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Haimanti Bhattacharya
The University of Arizona

Robert Innes
The University of Arizona

Department of Agricultural and Resource Economics
College of Agriculture and Life Sciences
The University of Arizona

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Is There a Nexus between Poverty and Environment in Rural India?

Haimanti Bhattacharya and Robert Innes*
University of Arizona

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Abstract

This paper presents an empirical analysis of the relationship between rural poverty and environmental change using district-level data from South, Central and West India. Unlike prior works, this study puts the hypothesis of bi-directional link between poverty and environment to systematic econometric test by accounting for the joint endogeneity of poverty and environmental change. Environmental change is measured using a satellite-based vegetation index. Consonant with the dominant view in the literature, the evidence suggests that rural poverty spurs vegetation degradation. The results also indicate that the vegetation degradation spurs rural poverty but the magnitude of the effect varies across sub-regions classified on the basis of geographic and climatic factors. Thus these results provide evidence in support of existence of a poverty-environment nexus in the rural areas of the study region.

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* Department of Economics and Department of Agricultural & Resource Economics, University of Arizona, Tucson, AZ 85721. Phone: (520) 621-9741, Fax: (520) 621-6250, Email: haimanti@email.arizona.edu and innes@ag.arizona.edu.
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1. Introduction

The link between poverty and environment in the developing countries has been gaining increasing attention of the international development agencies and policy makers (Angelsen, 1997; Dasgupta et al., 2004) as poverty and environmental degradation are two very important issues that pose a huge challenge especially for the developing countries. This study attempts to advance the understanding of this link by focusing on a specific aspect of environment[1], namely, *vegetation*, and investigates its bi-directional relationship with poverty[2].

Many studies have established that the rural poor in developing countries are heavily dependent on local natural resource extraction for their sustenance (e.g. Cavendish, 2000; Jodha, 2000; Shiva & Verma, 2002; Escobal and Aldana, 2003; Narain, Gupta & Veld, 2005). Due to weak property rights and limited access to credit, insurance and capital markets, rural poverty leads to resource degradation in many ways (e.g. Dasgupta and Mäler, 1994; Mäler, 1997; Swinton, Escobar and Reardon, 2003; Bahamondes, 2003). The poor depend heavily on the open access resources like the forests, pastures, water resources that leads to their over exploitation (Jodha, 2000). Animals like sheep or goats that act as capital resource for the rural poor degrade the vegetation and soil faster than the livestock of the richer rural population like buffaloes (Rao, 1994). Cultivable land degrades quickly due to lack of investment for maintaining the soil quality that erodes the soil fertility (Reardon and Vosti, 1995). Land tenure system can also play a crucial role in the investment for maintaining soil quality. Since the natural environment is not just an amenity but a necessary input for the rural households, environmental degradation in turn implies a shrinking input base for the poor households that increase their severity of poverty (Mink, 1993;

[1] Environment is a very broad term that is defined as the conditions and circumstances that surround and affect the development of organisms (Maler, 1997).

[2] Several alternative measures of poverty have been used in the literature. We use two measures – poverty gap index and squared poverty gap in this analysis. See the data section for details.

Jodha, 2000). This cyclical relationship is commonly referred to as the poverty-environment nexus (Nelson and Chomitz, 2004; Dasgupta et al. 2004, Duraiappah, 1998).

Empirical validation of this rural poverty-environment nexus hypothesis has profound policy implications. Designing adequate policies to tackle both poverty and environmental degradation in the presence of such a nexus can be very challenging. For example – privatizing the forests or strictly regulating the forest access for the rural population in a developing country can help in restricting the environmental degradation but it can increase the severity of poverty for the poor households heavily dependent on open access or common property forest resource extractions. Hence, it is important for policies geared to improve environmental quality to take into consideration the plausible impact of the policy on poverty. Similarly poverty reduction policies should consider the effect on environment as well. Existence of a poverty-environment nexus therefore may imply that the policies have failed to treat these two issues in a unified framework or the policies that aimed to tackle both the problems were not adequate enough to succeed in handling both the issues.

In order to test the poverty-environment 'nexus' hypothesis it is important to analyze the bi-directional relationship between poverty change and environmental change and account for their joint endogeneity as the hypothesis argues that environmental degradation not only gets affected by poverty, it also affects poverty. Yet, in spite of the assertion of existence of such a nexus the empirical studies have not accounted for the endogeneity.

Several empirical studies have established the importance of natural environment for the poor population of the developing countries by depicting the strong dependence of rural households on the natural resource extraction – especially the common property or open access resources. Such studies have been done using data from developing countries like India (Rao,1994; Jodha,2000;

Narain, Gupta & Veld, 2005), Zimbabwe (Cavendish, 2000), Peru (Escobal & Aldana, 2003). Other studies have analyzed the effect poverty or income levels of rural households on the resource management practices or environmental degradation in developing countries like Chile (Bahamondes, 2003), Peru (Swinton and Quiroz, 2003; Escobal & Aldana, 2003), Cambodia and Lao PDR (Dasgupta et al., 2004), Guatemala and Honduras (Nelson and Chomitz, 2004). The evidence regarding the effect of poverty on resource degradation is mixed, yet the dominant view in the literature is that poverty is an important cause of resource degradation. Many studies have focused on forest as a measure of environmental quality; some studies have also analyzed other aspects of environmental degradation like soil quality, water quality, indoor and outdoor air pollution.

One important limitation of this existing literature is that these studies focus either on the effect of poverty on environment or infer about the other direction of the relationship on the basis of extent of dependence of rural households on natural resources without direct estimation of the impact of resource degradation on poverty. It is vital to assess both the directions of the relationship in order to test the poverty-environment nexus hypothesis. The second and more important limitation of the literature is the failure to account for the potential joint endogeneity of environmental change and change in poverty. Failure to account for the endogeneity can provide downward biased results i.e. the magnitudes of the effects are expected to be smaller if the endogeneity is ignored.

The lack of systematic econometric analysis of the bi-directional relationship can be attributed to the lack of or difficulty in obtaining adequate disaggregated panel data on environmental quality measures, poverty and other socio-economic variables that affect these outcomes in rural areas of developing countries. While many studies depicting the extent of dependence of the rural households on natural resources have done the analysis with household as unit of observation, studies assessing the impact of poverty on environmental degradation have done analysis at more aggregated level as environmental outcomes are usually the result of collective actions of the population that can affect the natural resource. The adequate level of aggregation depends upon the nature of natural resource in focus.

In this paper, we seek to advance this literature by performing a systematic econometric analysis of the bi-directional links between rural poverty and environmental change while accounting for the joint endogeneity of poverty and environment by using a unique data set. We have used district level data from South, West and Central India. Districts were chosen as the unit of analysis as this is the most disaggregated level for which the required socio-economic data could be obtained[3]. To measure environmental health, we use satellite-based “vegetation” indices that implicitly capture both forest and overall biomass resources in India’s rural environment. Only rural poverty has been included in this analysis as rural poor are heavily dependent on our measure of environment - vegetation. The urban poor have stronger links with other aspects of environment like air and water (Satterthwaite 2003). The terms environment and vegetation have been used interchangeably as our measure of environmental quality is vegetation. The reason behind the choice of the country and the details of the data follow.

2. Data

India is an interesting case for the purpose of this study as it is one of the fast growing developing countries both in terms of population as well as economic growth, where poverty is still a predominant problem. India is the second most populated country in the world, with a population over a billion that is growing at the rate of 1.5 percent per annum (World Development Indicators,

[3] A more disaggregated study might become feasible in future with better data availability, but this is a reasonable first step given that the studies analyzing poverty and its association with other socio-economic problems in India are predominantly at more aggregated level i.e. state level (e.g. Ravallion and Dutt, 2002; Gupta and Mitra, 2004; Jha, 2001).

2003) and with per capita GDP growth rate of approximately 8 percent per annum (2005-06). According to official estimates, the national head count index of poverty (percentage of people below poverty line in total population) was approximately 23 percent in 1999-2000. The corresponding rural head count index was 27 percent. According to the 2001 Census of India, approximately 72 percent of the population resides in rural areas. Hence the analysis of the relationship between rural poverty and vegetation change is likely to have pronounced policy implications for sustainable development of this country.

We use district level data from 172 districts[4] in eight states of India. These states are from the southern, western and central regions of the country: Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Maharashtra, Gujarat, Rajasthan and Madhya Pradesh. A map of the study region (the shaded portion of the map) is presented in figure 1. Our data set exhibits enormous variation in climatic as well as socio-economic conditions. For example, the normal annual rainfall varies from less than 33 cm to 350 cm and rural literacy rates vary from 14 percent to 96 percent in our sample districts. The study uses the change in vegetation and poverty indices over the period 19994-95 to 2000-01. Table 1 describes the variables that are used in this study. Table 2 provides summary statistics for these variables. Details on the sources and construction of the variables follow.

Measuring Environmental Health

Direct disaggregated time series data on measures of environmental health are rarely available for India. Hence, to measure the state of the rural environment at a district level, we rely on the satellite imaging data that is available for the entire period of our study. Satellite imaging data is more accurate and reliable as it is free from the measurement errors associated with the traditional survey measures of environmental quality. For example, the vegetation index can

[4] The study region contains 199 districts. Adjusting for district redefinitions and missing data, gives a usable sample size of 172 districts.

distinguish higher quality vegetation from lower quality vegetation per unit of land area, which is usually not the case with traditional measures like area under forests. We use the Normalized Difference Vegetation Index (NDVI)[5] as a measure of vegetation or "greenness". This index is known to be highly correlated with plant matter; to take on higher values when forest vegetation is present; and to be robust to topographical variation, the sun's angle of illumination, and atmospheric phenomena such as haze. The satellite image based vegetation indices are gaining wider applications (Moran et al., 1996; Foster & Rozensweig, 2003). The NDVI is measured on a 10-day composite basis and with a resolution one pixel equal to eight square kilometers in size. Satellite images were obtained from the National Aeronautics and Space Administration (NASA) and were processed using Geographic Information System (GIS) techniques to obtain district-specific index values.[6]

NDVI data is used to construct two measures of the state of the environment. The first is the average district-level NDVI, a measure of overall vegetation. The second, z-NDVI, represents an index of highest quality of vegetation, measuring the extent to which a district has high NDVI land. Annual (or two year) average value (μ_S) and standard deviation (σ_S) are calculated from all monthly pixels in the study area. A critical NDVI index is then constructed such that

[5] Calculation of NDVI is based on several spectral bands of the photosynthetic output in a pixel of a satellite image. It measures the amount of green vegetation in an area. NDVI calculations are based on the principle that green plants strongly absorb radiation in the visible region of the spectrum called Photosynthetically Active Radiation (PAR), while strongly reflecting radiation in the Near Infrared region (NIR). The concept of vegetative “spectral signatures (patterns) is based on this principle. NDVI can take a value between 0 and 256. NDVI for a pixel is calculated from the following formula: NDVI = (NIR – PAR) / (NIR + PAR).

[6]Monthly composite images downloaded from NASA are reprojected into geographic format and stacked to calculate pixel-level averages and standard deviations for one or two-year timeframes. Using the political map of India, district level NDVI averages and standard deviations are extracted from the pixel-level data.

approximately 20 percent of the study region's month-pixel NDVI values are higher than this index:[7]

$$N = \mu_S + n_{.20}\,\sigma_S,$$

where $n_{.20}$ = critical value of a standard normal random variable such that the upper tail has a 20 percent probability ≈ .84. For any given time interval of interest, a "z-NDVI" is then constructed for each district. The z-NDVI is monotonically related to the approximate proportion of time-pixels that are above the critical NDVI index value:[8]

$$\text{z-NDVI for district } j = (\mu_j - N)/\sigma_j,$$

where μ_j = district j average of time-pixel NDVI and σ_j = district j standard deviation of time-pixel NDVI [9]. This measure of high quality vegetation is an approximate measure of forests. Forests not only have higher 'greenness' value, they also have less intra-year fluctuation compared to agricultural lands and this is the essence that is captured by the z-NDVI measure.

Measuring Poverty and Income Inequality

Due to unavailability of direct district-level measures of income, poverty and income inequality in India, district level rural and urban consumption expenditure data have been used to proxy for income and construct the poverty and inequality measures. National Sample Survey of India has been conducting random household sample surveys for a long time. But publication of district wise household survey data on consumption expenditure started from 51st round (1994-95) onwards. Hence the initial period of this study is 1994-95. The consumption expenditure data from NSS 51st

[7]In 1995, approximately 19.1 percent of our study region was in forests. In 1990-91, approximately 21 percent of India's land was forested. We thus use a 20 percent upper tail probability in constructing our "z-NDVI" measure of forest cover.

[8]The NDVI takes on values between zero and 256. The calculated critical N index value is 177. This is somewhat higher than the critical index value used by Foster and Rosenzweig (2003) to measure forest cover. We experimented with alternative N values and obtained results qualitatively similar to those presented in this paper.

[9]The z-NDVI is a measure of high-NDVI frequency that is commonly used by GIS geographers (see Yool, 2001).

and 56th rounds, corresponding to 1994-95 and 2000-01 respectively, have been used to construct district level rural and urban per-capita consumption expenditure, income inequality and poverty measures.

Poverty

In the context of environmental degradation, poverty can be defined in two ways – welfare poverty and investment poverty (Reardon and Vosti, 1995). Welfare poverty is the traditional definition of poverty accounting for people below a 'poverty line'[10]. Investment poverty goes one step further. It accounts for people who do not have adequate assets to invest in sustaining the environment as this definition considers sustainability of environment as one of the basic requirements for human sustenance. Due to lack of data on assets ownership, access to credit and capital markets of the rural households, investment poverty cannot be captured in this study.

There are several measures of the traditional welfare poverty: Head count index, Poverty gap index, Squared Poverty Gap Index. These measures are called Foster-Greer-Thorbecke (FGT) class of poverty measures:

$$Y_\alpha = \sum_{(y_i < p)} [(p - y_i) / p]^\alpha / n$$

where,

Y is the measure of poverty,

y_i is the consumption of the *i*th household,

p is the poverty line,

n is the population size,

α is a non-negative parameter.

[10] Poverty line is a benchmark level of income, usually defined by government, that is expected to enable a person to procure the basic basket of commodities needed for sustaining human life.

If $\alpha = 0$, Y gives the Head Count Index[11].

If $\alpha = 1$, Y gives the Poverty Gap Index[12].

If $\alpha = 2$, Y gives the Sqaured Poverty Gap (SPG) index.

The basic needs of people can vary across location and time. To set up a standard benchmark for measuring poverty, the governments define poverty lines. People with income below the poverty line are counted as poor. In India the poverty lines are defined to capture rural-urban and inter-state differentials in cost of living. Hence the most disaggregated poverty lines that are defined by the government are available are at state level classified by rural and urban areas. These official poverty lines are presented in Table 3. Though the cost of living can vary across districts within a state, due to lack of officially defined district level poverty lines, the state level rural poverty lines have been used for constructing the district level rural poverty measures. The poverty lines used for constructing the poverty measures of this study are twice the actual government specified poverty lines. The official poverty lines are too low as they are constructed to depict the minimum expenditure required for bare survival[13]. Hence people just above the official poverty line live in absolute poverty as well. In the construction of the poverty indices, using the official poverty line will put zero weight to the people barely above the poverty line, which is not desirable. The poverty line was modified for constructing the poverty indices to reduce this

[11] The percentage of people who fall below the poverty line in a population is known as the headcount index.

[12] *Poverty gap index*: The mean distance below the poverty line as a proportion of the poverty line where the mean is taken over the whole population, counting the non-poor as having zero poverty gap. That is the mean shortfall from the poverty line (counting the non-poor as having zero shortfall), expressed as a percentage of the poverty line (United Nations Statistics Department).

[13] There are many possible incentives for the government to keep the poverty lines as low as possible. For example, low poverty lines can project better performance of the government in controlling poverty; can reduce the financial burden for the policies that assures food and other aids for people below poverty line.

undesirable effect of official poverty line[14]. Our aim is to analyze the impact of vegetation change on change in the severity of poverty, hence we use the poverty gap index and the squared poverty gap in the analysis as these provide better measure of the severity of poverty than the head count index (Ravallion and Dutt, 1996 and 1999; Jha, 2001).

Income Inequality

The most commonly used measure of inequality is *Gini* coefficient. It is derived from the Lorenz curve. Lorenz curve, l=l(y), plots the relationship between cumulative proportion of income receivers, y, and the corresponding cumulative proportion of income. Gini coefficient is defined as: $G = 1 - 2 \int_0^1 l(y)\, dy$, where G lies in the range (0,1). Higher values of G indicate higher inequality. G=1 implies perfect inequality i.e. all income is received by one person and G=0 indicates perfect equality. This study uses a commonly used formula for estimating the Gini coefficients called the Pyatt et al. (1980) formula: $G = 2\ Cov(y, r_y) / (n\ y_m)$ where, $Cov(y, r_y)$ is the covariance between income, y, and the ranks of income (in ascending order) recipients, r_y; ym denotes the mean income and n is the population size (Abounoori and McCloughan, 2003).

Rainfall

Rainfall is an important climatic factor that affects the vegetation. Actual annual and normal rainfall data are available for meteorological subdivisions of India. Each meteorological subdivision is defined according to climatic features and contains several districts. Since there are only 19 subdivisions and within a subdivision "greener" districts are likely to have higher rainfall, we obtain approximations to district-level actual rainfall by combining subdivision rainfall and district-level NDVI data as follows:

$$Rain_{ij} = Rain_j * (NDVI_i / NDVI_j)$$

[14] This modification is very subjective, as we could have used any other scaling factor instead of 2. We also tried a poverty line scaled up by 1.5 times. The results were qualitatively similar.

where $Rain_{ij}$ = "rainfall" for district i in subdivision j, $Rain_j$ = annualized 1994-2000 rainfall of subdivision j, $NDVI_i$ = average NDVI of district i for 1990-91, $NDVI_j$ = average NDVI of subdivision j for 1990-91.

Rainfall deviations can play an important role in affecting poverty change and vegetation change. We constructed two pairs of district level measures of rainfall deviations. The first pair is obtained by summing up positive and negative deviations in rainfall, over the period 1994 to 2000, from the usual mean annual rainfall respectively. The mean represents the average annual rainfall for the twenty-one year period – 1981 to 2000. We distinguish between the positive and the negative deviations in rainfall in order to account for distinct effects of excess rain and shortfall in rain, This is more important in case of extreme deviations in rainfall as the extent of damaging effect of floods and droughts can be very different. In order to capture extreme deviations in rainfall we constructed another pair of rainfall deviation measures. We constructed these measures by summing those positive and negative deviations respectively (during 1994 to 2000), which were more than the benchmark standard deviation in magnitude. The benchmark standard deviation is computed on the basis the variance in annual rainfall for the twenty-one year period covering 1981 to 2000.

Population

There is a vast literature that depicts the importance of population growth in affecting poverty as well as environmental degradation (e.g. Nerlove 1991, Mink 1993, Dasgupta 1995 and 2000). The Registrar General's Office of India, released data revealing district level births and deaths (total, rural, and urban), statistics for the four years 1991-1994. Using this data, as well as district-level rural and urban population levels from the 1991 Census of India, we derive rural and urban natural population growth rate[15] for the period 1991 to 1994. This provides a better measure of the population growth rate over this period than the imputed value from the decadal census data.

Socio-Economic Data

The socio-economic data that are expected to affect poverty and vegetation change have been obtained from various sources[16]. The data on these socio economic variables - population density, proportion of urban population, net sown area, literacy rates, infant mortality rate, life expectancy at birth, sex ratio, female work force participation rate and average household size are for the year 1991[17]. These variables act as indicators of the initial socio-economic conditions of the rural areas of the districts of this study.

3. Hypotheses

The objective of this study is to test the poverty-environment nexus hypothesis. We test the hypothesis by analyzing the effect of poverty on environmental change as well as the effect of environmental change on poverty. The relationship between poverty and environment has been analyzed in the literature mostly by descriptive and empirical studies. Ikefuji and Horii (working paper - 2005) is the only study that provides a formal (dynamic mathematical) model to depict the poverty-environment trap. They show that the income distribution plays a crucial role in shaping the poverty-environment relationship as under certain conditions, high initial income inequality can help in breaking the trap. We control for the income inequality in our regressions to test this

[15] Natural population growth rate is the birth rate minus the death rate. From the available data, we could have estimated the migration numbers for the districts for the period 1991 to 1994 but they could not be classified by rural and urban areas. Hence the rural and urban population growth rate does not include migration.

[16] The data sources for the socio-economic variables are Human Development Reports published by National Council for Applied Economic Research (NCAER), India; various reports from International Institute for Population Sciences (IIPS) ; data portal site 'www.indiastat.com'

[17] We could not get data on these variables for 1994-95, the beginning of the study period as these data are available for census years only (for eg. 1981, 1991, 2001). Hence 1991 socio-economic data was the best choice for this study.

implication of their model. The effect of income inequality on environmental change has not been taken into account in any of the prior studies in this literature.

Despite the dominant view in the literature that poverty causes environmental degradation, there are some contradicting empirical evidences. Some studies show that traditional communities have managed the resources efficiently despite their poverty (Tiffen, Mortimore & Gichuki, 1994) while others show that it is not the poor but the non-poor population that deplete the rural environment (Ravnborg, 2003). Hence the effect of poverty on vegetation degradation is an empirically testable issue. We want to test the dominant hypothesis:

Hypothesis 1. Higher rural poverty leads to increased environmental degradation.

Since vegetation change is our measure of change in environmental quality, we test this hypothesis by estimating the effect of rural poverty on vegetation change. We include both initial level of poverty and change in poverty to assess the impact of poverty on vegetation change.

Turning to the other direction of the relationship, as mentioned earlier, the literature acknowledges that the strong dependence of the rural poor on natural resource extraction makes them vulnerable to environmental changes. In the absence of (or limited) alternative employment opportunities, access to credit and capital markets and government policy interventions, environmental degradation is expected to negatively affect the severity of poverty. This observation leads to the second hypothesis of the study:

Hypothesis 2. Environmental degradation increases the severity of poverty.

This hypothesis is tested by estimating the effect of vegetation change on change in rural poverty. Significant evidence in support of these two hypotheses would indicate the existence of a poverty-environment nexus in the study region.

4. Empirical Estimation Strategy

In order to empirically test the two hypotheses, we employ a set of linear regressions:

$$\Delta E = \alpha_1 + \beta_1 \Delta P + \gamma_1 X_1 + \varepsilon_1$$

$$\Delta P = \alpha_2 + \beta_2 \Delta E + \gamma_2 X_2 + \varepsilon_2$$

Where

ΔE: Change in environmental quality (*1994-95 to 2000-01)*

ΔP: Change in poverty index (*1994-95 to 2000-01)*

X_i : Exogenous explanatory variables in equation *i* (see Table 4 for details)

The poverty-environment nexus hypothesis hypothesizes a spiraling relationship between environmental degradation and increase in poverty. Hence we want to assess the effect of change in severity of poverty on environmental change and vice versa. In order to capture the dynamics of the relationship using cross sectional variations, the dependent variables have been used in form of changes rather than levels[18]. The district level rural socio-economic variables for the year 1991 depict the initial socio-economic conditions of the districts[19]. We use two alternative measures of environmental quality – overall vegetation represented by NDVI and high quality vegetation (an approximate measure of forests) represented by z-NDVI. We also use two alternative measures of poverty – poverty gap index (PGI) and squared poverty gap (SPG).

Exogenous Explanatory Variables for Vegetation Change Regression: Beyond the impact of change in poverty, environmental change is expected to be influenced by climatic factors,

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[18] The ideal dataset would be a panel dataset spanning across a long period of time that can capture the long run dynamics of the relationship. But given the problems associated with availability of data (i.e. although satellite imagery data is available for two decades, but we could construct district level rural poverty only for two time points and the other district level rural socio-economic variables are available only for 1991), this is the second-best alternative way to address the dynamic nature of the relationship.

[19] Banerjee and Somanathan (2005) and Chopra and Gulati (1997) use similar empirical models i.e. dependent variable is in form of change and explanatory variables are at levels and changes, although these studies analyze different issues than our study.

demographic factors, income distribution, land use pattern and other socio-economic factors represented by 'X_1' in the model above. Initial vegetation (1994-95) and average rainfall (1994-2000) represent the climatic factors. Rural population growth rate (1991-94) and rural population density (1991) represent the rural demographic factors. Rural per capita consumption expenditure (1994-95), initial rural poverty (1994-95) and rural Gini-coefficient (1994-95) represent the rural income distribution. Proportion of area under agriculture represented by proportion of net sown area indicates initial land use pattern. Rural literacy rate (1991), rural sex ratio (1991), rural life expectancy at birth (1991) and rural female work force participation rate (1991) are the social indicators that can affect environmental change. Literacy rate is an indicator of general education and awareness about the importance of environment. Higher sex ratio (female to male) and lower female work force participation rate represent greater availability of female labor for resource extraction. The extent of urbanization of a district can affect the environmental change. These are captured by proportion of urban population (1991), urban population growth rate (1991-94), urban population density (1991) and urban per capita consumption expenditure (1994-95). The level of initial poverty represents the history prior to 1994. Hence initial poverty level is treated as an exogenous variable. However the change in poverty (1994-95 to 2000-01) is contemporaneous with respect to environmental change and hence it is treated as an endogenous variable that is identified by the socio-economic variables described below.

Identifying Rural Poverty Change. We seek to identify poverty change in our environmental change regressions using two instruments - district level rural infant death rate (1991) and average rural household size (1991). In judging the merits of these instruments, several issues arise. First, are these strong instruments in the sense that are these indeed highly correlated with poverty change? Rural infant death rate is a health indicator that is expected to explain average productivity and poverty variations across rural areas of the districts as poor health conditions (indicated by high infant mortality rate) are expected to negatively affect productivity and thus is expected to be associated with higher poverty. Average household size is a socio-economic variable that can affect poverty as larger household size is expected to increase the severity of poverty. This argument is based on the positive correlation between larger family size and high dependency ratio (i.e. larger family sizes indicate larger proportion of household members are children and elderly who are dependent on the smaller proportion of the working age members). Following standard practice (Bound, et al., 1995), we assess the instruments' strength from their performance in a first stage regression of poverty change on all exogenous variables in our model. As reported in the first stage regression results in Table 5b, the instruments perform well in these regressions as they have the expected signs (positive coefficients) and are statistically significant.

Second, are these instruments exogenous to environmental change? For example, in principle, rural infant death rate and rural average household size can affect rural population growth, which in turn affect environmental change; could these effects imply that our instruments are correlated with the error in the poverty regressions? We expect the answer to be "no" because we control for the likely channel through which such effects may manifest themselves i.e. population growth rate in the rural sector. Since the instruments, death rate and infant mortality rate capture the health status of the rural areas, one might argue that better health status implies longer life expectancy and people living longer might care for preserving natural resources more than those with shorter life expectancies. We did not expect this effect to be strong enough in rural India, yet we mitigated the doubt by including life expectancy at birth as a regressor. By controlling for life expectancy, we are controlling for the channel through which better health status might have any effect on resource conservation. We provide the Hansen's J test statistics that tests the moment conditions for the validity of these instruments at the end of Table 5a. Since the test statistics indicate that the null hypothesis (the instruments are orthogonal to the error term) cannot be rejected, it provides evidence in support of our argument that the instruments are exogenous to environmental change.

Exogenous Explanatory Variables for Poverty Change Regression: Beyond the impacts of the environment, poverty change is influenced by initial income distribution (initial poverty level, average income and Gini coefficient) and socio-economic factors like population growth rate, population density, literacy, health services (infant mortality rate is an indicator of average health services), female work force participation, average household size, sex ratio, as has been depicted in the literature on poverty (e.g. Subramaniyan, 1984; Mink, 1993; Ravallion and Dutt, 2002; Jha, 2001; Gupta and Mitra, 2004). Vegetation change is the endogenous variable that is instrumented with a climatic variable described below.

Identifying Environmental Change. We seek to identify environmental change in our poverty regressions using our district level rainfall measure. In judging the merits of this instrument, several issues arise as mentioned earlier. First, is it a strong instrument in the sense that is it indeed highly correlated with environmental change? We assess the instrument's strength from its performance in a first stage regression of environmental change on all exogenous variables in our model. As reported at the end of Table 6b, the instrument performs well in these regressions as rainfall has significant positive effect on vegetation change.

Second, is our instrument exogenous to poverty? For example, one might argue that rainfall may affect agricultural productivity, which in turn affects poverty; could these effects imply that our instrument is correlated with the error in the poverty regressions? We again expect the answer to be "no" because we control for the likely channels through which such effects may manifest themselves, including incomes in the rural sector, the initial state of the environment, the extent of agricultural cultivation (net sown area) and most importantly the deviations in rainfall from the normal – both positive and negative. The rainfall deviations capture the plausible shocks that can affect change in poverty – i.e. change in agricultural productivity in case of floods and droughts as well as loss of assets in case of floods. Since rainfall beyond a certain normal range has productivity hampering effect[20], by controlling for deviations we control for the channel through which the agricultural productivity can be affected which in turn can affect poverty. Hence controlling for rainfall deviations, the average rainfall represents a climatic variation across districts that can affect variations in vegetation only. We tried two alternative pairs of measures of rainfall deviations. One pair represents extreme positive and negative deviations (i.e. magnitude of deviation over the benchmark described in the data section) and the other pair represents overall positive and negative deviations beyond the norm. The results are reported for the models using the extreme measures[21].

To account for the endogeneity of poverty change in the vegetation change regression and vice versa, the empirical models have been estimated by the single equation two-step generalized method of moments (GMM) estimation procedure that yields consistent estimates of the coefficients as well as the standard errors of the coefficients.

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[20] See Azzam and Sekkat's study on Morocco that distinctly separates out the effect of rainfall on total factor productivity and provides the argument that rainfall deviations beyond a certain norm affects productivity and the positive and negative deviations have different effects.

[21] The results were qualitatively similar with the other pair of rainfall deviations i.e. sum of positive and negative rainfall deviations.

5. Results

Table 5a and 5b present the vegetation change regression results and tables 6a-6c present the poverty change regression results. A number of conclusions are evident from these estimation results.

Vegetation Change Regression Results

i) *Rural poverty negatively affects environmental quality.* Rural poverty change (1994-95 to 2000-01) as well as the initial level of poverty (1994-95) has statistically significant negative effect on the environmental quality change (1994-95 to 2000-01) in all the model specifications. The result is robust for the different measures of poverty as well as environmental quality. Hence we find very strong evidence in support of our hypothesis that rural poverty aggravates vegetation degradation.

ii) *Rural per capita consumption expenditure negatively affects environmental quality.* This result is also robust across model specifications. It indicates that districts with higher initial rural per capita consumption expenditure, our proxy for per capita income, experienced more environmental degradation. This is consonant with the view that in a developing country setup higher levels of economic activity comes at the cost of greater resource degradation.

iii) *Greater availability of rural female labor tends to worsen environmental decline*. Higher rural sex (female to male) ratios and lower rural rates of female workforce participation, both of which imply a greater availability of female labor for resource gathering activities, have a statistically significant negative effect on environmental change.

iv) *Environmental scarcity spurs environmental improvement*. Significant negative effect of initial environmental quality (for both types of environmental quality measures) indicates prior environmental scarcity generates subsequent environmental improvement. The positive effect of net sown area (higher net sown area is reflection of scarcity of high quality vegetation like forests) on z-NDVI change further strengthen the conclusion that prior environmental degradation is offset, to some extent, by subsequent environmental improvement.

v) *Higher rural income inequality improves high quality vegetation.* The positive effect of rural Gini coefficient provides evidence in support of the Ikefuji & Horii (2005) model prediction that suggests that controlling for average income and poverty, higher income inequality implies that the richer segment has more investment capacity that can be invested for environmental improvement. It is worth noting that rural poverty aggravates vegetation degradation not only by over extraction but also due to lack of investment ability to maintain the natural resources, referred to as investment poverty by Reardon & Vosti (1995).

vi) *Higher proportion of urban population has negative effect on environmental quality.* It indicates that urbanization has damaging effect of vegetation change.

vii) *Literacy rate boosts high quality vegetation.* Literacy is a very crude measure of education. Yet it reflects that higher literacy can create awareness that can benefit the vegetation. This is especially the case for high quality vegetation (z-NDVI change) that represents the forests.

Poverty Change Regression Results

i) The overall effect of environmental change on rural poverty change appears to be statistically insignificant for all the GMM models reported in table 6a. We expected sub-regions specific differences in the effect of environmental change on poverty might be driving this result. Hence we tried breaking the environmental change intro three regions based on geographic and climatic factors[22]. Group 1 consists districts in the states of Gujarat and Rajasthan; Group2 consists

[22] We also tested the hypothesis of distinct region specific effects of poverty on vegetation change. The null hypothesis of equality of the region specific effects could not be rejected. Hence we have presented the overall results for vegetation change regressions.

of districts in the states of Maharashtra, Madhya Pradesh and Karnataka; Group3 consists of districts in the states of Andhra Pradesh, Kerala, and Tamilnadu. The states included in region 1 fall in the most arid part of India, those in region 2 are in the medium range in terms of normal annual rain and the states in region 3, with the exception of Andhra Pradesh[23], get the maximum average annual rainfall amongst the states included in our study region (see Table 2a for state level rainfall). When the environmental changes are broken into these three groups – the group specific environmental change effects are statistically different from each other as is depicted by the strong rejection of the null hypothesis of equality of these effects (test statistics reported at end of Table 6c). The group specific effects of vegetation change on poverty change are significant and negative as reported in table 6c. This implies that in all the sub-regions vegetation deterioration spurs rural poverty but the magnitude of the effect varies.

ii) *Rural infant death rate and average household size increases rural poverty.* The statistically significant positive effect of rural infant death rate and average household size on rural poverty provides evidence in support of our argument that these are measures of poor health and dependency ratio that intensify poverty.

iii) *Districts with higher initial rural poverty experienced greater reduction in poverty.* This might be attributed to stronger policy interventions to aid poorer districts.

iv) *Net sown area has negative effect on poverty change*. Since, net sown area is indicative of agricultural intensity in a district, combined with the result that net sown area has positive effect on environmental quality, it implies agriculture can aid in environmental improvement as well as poverty reduction.

[23] We also tried an alternate grouping with Andhra Pradesh in group 1, with the low rain states. The results were qualitatively similar.

6. Conclusion

The aim of the study was to empirically test the bi-directional relationship between rural poverty and environmental change while accounting for their joint endogeneity. The results provide evidence in consonance with the dominant view in the literature that rural poverty spurs vegetation degradation. We find that vegetation degradation spurs rural poverty but the magnitude of the effect varies across sub regions classified on the basis of geographic and climatic factors. Together, these two results indicate a cyclical relationship i.e. vegetation deterioration spurs rural poverty and rural poverty spurs vegetation degradation – thereby providing evidence in support of the poverty environment nexus in the study region.

The results also bring forward several other interesting aspects. Negative effect of rural per capita consumption expenditure (proxy for per capita income) and positive effect of rural Gini coefficient (for high quality vegetation) highlights the fact that income distribution plays an important role in vegetation change. This implies that the literature on relationship between economic growth and environmental quality (represented by the empirical Environmental Kuznets Curve studies – e.g. Grossman and Krueger, 1994; Seldon and Song, 1994) that typically use per capita income to represent level of economic progress should take into account the income distribution aspect as well. The result that environmental scarcity spurs environmental improvement, provides support to the Boserupian school of thought that argues that resource scarcity generates demand for resource conservation and thereby producing resource conserving management or technological innovations. The results also depict that social factors also play important role in environmental change and poverty change. While greater availability of female labor for resource extraction spurs environmental degradation, higher literacy rate can help in improving high quality vegetation i.e. forests. Evidence also suggests that larger household size and higher infant mortality spurs rural poverty. Thus this study provides some important insights into the interrelationship between vegetation change and poverty change and other socio-economic factors affecting them that might be useful for policy formulations for rural development and environmental planning.

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Figure 1. The Study Region

Table 1: Variables Definitions

Variable Name	Description
Initial NDVI	NDVI 1994-95
NDVI ch	Change in average NDVI from 1994-95 to 2000-01
Initial z-NDVI	z-NDVI 1995-95
z-NDVI ch	Change in z-NDVI from 1994-95 to 2000-01
Rainfall	Average rainfall in centimeters (1994 to 2000)
+ Deviation in Rain	Sum of positive deviations in rainfall from the normal (1994 to 2000)
- Deviation in Rain	Sum of negative deviations in rainfall from the normal (1994 to 2000)
Net Sown Area	Net sown area as a proportion of total district area (1991)
Initial PGI	Poverty gap index for 1994-95 (NSS round 51)
Initial SPG	Squared poverty gap for 1994-95 (NSS round 51)
PGI ch	Change in PGI from 1994-95 to 2000-01
SPG ch	Change in SPG from 1994-95 to 2000-01
Initial GINI	Gini coefficient for 1994-95 (NSS round 51)
Cons Exp	Per capita average monthly consumption expenditure (1994-95) (unit – hundreds, Rupees)
Popn Growth	Births minus deaths (1991 to 1994) per thousand 1991 population
Popn Density	Population (in thousands) per square kilometer in 1991
Urban Popn	% of urban population in a district (1991)
Female Workers	Females in workforce as percentage of working age female population (1991)
Infant Death Rate	Infant deaths per thousand live births (1991)
Literacy Rate	Literates per thousand population (1991)
Avg Hh Size	Average household size(1991)
Sex Ratio	Females per thousand male(1991)
Life Expectancy	Life expectancy at birth (1991)

Table 2. Summary Statistics

	Min	Max	Mean	Sdev
ENVIRONMENTAL VARIABLES				
Initial NDVI	139.63	198.8	174.16	11.51
NDVI ch	-18.99	8.5	-10.26	4.63
Initial z-NDVI	-5.20	1.68	-0.19	0.97
z-NDVI ch	-1.41	0.72	-0.57	0.35
Net Sown Area	0.05	0.83	0.51	0.16
Rainfall	27.89	346.51	113.17	84.47
+ Deviation in Rain	6.98	136.49	58.29	31.93
- Deviation in Rain	-109.72	-15.51	-46.39	24.26
INCOME DISTRIBUTION VARIABLES				
Initial PGI	0.04	0.46	0.22	0.08
Initial SPG	0.01	0.26	0.09	0.05
Initial GINI	0.13	0.58	0.24	0.06
PGI ch	-0.18	0.33	0.06	0.10
SPG ch	-0.14	0.23	0.036	0.06
GINI ch	-0.45	0.18	0.002	0.07
Cons Exp(R)	2.04	8.65	3.56	.93
Cons Exp(U)	2.92	9.09	4.71	1.01
SOCIO-ECONOMIC VARIABLES				
Popn Growth Rate(R)	-3.72	91.36	19.5	18.86
Popn Growth Rate(U)	5.28	229.58	77.39	41.38
Popn Density(R)	0.007	1.236	0.223	0.190
Popn Density(U)	0	27.49	3.015	2.677
Urban Population	3.41	86.16	24.79	14.32
Sex Ratio(R)	786	1230	958.42	57.98
Literacy Rate(R)	13.74	95.67	46.60	17.92
Female Workers(R)	2.18	58.82	28.16	13.36
Infant Death Rate(R)	0.91	88.6	23.33	18.01
Avg Hh Size(R)	3.74	7.07	5.39	0.71
Life Expectancy(R)	39.5	74.9	60.52	7.33

Table 2a. State level average annual rainfall

State	Annual Rainfall (cm)
Andhra Pradesh	60.47
Gujarat	64.96
Karnataka	98.49
Kerala	185.02
Madhya Pradesh	95.29
Maharashtra	94.41
Rajasthan	55.49
Tamilnadu	307.32

Table 3. Official Poverty Line (Monthly per capita expenditure in Rupees)

	Rural (1993-94)	Urban (1993-94)	Rural (2000-01)	Urban (2000-01)
Andhra Pradesh	163.02	278.14	262.94	457.40
Gujarat	202.11	297.22	318.94	474.41
Karnataka	186.63	302.89	309.59	511.44
Kerala	243.84	280.54	374.79	477.06
Madhya Pradesh	193.1	317.16	311.34	481.65
Maharashtra	194.94	328.56	318.63	539.71
Rajasthan	215.89	280.85	344.03	465.92
Tamil Nadu	196.53	296.63	307.64	475.60
India	205.84	281.35	327.56	454.11

Table 4. Model Structure

	X1	X2
ENVIRONMENTAL VARIABLES		
Initial Environmental quality	√	√
Lagged Δ Environmental quality	√	√
Rainfall	√	
+ Deviation in Rain	√	√
- Deviation in Rain	√	√
Net Sown Area	√	√
INCOME DISTRIBUTION VARIABLES		
Initial Poverty(R)	√	√
Per capita Cons Expenditure(R)	√	√
Per capita Cons Expenditure(U)	√	√
Initial Gini(R)	√	√
SOCIO ECONOMIC VARIABLES		
Population Growth Rate(R)	√	√
Population Growth Rate(U)	√	√
Population density (R)	√	√
Population density (U)	√	√
Urban Population	√	√
Literacy rate (R)	√	√
Female workers(R)	√	√
Sex ratio(R)	√	√
Life Expectancy at Birth (R)	√	√
Infant death rate (R)		√
Average household size(R)		√

X1 : exogenous explanatory variables in Environmental Change regressions
X2 : exogenous explanatory variables in Poverty Change regressions

Table 5a. Environmental Change Regressions

Dependent Variable:	NDVI change (1994 – 2001)				z-NDVI change (1994 – 2001)			
	(1) OLS	(2) GMM	(3) OLS	(4) GMM	(5) OLS	(6) GMM	(7) OLS	(8) GMM
ENVIRONMENTAL VARIABLES								
Initial NDVI(1994)	-0.2695***	-0.2652***	-0.2636***	-0.2466***				
	(0.000)	(0.000)	(0.000)	(0.000)				
Lagged NDVI ch(1991-1994)	-0.2264*	-0.0429	-0.2157	-0.0300				
	(0.093)	(0.799)	(0.111)	(0.859)				
Initial z-NDVI(1994)					-0.2608***	-0.2593***	-0.2584***	-0.2475***
					(0.000)	(0.000)	(0.000)	(0.000)
Lagged z-NDVI ch(1991-1994)					-0.1933***	-0.1396	-0.1944***	-0.1412
					(0.010)	(0.230)	(0.010)	(0.223)
Net Sown Area(1991)	0.9244	-0.8994	0.7693	-1.4167	0.4083***	0.3359**	0.3999***	0.3133*
	(0.648)	(0.677)	(0.707)	(0.518)	(0.006)	(0.041)	(0.008)	(0.064)
Average Rainfall(1994-2001)	0.0392***	0.0390***	0.0382***	0.0396***	0.0029***	0.0030***	0.0028***	0.0030***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
+ Deviation in Rain(1994-2001)	0.0184	0.0158	0.0161	0.0103	0.0003	0.0002	0.0002	-0.0001
	(0.156)	(0.228)	(0.219)	(0.460)	(0.779)	(0.855)	(0.859)	(0.877)
- Deviation in Rain(1994-2001)	0.0484**	0.0299	0.0453*	0.0272	0.0039**	0.0033**	0.0037**	0.0032**
	(0.040)	(0.217)	(0.057)	(0.274)	(0.027)	(0.021)	(0.037)	(0.034)
INCOME DISTRIBUTION VARIABLES								
PGI ch(1994-2001)	-7.9028**	-33.7764***			-0.4366*	-1.6858**		
	(0.016)	(0.003)			(0.083)	(0.011)		
Initial PGI(1994)	-23.0160***	-38.3060***			-1.5120***	-2.2830***		
	(0.000)	(0.000)			(0.001)	(0.000)		
SPG ch(1994-2001)			-10.2898**	-55.1949***			-0.4852	-2.7585***
			(0.045)	(0.003)			(0.213)	(0.009)
Initial SPG(1994)			-33.8340***	-61.6241***			-2.3831***	-3.7669***
			(0.001)	(0.000)			(0.002)	(0.000)
Cons exp (R)(1994)	-2.7449***	-2.2512***	-2.5777***	-2.2080***	-0.2320***	-0.2056***	-0.2323***	-0.2082***
	(0.000)	(0.006)	(0.000)	(0.005)	(0.000)	(0.001)	(0.000)	(0.000)
Cons exp (U)(1994)	-0.2598	-0.5236	-0.2432	-0.5078	-0.0437*	-0.0572**	-0.0414*	-0.0559**
	(0.417)	(0.158)	(0.453)	(0.184)	(0.077)	(0.023)	(0.095)	(0.029)
Initial Gini(1994)	7.9546	7.9142	8.4638	9.1833	0.9656*	0.9499**	1.0959*	1.0981**
	(0.250)	(0.272)	(0.249)	(0.238)	(0.074)	(0.050)	(0.055)	(0.033)

Dependent Variable:	NDVI change (1994 - 2001)				z-NDVI change (1994 - 2001)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM
SOCIO-ECONOMIC VARIABLES								
Popn Growth Rate(R)(1991-1994)	-0.0228	0.0095	-0.0223	0.0137	-0.0009	0.0009	-0.0009	0.0012
	(0.182)	(0.673)	(0.200)	(0.545)	(0.506)	(0.502)	(0.523)	(0.402)
Popn Growth Rate(U)(1991-1994)	-0.0031	-0.0153	-0.0027	-0.0175	-0.0003	-0.0008	-0.0002	-0.0009
	(0.728)	(0.184)	(0.766)	(0.151)	(0.689)	(0.317)	(0.762)	(0.295)
Popn density (R)(1991)	3.1875	3.0072	3.1953	3.2639	-0.0341	-0.0304	-0.0340	-0.0246
	(0.155)	(0.292)	(0.160)	(0.273)	(0.843)	(0.885)	(0.844)	(0.908)
Popn density (U)(1991)	-0.0080	-0.0157	0.0158	0.0079	-0.0142	-0.0152	-0.0128	-0.0139
	(0.944)	(0.894)	(0.891)	(0.944)	(0.105)	(0.139)	(0.145)	(0.169)
Urban popn(1991)	-0.0360	-0.0716**	-0.0294	-0.0654**	-0.0025	-0.0043**	-0.0021	-0.0038*
	(0.125)	(0.024)	(0.213)	(0.040)	(0.168)	(0.032)	(0.250)	(0.056)
Literacy rate (R)(1991)	0.0704**	0.0509	0.0691**	0.0491	0.0064***	0.0051**	0.0064***	0.0050**
	(0.022)	(0.147)	(0.026)	(0.162)	(0.007)	(0.046)	(0.007)	(0.048)
Female workers(R)(1991)	0.0971***	0.1069***	0.0932***	0.1053***	0.0106***	0.0109***	0.0103***	0.0107***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Sex ratio(R)(1991)	-0.0102	-0.0184**	-0.0098	-0.0176**	-0.0013**	-0.0016***	-0.0012**	-0.0016***
	(0.128)	(0.026)	(0.149)	(0.037)	(0.016)	(0.003)	(0.019)	(0.005)
Life Expectancy(R)(1991)	0.0727*	-0.0294	0.0814*	-0.0418	0.0059*	0.0008	0.0065*	0.0002
	(0.096)	(0.613)	(0.068)	(0.511)	(0.085)	(0.835)	(0.060)	(0.960)
Constant	48.9903***	67.6799***	44.2437***	61.2848***	0.6643	1.5905**	0.4394	1.4222**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.230)	(0.015)	(0.417)	(0.027)
Observations	172	172	172	172	172	172	172	172
R-squared	0.579		0.567		0.547		0.541	
Hansen J statistic		0.001		0.108		1.549		0.853
(OIR Test)		(0.9772)		(0.7429)		(0.2133)		(0.3558)
Pagan-Hall test		18.228		18.321		18.489		17.080
for Heteroskedasticity		(0.6345)		(0.6286)		(0.6179)		(0.7062)

p values in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Instruments for poverty change: Infant death rate and average household size

Table 5b. First Stage Estimates

	(1) PGI ch	(2) SPG ch	(3) PGI ch	(4) SPG ch
ENVIRONMENTAL VARIABLES				
Initial NDVI(1994)	-0.0002	0.0001		
	(0.773)	(0.873)		
Lagged NDVI ch(1991-1994)	0.0046	0.0028		
	(0.160)	(0.162)		
Initial z-NDVI(1994)			0.0103	0.0080
			(0.264)	(0.157)
Lagged z-NDVI ch(1991-1994)			0.05*	0.03*
			(0.066)	(0.082)
Net Sown Area(1991)	-0.1287**	-0.0839**	-0.1230***	-0.0833***
	(0.022)	(0.018)	(0.008)	(0.006)
Rainfall(1994-2001)	-0.0002	-0.0001	-0.0002	-0.0001
	(0.473)	(0.503)	(0.453)	(0.484)
+ Deviation in Rain(1994-2001)	0.0001	0.0000	0.0002	0.0000
	(0.631)	(0.966)	(0.515)	(0.864)
- Deviation in Rain(1994-2001)	-0.0009	-0.0006	-0.0008	-0.0005
	(0.105)	(0.122)	(0.127)	(0.138)
INCOME DISTRIBUTION VARIABLES				
Initial PGI (1994)	-0.8384***		-0.8776***	
	(0.000)		(0.000)	
Initial SPG (1994)		-0.8661***		-0.9030***
		(0.000)		(0.000)
Cons exp (R) (1994)	-0.0042	-0.0045	-0.0074	-0.0061
	(0.784)	(0.634)	(0.628)	(0.501)
Cons exp (U) (1994)	-0.0058	-0.0032	-0.0054	-0.0030
	(0.370)	(0.418)	(0.426)	(0.480)
Initial Gini (1994)	0.1759	0.1334	0.1930	0.1452
	(0.31)	(0.28)	(0.25)	(0.23)
SOCIO-ECONOMIC VARIABLES				
Popn Growth Rate(R) (1991-1994)	0.0006*	0.0004*	0.0006	0.0004*
	(0.099)	(0.072)	(0.112)	(0.082)
Popn Growth Rate(U) (1991-1994)	-0.0003	-0.0002*	-0.0003	-0.0002
	(0.104)	(0.088)	(0.163)	(0.134)
Popn density (R) (1991)	0.0205	0.0210	0.0080	0.0147
	(0.663)	(0.467)	(0.863)	(0.602)
Popn density (U) (1991)	-0.0009	-0.0004	-0.0010	-0.0005
	(0.737)	(0.785)	(0.681)	(0.722)
Urban popn(1991)	-0.0013**	-0.0007**	-0.0011 *	-0.0006*
	(0.020)	(0.046)	(0.051)	(0.097)
Literacy rate (R) (1991)	0.0002	0.0001	0.0001	0.0001
	(0.758)	(0.756)	(0.877)	(0.831)
Female workers(R) (1991)	0.0015**	0.0009**	0.0015**	0.0009**
	(0.031)	(0.035)	(0.041)	(0.044)
Sex ratio(R) (1991)	-0.0001	-0.0001	-0.0001	0.0000
	(0.416)	(0.595)	(0.607)	(0.783)
Life Expectancy(R)(1991)	-0.0038***	-0.0025***	-0.0040***	-0.0027***
	(0.000)	(0.000)	(0.000)	(0.000)
Inf Death Rate(R) (1991)	0.0015***	0.0011***	0.0017***	0.0012***
	(0.002)	(0.002)	(0.000)	(0.000)
Avg Hh Size(R) (1991)	0.0411***	0.0238**	0.0465***	0.0268***
	(0.004)	(0.011)	(0.001)	(0.003)
Constant	0.3871	0.1567	0.2853	0.1378
	(0.174)	(0.374)	(0.128)	(0.241)
Observations	172	172	172	172
F stats for Instruments	8.33***	8.27***	11.12***	10.86***
(Inf Death Rate & Avg Hh Size)	(0.0004)	(0.0004)	(0.0000)	(0.0000)

p values in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 6a. Poverty Regressions

Dependent Variable :	PGI change (1994 – 2001)				SPG change (1994 – 2001)			
	(1) OLS	(2) GMM	(3) OLS	(4) GMM	(5) OLS	(6) GMM	(7) OLS	(8) GMM
ENVIRONMENTAL VARIABLES								
NDVI ch(1994-2001)	-0.0031*	-0.0035			-0.0014	-0.0020		
	(0.092)	(0.425)			(0.233)	(0.460)		
Initial NDVI(1994)	-0.0010	-0.0011			-0.0003	-0.0004		
	(0.257)	(0.409)			(0.635)	(0.618)		
Lagged NDVI ch(1991-1994)	0.0039	0.0039			0.0024	0.0024		
	(0.197)	(0.152)			(0.216)	(0.155)		
z-NDVI ch(1994-2001)			-0.0279	-0.0440			-0.0091	-0.0253
			(0.234)	(0.407)			(0.551)	(0.441)
Initial z-NDVI(1994)			0.0029	-0.0009			0.0054	0.0016
			(0.801)	(0.953)			(0.469)	(0.877)
Lagged z-NDVI ch(1991-1994)			0.0395*	0.0374			0.0238*	0.0217
			(0.074)	(0.115)			(0.098)	(0.147)
Net Sown Area(1991)	-0.1169**	-0.1165**	-0.1059**	-0.1005**	-0.0774**	-0.0769**	-0.0758**	-0.0704**
	(0.017)	(0.018)	(0.028)	(0.030)	(0.015)	(0.016)	(0.016)	(0.024)
+ Deviation in Rain(1994-2001)	0.0002	0.0002	0.0001	0.0002	0.0000	0.0000	-0.0000	0.0000
	(0.550)	(0.545)	(0.590)	(0.473)	(0.993)	(0.887)	(0.919)	(0.864)
- Deviation in Rain(1994-2001)	-0.0007*	-0.0007*	-0.0006	-0.0006*	-0.0004*	-0.0004*	-0.0004	-0.0004*
	(0.084)	(0.055)	(0.124)	(0.082)	(0.093)	(0.073)	(0.131)	(0.097)
INCOME DISTRIBUTION VARIABLES								
Initial PGI(1994)	-0.8697***	-0.8735***	-0.8987***	-0.9138***				
	(0.000)	(0.000)	(0.000)	(0.000)				
Initial SPG(1994)					-0.8845***	-0.8933***	-0.9095***	-0.9366***
					(0.000)	(0.000)	(0.000)	(0.000)
Cons exp (R)(1994)	-0.0109	-0.0116	-0.0133	-0.0167	-0.0073	-0.0083	-0.0079	-0.0114
	(0.549)	(0.462)	(0.459)	(0.344)	(0.530)	(0.361)	(0.494)	(0.263)
Cons exp (U)(1994)	-0.0067	-0.0069	-0.0066	-0.0074	-0.0037	-0.0039	-0.0033	-0.0041
	(0.380)	(0.261)	(0.381)	(0.274)	(0.461)	(0.309)	(0.498)	(0.328)
Initial Gini(1994)	0.1831	0.1827	0.2169	0.2269	0.1364	0.1361	0.1537	0.1661
	(0.284)	(0.243)	(0.205)	(0.148)	(0.241)	(0.227)	(0.188)	(0.138)

Dependent Variable :	PGI change (1994 - 2001)				SPG change (1994 - 2001)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM
SOCIO-ECONOMIC VARIABLES								
Popn Growth Rate(R)(1991-1994)	0.0006	0.0006	0.0006	0.0006*	0.0004	0.0004*	0.0004*	0.0004*
	(0.137)	(0.110)	(0.109)	(0.093)	(0.110)	(0.075)	(0.089)	(0.062)
Popn Growth Rate(U)(1991-1994)	-0.0004*	-0.0004*	-0.0003	-0.0003*	-0.0002*	-0.0002*	-0.0002*	-0.0002*
	(0.091)	(0.062)	(0.114)	(0.097)	(0.072)	(0.054)	(0.088)	(0.083)
Popn density (R)(1991)	0.0272	0.0287	0.0041	0.0036	0.0235	0.0256	0.0126	0.0120
	(0.614)	(0.545)	(0.939)	(0.936)	(0.502)	(0.381)	(0.715)	(0.663)
Popn density (U)(1991)	-0.0008	-0.0008	-0.0014	-0.0016	-0.0004	-0.0003	-0.0006	-0.0008
	(0.757)	(0.736)	(0.600)	(0.533)	(0.830)	(0.803)	(0.715)	(0.577)
Urban popn(1991)	-0.0014**	-0.0014***	-0.0012**	-0.0012**	-0.0007**	-0.0007**	-0.0006*	-0.0006**
	(0.012)	(0.005)	(0.033)	(0.014)	(0.036)	(0.016)	(0.076)	(0.038)
Literacy rate (R)(1991)	0.0003	0.0004	0.0002	0.0003	0.0002	0.0002	0.0001	0.0002
	(0.660)	(0.564)	(0.764)	(0.616)	(0.721)	(0.579)	(0.818)	(0.590)
Female workers(R)(1991)	0.0017**	0.0017**	0.0017**	0.0019**	0.0010**	0.0010**	0.0009**	0.0011**
	(0.018)	(0.020)	(0.022)	(0.035)	(0.033)	(0.024)	(0.049)	(0.041)
Sex ratio(R)(1991)	-0.0002	-0.0002	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0001
	(0.252)	(0.271)	(0.447)	(0.383)	(0.442)	(0.420)	(0.671)	(0.530)
Life Expectancy(R)(1991)	-0.0035***	-0.0034***	-0.0038***	-0.0037***	-0.0024***	-0.0023***	-0.0026***	-0.0025***
	(0.001)	(0.002)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.001)
Infant death rate (R)(1991)	0.0013***	0.0013***	0.0015***	0.0015***	0.0010***	0.0009***	0.0011***	0.0010***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)	(0.002)	(0.000)	(0.000)
Avg hh size (R)(1991)	0.0368**	0.0361**	0.0456***	0.0451***	0.0217**	0.0208**	0.0263***	0.0259***
	(0.012)	(0.015)	(0.001)	(0.001)	(0.020)	(0.040)	(0.004)	(0.003)
Constant	0.5583**	0.5795*	0.3195	0.3274*	0.2353	0.2661	0.1538	0.1611
	(0.033)	(0.096)	(0.109)	(0.066)	(0.164)	(0.218)	(0.235)	(0.145)
Observations	172	172	172	172	172	172	172	172
R-squared	0.505		0.508		0.462		0.464	
Pagan Hall Test		18.574		16.371		21.453		18.689
For Heteroskedasticity		(0.6124)		(0.7484)		(0.4316)		(0.6051)

p values in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Instrument for vegetation change: Rainfall

Table 6b. First Stage Estimates

	(1) NDVI ch	(2) z-NDVI ch	(3) NDVI ch	(4) z-NDVI ch
ENVIRONMENTAL VARIABLES				
Initial NDVI(1994)	-0.2579***		-0.2558***	
	(0.000)		(0.000)	
Lagged NDVI ch(1991-1994)	-0.1976		-0.1791	
	(0.223)		(0.255)	
Initial z-NDVI(1994)		-0.2556***		-0.2539***
		(0.000)		(0.000)
Lagged z-NDVI ch(1991-1994)		-0.2256**		-0.2223**
		(0.029)		(0.032)
Net Sown Area(1991)	3.4656	0.5131***	3.4567	0.5104***
	(0.114)	(0.004)	(0.115)	(0.004)
Rainfall(1994-2001)	0.0442***	0.0035***	0.0435***	0.0035***
	(0.000)	(0.000)	(0.000)	(0.000)
+ Deviation in Rain(1994-2001)	0.0109	-0.0001	0.0093	-0.0001
	(0.385)	(0.955)	(0.455)	(0.898)
- Deviation in Rain(1994-2001)	0.0600***	0.0049***	0.0578***	0.0047***
	(0.003)	(0.001)	(0.004)	(0.002)
INCOME DISTRIBUTION VARIABLES				
Initial PGI (1994)	-9.9788*	-0.8231*		
	(0.090)	(0.097)		
Initial SPG (1994)			-13.4186	-1.3287
			(0.154)	(0.077)
Cons exp (R) (1994)	-2.1037**	-0.2124***	-1.8880**	-0.2076***
	(0.012)	(0.001)	(0.018)	(0.001)
Cons exp (U) (1994)	-0.3298	-0.0459**	-0.3411	-0.0455**
	(0.326)	(0.048)	(0.310)	(0.051)
Initial Gini (1994)	1.9442	0.7722	1.3320	0.8268
	(0.768)	(0.127)	(0.846)	(0.108)
SOCIO-ECONOMIC VARIABLES				
Popn Growth Rate(R) (1991-1994)	-0.0115	-0.0001	-0.0095	0.0000
	(0.470)	(0.927)	(0.557)	(0.976)
Popn Growth Rate(U) (1991-1994)	-0.0038	-0.0005	-0.0040	-0.0005
	(0.685)	(0.495)	(0.676)	(0.516)
Popn density (R) (1991)	2.3279	-0.1004	2.2631	-0.1047
	(0.400)	(0.618)	(0.421)	(0.603)
Popn density (U) (1991)	0.0132	-0.0122	0.0258	-0.0115
	(0.888)	(0.170)	(0.780)	(0.197)
Urban popn(1991)	-0.0288	-0.0025	-0.0268	-0.0023
	(0.205)	(0.150)	(0.244)	(0.186)
Literacy rate (R) (1991)	0.0438	0.0052*	0.0406	0.0050*
	(0.258)	(0.073)	(0.295)	(0.077)
Female workers(R) (1991)	0.0549*	0.0088***	0.0512*	0.0085***
	(0.069)	(0.001)	(0.082)	(0.001)
Sex ratio(R) (1991)	-0.0135*	-0.0015***	-0.0141**	-0.0015***
	(0.062)	(0.006)	(0.052)	(0.006)
Life Expectancy(R)(1991)	0.0983**	0.0070**	0.1017**	0.0071**
	(0.014)	(0.018)	(0.011)	(0.015)
Inf Death Rate(R) (1991)	-0.05***	0.00***	-0.05***	0.00***
	(0.01)	(0.00)	(0.01)	(0.00)
Avg Hh Size(R) (1991)	-1.4029	-0.0312	-1.5109**	-0.0359
	(0.060)	(0.558)	(0.034)	(0.482)
Constant	54.7168***	0.9575*	53.9770***	0.9236*
	(0.000)	(0.091)	(0.000)	(0.104)
Observations	172	172	172	172
F stats for Instrument (Rainfall)	23.40***	30.13***	23.59***	30.18***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

p values in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6c. Poverty Regressions with Groups

Dependent Variable:	PGI change (1994 - 2001)				SPG change (1994 - 2001)			
	(1) OLS	(2) GMM	(3) OLS	(4) GMM	(5) OLS	(6) GMM	(7) OLS	(8) GMM
ENVIRONMENTAL VARIABLES								
Group 1 NDVI ch(1994-2001)	-0.0004	-0.0061*			0.0004	-0.0035		
	(0.844)	(0.100)			(0.803)	(0.139)		
Group 2 NDVI ch(1994-2001)	-0.0069***	-0.0165***			-0.0039***	-0.0098***		
	(0.001)	(0.000)			(0.003)	(0.000)		
Group 3 NDVI ch(1994-2001)	0.0009	-0.0121*			0.0011	-0.0073*		
	(0.708)	(0.052)			(0.484)	(0.071)		
Initial NDVI(1994)	-0.0013	-0.0048***			-0.0005	-0.0027**		
	(0.178)	(0.007)			(0.436)	(0.023)		
Lagged NDVI ch(1991-1994)	0.0015	0.0009			0.0008	0.0006		
	(0.607)	(0.757)			(0.676)	(0.744)		
Group 1 z-NDVI ch(1994-2001)			-0.0153	-0.0850*			0.0014	-0.0477
			(0.575)	(0.083)			(0.938)	(0.111)
Group 2 z-NDVI ch(1994-2001)			-0.1074***	-0.2750***			-0.0620***	-0.1645***
			(0.001)	(0.000)			(0.002)	(0.000)
Group 3 z-NDVI ch(1994-2001)			0.0210	-0.1561*			0.0202	-0.0969*
			(0.501)	(0.082)			(0.321)	(0.094)
Initial z-NDVI(1994)			-0.0005	-0.0444*			0.0025	-0.0254
			(0.966)	(0.069)			(0.744)	(0.109)
Lagged z-NDVI ch(1991-1994)			0.0399*	0.0176			0.0236*	0.0093
			(0.059)	(0.485)			(0.085)	(0.561)
Net Sown Area(1991)	-0.1222***	-0.1044**	-0.1014**	-0.0256	-0.0806***	-0.0691**	-0.0714**	-0.0237
	(0.009)	(0.034)	(0.031)	(0.662)	(0.008)	(0.031)	(0.019)	(0.535)
+ Deviation in Rain(1994-2001)	0.0006*	0.0014***	0.0005*	0.0014***	0.0003	0.0008***	0.0002	0.0008***
	(0.051)	(0.001)	(0.095)	(0.001)	(0.124)	(0.004)	(0.206)	(0.005)
- Deviation in Rain(1994-2001)	-0.0003	-0.0002	-0.0003	-0.0000	-0.0002	-0.0001	-0.0002	-0.0000
	(0.408)	(0.509)	(0.462)	(0.906)	(0.467)	(0.492)	(0.541)	(0.863)
INCOME DISTRIBUTION VARIABLES								
Initial PGI(1994)	-0.7893***	-0.8132***	-0.7935***	-0.8131***				
	(0.000)	(0.000)	(0.000)	(0.000)				
Initial SPG(1994)					-0.7994***	-0.8258***	-0.7917***	-0.8417***
					(0.000)	(0.000)	(0.000)	(0.000)
Cons exp (R)(1994)	-0.0017	-0.0110	-0.0024	-0.0194	-0.0015	-0.0076	-0.0008	-0.0136
	(0.924)	(0.458)	(0.888)	(0.260)	(0.891)	(0.391)	(0.941)	(0.184)
Cons exp (U)(1994)	-0.0080	-0.0079	-0.0094	-0.0137*	-0.0044	-0.0044	-0.0051	-0.0078
	(0.279)	(0.279)	(0.196)	(0.074)	(0.357)	(0.344)	(0.280)	(0.105)
Initial Gini(1994)	0.1030	-0.0155	0.1356	0.0883	0.0788	0.0080	0.0901	0.0772
	(0.540)	(0.928)	(0.417)	(0.596)	(0.491)	(0.946)	(0.429)	(0.499)

Dependent Variable:	**PGI change** (1994 - 2001)				**SPG change** (1994 - 2001)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM
SOCIO-ECONOMIC VARIABLES								
Popn Growth Rate(R)(1991-1994)	0.0006	0.0005	0.0007*	0.0006	0.0004*	0.0003	0.0005*	0.0004*
	(0.106)	(0.230)	(0.062)	(0.118)	(0.088)	(0.172)	(0.050)	(0.084)
Popn Growth Rate(U)(1991-1994)	-0.0005***	-0.0004*	-0.0005***	-0.0004*	-0.0004***	-0.0003*	-0.0004***	-0.0003*
	(0.009)	(0.095)	(0.008)	(0.058)	(0.007)	(0.079)	(0.005)	(0.054)
Popn density (R)(1991)	0.0582	0.0651	0.0463	0.0116	0.0434	0.0464	0.0388	0.0146
	(0.266)	(0.227)	(0.380)	(0.836)	(0.201)	(0.166)	(0.256)	(0.676)
Popn density (U)(1991)	-0.0004	0.0011	-0.0004	-0.0004	-0.0001	0.0008	-0.0000	-0.0001
	(0.871)	(0.671)	(0.864)	(0.880)	(0.935)	(0.578)	(0.990)	(0.939)
Urban popn(1991)	-0.0016***	-0.0017***	-0.0014***	-0.0017***	-0.0009***	-0.0010***	-0.0008**	-0.0010***
	(0.002)	(0.001)	(0.006)	(0.001)	(0.008)	(0.003)	(0.016)	(0.004)
Literacy rate (R)(1991)	0.0000	0.0002	0.0001	0.0004	-0.0000	0.0001	0.0000	0.0002
	(0.948)	(0.717)	(0.870)	(0.607)	(0.987)	(0.748)	(0.948)	(0.594)
Female workers(R)(1991)	0.0004	0.0011	0.0006	0.0016	0.0002	0.0007	0.0003	0.0010
	(0.578)	(0.230)	(0.410)	(0.128)	(0.715)	(0.248)	(0.595)	(0.136)
Sex ratio(R)(1991)	-0.0002	-0.0002	-0.0002	-0.0003	-0.0001	-0.0001	-0.0001	-0.0001
	(0.241)	(0.191)	(0.332)	(0.156)	(0.458)	(0.341)	(0.571)	(0.275)
Life Expectancy(R)(1991)	-0.0022**	-0.0020*	-0.0025**	-0.0020*	-0.0016**	-0.0015*	-0.0018***	-0.0015*
	(0.034)	(0.090)	(0.014)	(0.099)	(0.018)	(0.071)	(0.007)	(0.073)
Infant death rate (R)(1991)	0.0003	0.0001	0.0005	-0.0002	0.0003	0.0002	0.0004	0.0000
	(0.480)	(0.889)	(0.258)	(0.686)	(0.317)	(0.569)	(0.168)	(0.928)
Avg hh size (R)(1991)	0.0142	0.0008	0.0208	0.0057	0.0075	-0.0001	0.0103	0.0026
	(0.331)	(0.956)	(0.160)	(0.684)	(0.424)	(0.993)	(0.276)	(0.772)
Constant	0.7033***	1.3087***	0.4192**	0.4844***	0.3362**	0.7090***	0.2206*	0.2551**
	(0.006)	(0.000)	(0.029)	(0.006)	(0.043)	(0.002)	(0.076)	(0.020)
Observations	172	172	172	172	172	172	172	172
R-squared	0.565		0.562		0.526		0.523	
F test for instruments in Ist Stage								
Group 1 NDVI ch(1994-2001)		132.87***		77.17***		134.11***		75.40***
		(0.0000)		(0.0000)		(0.0000)		(0.0000)
Group 2 NDVI ch(1994-2001)		38.08***		26.43***		38.05***		26.38***
		(0.0000)		(0.0000)		(0.0000)		(0.0000)
Group 3 NDVI ch(1994-2001)		18.05***		13.93***		18.45***		14.04***
		(0.0000)		(0.0000)		(0.0000)		(0.0000)
Pagan Hall Test		10.428		9.493		13.521		12.013
For Heteroskedasticity		(0.9883)		(0.9940)		(0.9398)		(0.9703)
F test for equality of the	10.14***	21.17***	9.13***	27.57***	10.07***	19.34***	9.21***	23.96***
Group coeffs	(0.0001)	(0.0000)	(0.0002)	(0.0000)	(0.0001)	(0.0001)	(0.0002)	(0.0000)

p values in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Group1: districts in the states of Gujarat, Rajasthan; Group2: districts in the states of Maharashtra, Madhya Pradesh, Karnataka; Group3: districts in the states of Andhra Pradesh, Kerala, Tamilnadu