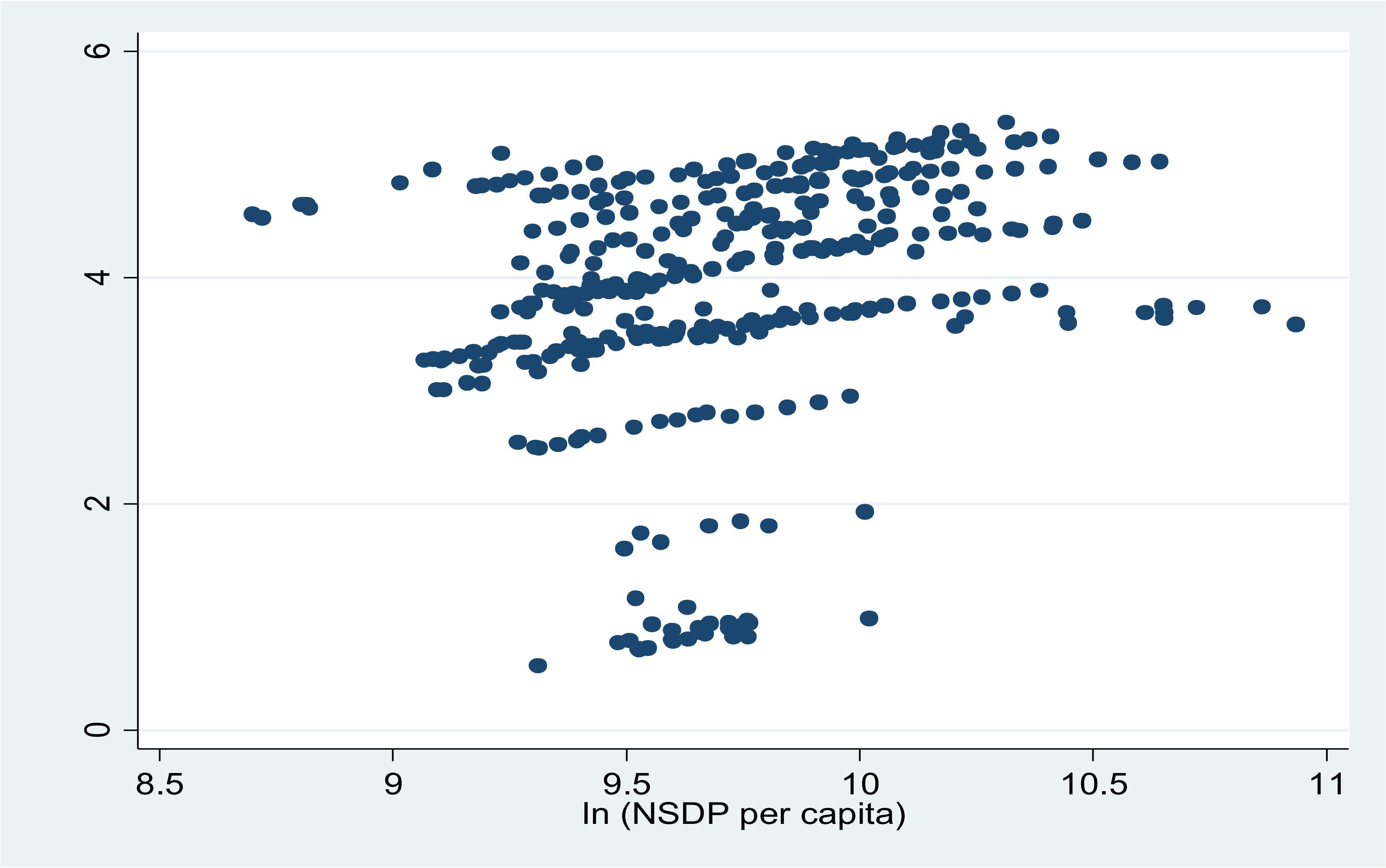
Estimation results by panel corrected standard error (PCSE) regression models for fertilizer consumption

Model	EKC	Extended EKC
Constant	4.969 (0.354)***	5.135 (0.303)***
ln NSDPPC	0.638 (0.107)***	0.782 (0.103)***
(ln NSDPPC)^2	-0.272 (0.084)***	-0.344 (0.086)***
ln PD	-0.055 (0.237)	-0.185 (0.202)
EG	-	-0.003 (0.0011)***
POPG	-	0.044 (0.016)***
R^2	0.939	0.941
Wald:	71372.32 (25)***	31018.55 (26)***
Rho	0.478	0.503
NSDPPC turning point (in 1999-00 constant prices)	53625.69	51720.90

Note: Panel corrected standard errors are in parenthesis. *, **, *** refers to significance at 10%, 5%, and 1% level

Fertilizers consumption and NSDP per capita



Discussion

- ❖ Results of basic EKC specification confirm a significant linear relationship between pesticide consumption per hectare and per capita income (NSDPPC) (see, table 8). However, results of extended EKC model confirms a U shaped relationship between the two variables.
- ❖ U shaped relationship between NSDPPC and pesticide consumption per hectare implies that people may start demanding more pesticide intensive commodities as they get more affluent.
- ❖ Change in quality of demand along with the shift of demand towards fruits and vegetables with increase in per capita NSDP seem to be the reason for U shaped relationship.
- ❖ Still, it remains a question why in an extended model squared income term becomes significant. To explore this phenomenon, we run some alternative specifications to deepen our understanding of relationship between development and pesticide use in post liberalization India.

χ^2

Discussion

	Model 1	Model 2	Model 3
Constant	-0.789 (0.133)***	0.837 (0.134)***	-0.836 (0.134)***
ln NSDPPC	-0.883 (0.166)***	-0.980 (0.183)***	-0.983 (0.183)***
$(\ln NSDPPC)^2$	0.315 (0.211)	0.435 (0.218)**	0.425 (0.216)**
ln PD	-	-	-
(ln NSDPPC) (EG)	-	-	0.0008 (0.0002)***
EG	-	0.007 (0.002)***	-
R^2	0.667	0.658	0.658
Wald:	12165.40 (22)***	12328.93 (23)***	17214.52 (23)***
Rho	0.464	0.489	0.488

❖ Results suggest that growth effect is so strong and positive that it turns squared income per capita term significant. Inclusion of growth rate aims to test the hypothesis that how far the relationship between level of material use (pesticide) and structural change in economy are affected by rate of economic growth.

❖ Increased trade of agricultural commodities strongly supports positive relationship between pesticide use per hectare and economic growth in India

Discussion

❖ High statistical significance of population density with negative sign suggests that densely populated states strongly oppose pesticide use in agriculture.

❖ A general explanation for this relationship is that densely populated societies always tends to reduce use of pollutants at every level of income than less densely populated societies (Panayotou, 1997).

❖ As a more specific explanation to justify negative relationship between two variables, we propose that immediate and fatal impact of pesticide exposure on human/ livestock health plays an important factor. High population elasticity (greater than one) of pesticide use supports this argument. Furthermore, societies tend to reduce pesticide use as pesticides don’t contribute directly to productivity rather they act as damage control agents.

χ^2

Discussion

❖ Unlike pesticides model, fertilizer consumption per hectare is showing nonlinearity in income per capita without presence of any confounder like growth.

❖ Presence of additional explanatory variables work to reduce the value of NSDP per capita at which fertilizer consumption per hectare shows inflection.

❖Food requirements of a society which is populating itself rapidly can be fulfilled only by intensive use of available land. Positive relationship between population growth and fertilizer consumption per hectare highlights this factor in states of India.

❖ However, small in magnitude, negative economic growth effect signifies declining importance of staple food items with respect to non food items in recent high growth realized in the economy.

Discussion

Income elasticity of agrochemicals for hypothetical level of income

NSDP per capita (constant 1999-00 Rs)	10000	20000	30000	35000	45000	50000	60000	75000
Affluence elasticity (Fertilizer)	1.130	0.653	0.374	0.268	0.095	0.023	-0.102	-0.255
Affluence elasticity (Pesticide)	-0.832	-0.299	0.011	0.130	0.323	0.403	0.543	0.715

- ❖ Rosa and Dietz (1998) developed concept of ecological elasticity which measures responsiveness of economy towards ecological attributes. Borrowing from them, we computed income elasticity of fertilisers and pesticides for hypothetical levels of NSDP per capita.
- ❖ It is observed that fertilizer use is more income elastic at low levels of income. It signifies dominance of food in total expenditure at low level of income as Engel’s hypothesis suggests.

Discussion

- ❖ Rapid decline in income elasticity for fertilizers can be realized only when average NSDP per capita reaches at the level of Rs 35000. On the other hand, income elasticity of pesticides increases rapidly which may be due to increasing share of pesticide intensive commodities like fruits and vegetables in food basket of consumers.
- ❖ However, in any case, results for both pesticides and fertilizers raise certain issues which demand serious attention.
- ❖ In pesticides case, analysis predicts an increase in consumption in immediate future assuming that economy will maintain high growth trajectory.
- ❖ In the case of fertilizers, observed turning point of EKC is very high and any kind of optimism on the basis of predicted inverted-U could be termed as too "naïve".

Concluding Remarks

✓ Contextualizing results in dematerialization framework discussed extensively under Industrial ecology, we claim that Indian agriculture is far away from dematerialization as far as fertilizers are concerned.

✓ Results for pesticides are rather dangerous in suggesting that high economic growth may increase pesticide use.

✓ However, further exploration into causes behind such finding is needed.

✓ Based on the results, we cannot be optimistic regarding claims that economic growth always brings improvements in environment quality.

I end here with a big

THANK YOU FOR YOUR ATTENTION