Bi-Directional Links Between Population Growth and the Environment: Evidence From India

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Abstract

This paper presents an empirical study of population growth and environmental change using cross-sectional district-level data from South, Central and West India. Environmental change is measured using a satellite-based "greenness" index. Unlike prior work, the analysis treats population and environmental change as jointly determined, distinguishes between rural and urban populations, and identifies distinct roles of fertility and migration. Among key findings are that population and "greenness" are jointly endogenous; increased rural fertility leads to environmental decline, which in turn prompts increased fertility; environmental scarcity spurs out-migration and environmental improvement; and increased urban fertility may lead to increased environmental quality, which in turn may spur increased fertility.

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I. Introduction

Links between population growth and the environment are extensively debated in many realms of social science. In the long-run, opposing views of "Malthusians" (Ehrlich, et al., 1993; Meadows, 1972) and "Boserupians" (Boserup, 1965; Kahn, Brown and Martel, 1976; Simon, 1996) conjecture, alternately, that unchecked population growth will ultimately lead to a complete collapse of the natural environment or, in contrast, that the combination of population growth and natural resource scarcity will spur innovation that conserves natural resources and increases the material services that the resources deliver. On one subject, however, there seems to be general agreement: Population growth impacts the state of the environment and, in turn, the state of the environment affects population growth (Dasgupta, 2000). Population growth may increase the exploitation of open access environmental resources; alternately, it may increase the demand for marketed environmental resources, such as forest products, thus raising the prices of environmental goods and spurring increased natural resource supply (Foster and Rosenzweig, 2003). In the other direction, environmental deterioration may increase the demand for children to fetch water and fuelwood (Dasgupta, 1994) or manage livestock (Nerlove, 1991) or, by worsening individual and public health (and thus raising child and adult mortality), to provide economic support to the household (Sah, 1991; Wolpin, 1997). Fusing these forces is the "vicious cycle" theory -- modern Malthusianism -- that conjectures a reinforcing downward spiral wherein population growth depletes the environment, spurring yet more population growth, and so on. Intermediating forces may operate to break or lessen this cycle, including migration and/or government and community action to stem environmental decline.

Despite apparent consensus that there are bi-directional links between population growth and the environment, and contention over the nature of these links, the empirical literature on these issues focuses on only uni-directional relationships. In this paper, we seek to advance this literature in three ways using cross-section data from South, West and Central India. First and foremost, we study bi-directional links between population and the environment, accounting for the joint determination of these outcomes. Second, we distinguish between rural and urban populations that may have very different effects on the environment and respond very differently to environmental changes. And third, in studying the environmental effects of population growth, we distinguish between fertility and migration. To measure environmental health in this paper, we use satellite-based "greenness" indices that implicitly capture both forest and overall biomass resources in India's rural environment.

There is a rather large literature on how population and other variables affect environmental health, as generally measured by forest stocks. Common in this literature are findings that population growth and/or elevated population density increase rates of deforestation, although Foster and Rosenzweig's (2003) study of Indian panel data finds a positive link between population and forest stocks.[1] Few studies distinguish effects of rural and urban population pressure or of fertility and migration.[2] And, to our knowledge, none treats population growth as endogenous.[3]

A smaller literature considers environmental effects on population growth, documenting both the empirical importance of the environment as a determinant of fertility in developing countries, and the distinct effects of environmental health on

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[1]Cross-national studies include Cropper and Griffiths (1994), Deacon (1994), Ehrhardt-Martinez, et al. (2002), Allen and Barnes (1985), and Lugo, et al. (1981). Within-nation cross-section studies focus on Brazil (Reis and Margulis, 1990; Pfaff, 1999), the Phillipines (Kummer and Sham, 1994), Uganda (Place and Otsuka, 2000), Cambodia and Lao PDR (Dasgupta, et al., 2003), Ecuador (Southgate, et al., 1991), and China (Rozelle, et al., 1997). Two papers study panel data from Thailand (Panayotou and Sungsuwan, 1994; Cropper, Griffiths and Mani, 1999). See Panayotou (2000) for further references.

[2]Exceptions are Cropper and Griffiths (1994), who consider effects of rural population density, and Martinez, et al. (2002), who consider rural-urban migration. Cropper, et al. (1999) distinguish effects of agricultural population density (vs. non-agricultural population).

[3]Southgate, et al. (1991) consider effects of roads on the agricultural population, but do not treat rates of deforestation and agricultural population as jointly endogenous. In fairness, we should note that a number of these studies are less concerned with population effects per se -- which they incorporate for purposes of proper control -- than with other forces driving environmental change, including land tenure, political systems, spatial forces, and economic growth.

fertility and migration as components of regional population growth.[4] Much (though not all) of this empirical evidence suggests that resource scarcity has a positive effect on rural fertility, but a negative effect on in-migration.

In view of this evidence, a failure to account for the joint determination of population and the environment may lead to false inferences from studies on the other direction of causation, namely, population effects on deforestation or environmental deterioration. Finding a positive link in such cases may be due to correlation, perhaps because environmental deterioration spurs population growth, even though population growth may not cause environmental deterioration per se. The policy implications of such false inferences are profound. For example, if environmental deterioration is the object of policy concern, such inferences, if false, imply a misplaced focus on reducing population growth as a mechanism to improve the environment.

In some studies on determinants of environmental degradation, scholars use population density measures that are arguably predetermined at the time that measured environmental deterioration takes place. Although the problem of joint determination is thereby attenuated or eliminated, such studies hide the population effects that may be of most policy relevance, namely, how population *growth* -- the potential object of policy -- affects the environment.

In this paper, we attempt to account for both directions of causation by modeling urban and rural fertility, net migration, and environmental change as jointly endogenous outcomes in a cross-section of 194 Indian districts during the 1990's. Distinguishing

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[4]We are aware of four papers that focus on environment - fertility linkages. Aggarwal, et al. (2001) and Filmer and Pritchett (2002) study cross-sectional survey data from South Africa and Pakistan, respectively, generally finding a positive relationship between fuelwood scarcity and fertility. Merrick (1981) studies cross-section data from Brazilian provinces, finding evidence of an indirect and positive effect of land scarcity on fertility. However, Loughran and Pritchett (1997) find a negative relationship between the time taken to collect fuelwood and water (interpreted as a measure of resource scarcity) and fertility in Nepal. Two other papers focus principally on how the environment affects migration. Amacher, Cruz, Grebner and Hyde (1998) study urban-rural migration in the Phillipines, finding that migration tends to be spurred by the presence of more open-access environmental resources (as measured by the share of forest land that is public and lesser road density in arable lands). Chopra and Gulati (1997) study cross-section data from districts in Central and Western India, finding that distress outmigration (as measured by the change in the district-level sex ratio) is spurred by environmental deterioration.

between rural and urban population growth is important for a number of reasons. Although rural populations have obvious links to natural resources, and this is why scholars often focus on these populations, urban populations potentially have important and different links as well. Urban populations demand goods produced from environmental resources, including food, water and fuel. To the extent that these resources are private and protected by property law, urban population growth can spur demand for their products and thereby spur their increased supply (Foster and Rosenzweig, 2003). However, if forest and/or land resources are open access and their products supplied by non-owner rural residents in local markets, then demand increases that attend urban population growth will lead to increased resource depletion. As natural resources become increasingly scarce, the urban population may generate political will for increased protection of the "common lands" otherwise exploited under open access. In contrast, as rural residents grow in number, the political will for maintaining the open access from which the rural population benefits may grow. In sum, vis-a-vis rural population growth, there are a number of reasons to expect urban population growth to have less negative -- and possibly positive -- effects on the rural environment.

In the opposite direction -- environmental effects on fertility -- urban and rural populations may also be subject to very different forces. For example, the demand for children as resource gatherers and labor in animal husbandry are likely to be less for urban than for rural households, implying a lesser effect of environmental deterioration on such demand. In urban households, children may also be more of a consumption good than a factor of production. To the extent that environmental services and children are complements in consumption (the "demand side" of fertility) and that a better environment lowers costs of food, wood and water that are borne in the support of children (the "supply side" of fertility), a better environment may be expected to increase fertility in urban households. Overall, therefore, it may be expected that environmental health may have a more positive impact on urban fertility than on rural fertility.

Regardless of how convincing one finds these hypotheses, they suggest that a complete study of interactions between population and the environment needs to account for, and distinguish between, urban and rural populations, as we do in this paper.

Some limitations of our analysis should be mentioned at the outset. First, a study of bi-directional links between population and the environment comes at a cost. Economists generally prefer to study micro-level determinants of fertility and migration behavior. However, effects of this behavior on the environment are at an aggregated level. For this and other reasons, we model fertility and migration as best we can at the level of a district in India -- rather than at the level of a household -- thus implicitly aggregating across the district population. While this approach is quite common in studies of fertility and migration (e.g., see Merrick, 1981; Bhattacharya, 1998; Barro, 1991; Chopra and Gulati, 1997), it abstracts from household-level heterogeneity for which we can only imperfectly control using district-level data. Second, we have only cross-section data for a relatively short time frame. Hence, much of the long-run technological innovation and change implicit in the "Boserupian" theory of environmental management cannot be captured by our data, although we may be implicitly measuring patterns of technological adoption across more and less stressed environments. Third, regrettably, we do not have data on point-to-point migration and instead can only measure total net migration to each district in our sample, without distinction between rural and urban areas.

The remainder of the paper is organized as follows. Section II discusses hypotheses of interest in this paper. Section III describes our data, followed by a description of our empirical models in Section IV. Section V presents and discusses our estimation results. Closing remarks are given in Section VI.

II. Hypotheses

In Table 1, we attempt to catalog potential bi-directional links between population growth and the rural environment, as well as the intermediating impact of resident income. Three remarks on Table 1 are in order before tackling its implications. First, the economic forces described in this table relate to our two measures of environmental status, one an index of overall vegetation (or "greenness") and the other a measure of the proportion of land that has a high level of "greenness." These measures will be described in more depth momentarily. At this juncture, we simply note that the former index incorporates both forest biomass and impacts of soil productivity on cropland vegetation, while the latter is constructed as a measure of forest cover. Notably, both indices are measures of *rural* environmental health that are correlated with fuelwood availability, water and soil resources, and “amenities” such as scenery and wildlife. Second, we assume that local economic conditions have price effects in local markets for environmental goods. For India, this premise is plausible for water and wood products that are costly to transport long distances and for which international trade is essentially non-existent (Foster and Rosenzweig, 2003). To a lesser extent, this premise is plausible for food products that are traded inter-regionally but are also costly to transport. Third, we use the nomenclature, "market resource," to denote an environmental resource, such as a forest, that is protected by property law and the products of which are sold for private benefit in local markets. Conversely, “open access” refers to land and forest resources that are unprotected by property law.

Turning first to Table 1(A), we have:

Hypothesis 1. Higher levels of rural population growth lead to increased deterioration of open access land and forest resources.

We can test this hypothesis by estimating effects of rural fertility on our measures of environmental change. Urban fertility and net migration (including migration to urban areas) have ambiguous effects on open access environmental resources. However:

Hypothesis 2. Higher levels of population growth -- both rural and urban -- lead to an increased supply of market environmental resources.

Hypotheses 1 and 2 imply opposite effects of rural fertility, distinguishing between dominance of open access resource effects (Hypothesis 1) and impacts on the provision of market resources (Hypotheses 2).

In general, resident income changes have ambiguous effects on the environment (Table 1(B)). However, for market resources, we have:

> *Hypothesis 3*. If environmental products are normal goods, then increased resident income will lead to an increased equilibrium supply of market environmental resources.

Suppose instead that forests are an open access resource. For a poor country such as India, the logic of the "environmental Kuznets curve" (EKC) (see Copeland and Taylor, 2004) suggests that the direct environmental depletion impacts of income growth will dominate the indirect increase in political demand for forest protection.

> *Hypothesis 4 (EKC)*. Increased income will tend to increase depletion of open access environmental resources.

The qualitative impact of resident income may depend upon the sector, rural vs. urban. For example, unlike their urban counterparts, increased rural incomes may reduce incentives for exploitation of an open access resource by raising the time costs associated with this exploitation and by raising the potential monetary penalty for illegal mining of a public resource. Alternately, increased average rural incomes may be associated with more sophisticated markets and cost-saving specialization for the exploitation of open access resources, leading ultimately to increased exploitation. It is an empirical question which of these effects may dominate.

In the other causal direction, Table 1(C) reveals the ambiguity of environmental impacts on fertility. However, consider the case of rural households in which the demand for children is driven principally by the household production needs of the family. Furthermore, consonant with this "household production" view of children, let us suppose that environmental impacts on the resource costs of children -- with environmental improvement lowering costs of food, water and/or fuel, and thereby favoring increased fertility -- are small by comparison with environmental impacts on the benefits of children in the production of resource-related goods. Then we have:

Hypothesis 5. To the extent that children are a factor of production in rural households, a better environment will tend to reduce rural fertility rates.

Conversely, consider the case of urban households in which children are viewed principally as consumption goods. For this case, let us also suppose that effects of rural environmental change on urban care-giver health are relatively small. Then we have:

Hypothesis 6. If children are "consumption goods" in urban households, and complements to environmental goods, then a better rural environment will tend to increase urban fertility rates.

In contrast to effects on fertility, the expected impact of environmental improvement on migration incentives is unambiguous (Table 1(D)).

Hypothesis 7. A better environment will spur increased net in-migration.

III. Data

In this study, we use district level data from eight states of the southern (Andhra Pradesh, Tamil Nadu, Karnataka, Kerala), western (Maharashtra, Gujarat, Rajasthan) and central (Madhya Pradesh) regions of India. In particular, our study region contains 199 districts. Adjusting for district redefinitions and missing data gives us a sample size of 194 districts. Table 2 describes the variables that are available and used in this sample. Table 3 provides sample statistics for these variables.

We estimate two sets of models, one "short run" and the other "long run." For the short run models, we have fertility (rural and urban), migration, and environmental / ”greenness” data for the three year period, 1991-1994. For the long run models, we have population growth (rural and urban) and environmental data for the ten year period, 1991-

2001.[5] Although a disadvantage of the long run analysis is the absence of distinct fertility and migration data, a compensating advantage is the longer time frame within which links between population and the environment can manifest themselves. We therefore present both analyses.

A few properties of our sample bear mention at the outset. District-level rural fertility averages 3.6 percent of 1991 population over the three year 1991-1994 period (our short run) and rural population growth averages 16.6 percent over the ten year 1991-2001 period (our long run). Urban fertility / population growth rates are much higher, averaging 9.5 percent over 1991-1994 and 32.7 percent over 1991-2001, respectively. Average net short-run (1991-1994) migration rates are 3.2 percent. However, there is a great deal of cross-district heterogeneity in all of these growth statistics. For example, short-run urban fertility rates vary from only .6 percent to over 25.7 percent. Population densities (1991) are also highly variable, averaging 223 people per square kilometer in rural areas and almost 3200 people per square kilometer in urban areas. Our sample districts are predominantly rural, with an average rural population percentage of almost 75 percent. Incomes are substantially lower in rural areas than in urban areas, with average 2001 consumption expenditures of approximately $145 per capita in rural areas and $210 in urban areas (at 45 rupees to the dollar). Urban areas also exhibit signs of greater development, with higher literacy rates and lower infant death rates than their rural counterparts. Average household sizes are about 5.4 people in both urban and rural areas. However, female workforce participation is much higher in rural areas (averaging 28.9 percent) than in urban areas (at 9.6 percent).

Climatically, districts in our sample are quite heterogeneous, with normal annual rainfall (RN) varying from less than one-third of a meter to 3.5 meters. The variation in

[5] In our data, urban (vs. rural) areas are defined, per the census of India, as (i) all places within a defined municipality, and (ii) all other places that have a minimum population of 5000, at least 75 percent of the male working population engaged in non-agricultural pursuits, and a population density of at least 400 persons per square kilometer.

our overall "greenness" index is less dramatic, but also substantial; out of a possible maximum value of 256, our sample districts have a two-year (1990-1991 average) "greenness" index value (N9091) that averages 168.6, ranging from a low of 133.3 to a high of 195.4. Changes in this index over time (NC91T95 and NC91T01) exhibit considerable heterogeneity; for example, short-run changes (ND91T95) range from -10.7 to 28.6.

Details on the sources and construction of our data follow.

The Environment. Direct disaggregated time series data on measures of environmental health are rarely available for India. For example, data on district-level forest cover is available for 1991, but not for the middle of the decade. Hence, to measure the state of the rural environment at a district level, we rely on satellite imaging data that are available throughout our short run and long run study periods. Specifically, we use the Normalized Difference Vegetation Index (NDVI) 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 NDVI is measured on a 10-day composite basis and at fine resolution (with each pixel eight square kilometers in size). Satellite images are obtained from the National Aeronautics and Space Administration (NASA) and are processed using Geographic Information (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 represents an index of forest cover, measuring the extent to which a district has high NDVI land. Specifically, for the two-year (24-month) interval, 1990-1991, we calculate

[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.

the average value (μ_s) and standard deviation (σ_s) for all monthly pixels in our study area. We then construct a critical NDVI index such that 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 year, or the two-year period 1990-1991, for example), we then construct a "z-score" for each district that is monotonically related to the approximate proportion of time-pixels that are above the critical NDVI index value:[8]

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

where μ_j = district j average of time-pixel NDVI and σ_j = district j standard deviation of time-pixel NDVI. The z-score is a measure of high-NDVI frequency that is commonly used by GIS geographers (see Yool, 2001).

Table 4 presents standard (Pearson) correlation coefficients between our various environmental indicators. Initial (1990-1991) values of our environmental measures (NDVI and z-score) are positively correlated with initial reported district-level percentage forest area and slightly negatively correlated with our “net sown area” variable – the proportion of a district’s land area that is cultivated in farms. Although reported forest area statistics are sometimes considered suspect (and, for this and other reasons, we do not rely on these data in our analysis), these correlations suggest the positive association between our environmental measures and forest cover that we desire in this study. They also loosely suggest that net sown area is associated with scarcity of common lands, as is often assumed in the development economics literature (e.g., see Angelsen, 1999). Note

7As of 1995, approximately 19.1 percent of our study region was in forest. In 1990-1991, approximately 21 percent of India was forested. We thus use a 20 percent upper tail probability in constructing our "z-score" measure of forest cover.

8The NDVI takes on values between zero and 256. Our 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.

also that, although initial values of our NDVI and z-score measures are very highly correlated, the changes in these measures over our short and long-run study periods are positively but quite imperfectly correlated. Hence, these measures capture somewhat different environmental phenomena, with one an indicator of biomass (NDVI) and the other an indicator of high-NDVI forest cover (z-score).

For the short run study, relevant environmental change is over the period from 1991 to 1994 . To obtain more precise measures of change, we construct two-year values for our environmental indices. The years 1990-1991 are used to measure the initial environmental state. Because NDVI data are not available for the last four months of 1994, our end-of-study-period environmental state is measured using the last four months of 1993, the first eight months of 1994, and the calendar year 1995. The corresponding environmental change variables are determined by the change in average NDVI / z-score between 1990-1991 and 1993-1995. Similarly for the long run study, NDVI data are not available for the last two months of 2001; hence, our end-of-study-period environmental state is measured using the last two months of 1999, the calendar year 2000, and the first ten months of 2001. Corresponding long run environmental change variables are determined by the change in average NDVI / z-score between 1990-1991 and 1999-2001.

Population. Our short run study is made possible by data recently released by the Registrar General's Office of India, revealing district level births and deaths (total, rural, and urban), as well as birth rates and death rates (district-wide), 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 district-level birth rates (rural and urban), death rates (rural and urban), and net migration rates (district-wide), for the three-year period mid-1991 to mid-1994, as fractions of relevant (rural, urban, and total) 1991 district populations.[9]

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[9]Because the birth and death rates are computed on the basis of the mid-year population, while the birth and death numbers represent the figures for the calendar years, we calculate the net migration as follows: Net migration = (P94-P91)-.5(NB91+NB94)-(NB92+NB93), where P and NB denote population and net births

For our long run study, district level rural and urban population levels for 2001 are available from the 2001 Census of India, based upon which we derive the decadal (1991-2001) district level rural and urban population growth. Because data on births and deaths are not available for the decade 1991-2001, the decadal population change could not be disaggregated into net births (fertility) and net migration.

Rainfall. Actual annual and normal rainfall data are available for meteorological subdivisions of India. Each meteorological subdivision is defined according to climatic features and consists of several districts. For time periods prior to and contemporaneous with our study periods, we construct the deviations between average actual annual rainfall and normal rainfall for each district.

Income. Direct district-level measures of income in India are not available for our study periods. District level rural and urban average per-capita consumption expenditure data are available from the Indian National Statistical Service for 1994 and 2000-2001, but not for 1991 or before. Because per-capita consumption expenditures are measured at the ends of our two study periods, there is the potential for joint endogeneity. In addition, per-capita consumption expenditures proxy for the "permanent incomes" that we would like to measure, but with error. For these reasons, we estimate our models both using the actual consumption expenditure data (Models 4 and 8 in what follows) and by treating rural and urban consumption expenditure as jointly endogenous (Models 1-3 and 5-7).[10]

Socio-Economic and Other Data. Demographic, socio-economic and land use data are obtained from IndiaStat and NCAER (2001a, 2001b). In addition, we define

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respectively and the numeric notations denote years. Birth rates and death rates for our short run study period are calculated similarly using approximate birth and death numbers for the three year period, mid-1991 to mid-1994.

[10]Instruments used to fit rural and urban per-capita consumption expenditures (when treated as jointly endogenous) in the short-run models are NC86T90/ZC86T90 (when included, in Models 1, 2, 5, and 6), N91/Z91, NSA, UP, MD (when included, in Models 1, 3, 5, and 7), state dummy variables, RDPOP94/UDPOP94, RPD/UPD, RIDR/UIDR, RTL/UTL, RSR/USR, and RFMW/UFMW; in addition, RBPOP94/UBPOP94 and NC91T95/ZC91T95 enter as jointly endogenous. The only differences in the long run are that RBPOP94/UBPOP94 and RDPOP94/UDPOP94 are replaced by the jointly endogenous RPCHG01/UPCHG01, and jointly endogenous environmental changes are over the long-run study period, NC91T01/ZC91T01.

three dummy variables to control for extraordinary district attributes. Two of these variables are for urban effects, one (MD) a dummy for four districts that are almost entirely metropolitan and the second (PMD) for suburban districts that are directly adjacent to the four urban centers in our sample (Bangalore, Madras, Hyderabad, and Mumbai). The metropolitan districts are economically more developed and have much higher population densities than do others in our sample. The third dummy variable is for the fourteen districts in the state of Kerala. Kerala is distinguished from other regions in our sample in a number of respects. It has long had stable left-wing governments and social policies. It has the highest literacy rate and sex ratio in India; is known for its predominantly matriarchal society; and is the only state with a large Christian population.[11] We estimate our models both with and without these three dummy variables in order to determine the robustness of our results.

IV. The Empirical Models

For our short run models, four simultaneous equations are estimated, one each for rural and urban fertility, net in-migration, and the change in our environmental / "greenness" index.[12] Similarly, in the long run models, three simultaneous equations are estimated, one each for rural and urban population growth (measured by the change in population density) and environmental change. In order to account for potential cross-equation correlation, we estimate by three stage least squares.[13] In all of the population equations -- fertility and migration (for the short run) and population growth (for the long

[11]In principle, we could estimate with dummy variables for all eight states in our sample. However, such a fixed state effects specification hides all cross-state heterogeneity in the population - environment links that we are attempting to uncover. For this reason, we instead control for relevant state and district level determinants of population and environment variables.

[12]For most of our models, we also treat our income measures, rural and urban per-capita consumption expenditures, as jointly endogenous (see Section III discussion of income data). Hence, in these models we estimate six simultaneous equations for the short-run and five for the long-run. See note 10 above. In addition, three of our sample districts are entirely urban and one is entirely rural. In our rural (fertility, population growth, and consumption expenditure) equations, we dummy out the three urban districts. Likewise in our rural equations, we dummy out the rural district.

[13]Under the assumption of joint normality of disturbances and a block diagonal covariance matrix ($\Sigma \otimes I_n$), 3SLS is also FIML, thus yielding consistent estimates of coefficient standard errors.

run) -- environmental change enters as a jointly endogenous variable; in addition, two other pre-determined environmental measures are included as regressors, the initial state of the environment (in 1991) and the environmental change over the preceding four year period (1986-1990).[14] The latter measures are included because population-related decisions are likely to depend upon both the state of the environment and the trajectory of environmental change. In the environmental change equations, all population variables enter as jointly endogenous regressors.

Fertility (Short Run) and Population Growth (Long Run) Equations. Beyond impacts of the environment, fertility is influenced by socio-economic factors that include income, literacy, health services, social norms and religious beliefs (Freedman, 1987; Dasgupta, 1995; Schultz, 1997; Rosenzwieg and Stark, 1997; Bhattacharya, 1998; Dreze and Murthy, 2001; Martine, Dasgupta and Chen, 1998). To capture these effects, we note that good district level socio-economic secondary data are extremely scarce. Nonetheless, we are able to include explanatory variables that measure per-capita consumption expenditure (a proxy for income), female literacy, female workforce participation, average household size, the sex (female to male) ratio, and the religious makeup of the population. Because Hindus and Muslims represent over 95 percent of the Indian population, we use the Muslim population share as our indicator of a district's religious composition. We include two measures of health status, infant death rates and overall population death rates. Potential congestion effects are captured by including population density as a regressor. All of these explanatory variables are specific to the rural / urban sector of a district. To account for potential spillover effects across a district, the urban birth rate is included as a jointly endogenous regressor in the rural fertility equation, and vice versa; likewise in the long run model, urban (rural) population growth is included in

[14]For each of our two environmental indices, we measure the "initial state of the environment" by averaging the calandar-year 1991 environmental index and the two-year 1990-91 index (see Table 2 definitions of N91 and Z91). Incorporating the 1990-91 index dampens transitory components of the 1991 index value that do not reflect the true state of the environment. Incorporating the 1991 index places appropriate added weight on the 1991 starting point for our study.

the rural (urban) population growth equation. In addition, Dasgupta (2000) observes that the extent of urbanization may affect the outward orientation of a district's population, which in turn may affect fertility behavior (as well as migration and attitudes toward the environment). We therefore include a district's urban population share as an explanatory variable. For rural fertility / population growth, the extent of agricultural cultivation may affect economic opportunities, the supply of common lands, food availability and, hence, fertility; we therefore include the district's proportionate net sown area in the rural population equations.

Migration Equation (Short Run). Migration is influenced by income, literacy, natural resources and other socio-economic factors (Chopra and Gulati, 1997; Bilsborrow, 1998; Khan and Shehnaz, 2000; Juarez, 2000). Because our measure of net migration is district-wide, we include both rural and urban measures of relevant socio-economic indicators. However, in view of the distinct economic forces driving fertility and migration, and in order to identify our equations, there are some differences between our fertility and migration specifications. First, while female literacy is potentially important as a determinant of fertility -- because women are the primary care-givers -- we instead use measures of total literacy in the migration equation, as overall educational status is likely to be the more relevant explanator of population movements. Second, we include as potential determinants of migration our income proxies (per capita consumption expenditures), district death rates (a health status indicator), population densities (one indicator of population pressure), average household sizes, percentage net sown area (an inverse indicator of the availability of common property resources), and the district urbanization percentage (for outward orientation).[15] We exclude socio-economic

[15] We note that expected effects of district per capita incomes on migration are ambiguous in general. Higher incomes may lead to positive spillovers for migrants. However, higher rural incomes may lessen the rural sector's political pull for continuation of open access resource opportunities, a potential disadvantage to rural migrants who could benefit from the open access. Higher urban incomes could spur higher prices for local products of environmental resources, including food and fuel, deterring urban migration. It is an empirical question which effects dominate, if any.

variables considered apriori to be of least potential relevance to migration decisions, namely, the Muslim, female workforce participation, infant death rate, and sex ratio variables.[16] Third, as population pressures and trends can potentially affect migration incentives, rural and urban fertility enter as jointly endogenous variables.

Environmental Change Equation (Short and Long Run). Our posited determinants of environmental change fall into three classes: (1) population variables, (2) socio-economic indicators, and (3) environmental and climatic factors. Population variables include predetermined population densities (short and long run), the jointly endogenous fertility and migration measures (population growth in the long run), and death rates (short run). Included socio-economic regressors are total literacy (rural and urban), the urban population share (the measure of "openness"), and per-capita consumption expenditures (our income proxy). Natural processes may also affect environmental change; to control for the risk of spurious correlation between these processes and the economic forces of interest in this paper, we use both rainfall data and data on prior (pre-determined) environmental change from 1986-1990. Three rainfall variables are constructed, each a contemporary deviation of actual average annual rainfall from normal rainfall during 1986-1990 (immediately preceding our study periods), 1991-1994 (our short run) and 1991-2001 (our long run).[17] In addition, we include the 1991 percentage net sown area (NSA) and the initial state of the environment in 1991 (N91 and Z91, respectively), both of which are interpreted as measures of environmental scarcity. NSA implicitly measures the scarcity of uncultivated common lands, while N91 and Z91

[16] Although we exclude more variables than necessary for identification, we experimented with inclusion of some of the excluded regressors, only to find that they had no significant explanatory power. For the fertility and population growth equations, identification is not an issue because only relevant rural or urban explanatory variables are included as regressors.

[17] Extraordinary environmental improvement may have a limiting effect on subsequent environmental change. Prior period rainfall deviations are included to help capture such effects. However, rainfall data is available only at a relatively aggregated subdivision level; in our sample, there are 19 subdivisions, compared with 194 districts. In addition to rainfall deviations, we therefore include the more disaggregated and direct measure of prior period environmental events, namely, the 1986-1990 change in our two environmental measures. To ensure that our results are not driven by this specification, we also present models (our Models 3 and 7) that exclude prior period environmental change.

are inverse indicators of biomass and forest stock scarcity, respectively.[18] Increased scarcity of common lands and biomass / forest resources is expected to generate heightened political and institutional incentives for environmental preservation.

V. Results

Tables 5 and 6 present results from our short-run and long-run estimations, respectively. Eight models are presented, four that use our average-NDVI environmental / biomass measures (Models 1-4) and four that use our z-score / forest cover measures (Models 5-8). Models 4 and 8 treat per capita consumption expenditures as exogenous; Models 1-3 and 5-7 treat these expenditures as jointly determined (see note 10). Models 1 and 5 include our three dummy variables for urban effects and Kerala (MD, PMD, KD), while Models 2 and 6 do not. Models 3 and 7 exclude the prior period (1986-90) environmental change variables and include district-level normal rainfall (RN) in the environmental change equations.

A number of conclusions are evident from Tables 5 and 6.

1) *Rural fertility rises with environmental scarcity and deterioration*. In all short-run and long-run specifications, environmental change has a statistically significant negative impact on rural fertility / population change (see Tables 5A and 6A). These effects are also quantitatively significant. For example, a contemporaneous increase in the NDVI index by one percent of its initial sample range is associated with a reduction in long-run rural population growth rates of approximately 12 percent and a reduction in

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[18]Our net sown area regressor may also be interpreted as a measure of the extent of agricultural cultivation in each district. For our first (NDVI) environmental measure, which is an overall index of vegetation (including agricultural vegetation), the extent of agricultural cultivation may affect measured environmental change. Specifically, the intensity with which agricultural land is cultivated may affect its vegetative density, and the extent to which changes in this intensity affect the district-wide average vegetation index is likely to depend upon the proportion of land in agriculture, our regressor. For the long run (but not the short run), we could also control for changes in district land areas used in agricultural activities. However, to a large extent, these changes (an increase in net sown area, for example) yield the very environmental effects (deforestation) that we are seeking to explain. Hence, we do not include them on the right-hand-side in our environment equations. With regard to our second (z-score) environmental measure, which is designed to filter out agricultural vegetation, we have no apriori expectation that the extent / intensity of agricultural cultivation will affect measured environmental change per se. However, we expect that, as an index of land scarcity, net sown area will have a positive association with environmental change.

short-run fertility rates of 5.4 to 9.8 percent, depending upon the Model.[19] Similarly, a contemporaneous increase in the z-index by one percent of its sample range is associated with approximately a 15.3 to 16.3 percent reduction in short-run rural fertility rates and an 18.5 to 21.8 percent reduction in long-run rural population growth.

In all short-run specifications, district-level net sown area (NSA) -- an indicator for scarcity of common lands -- has a significant positive impact on rural fertility. Similarly, in all long-run specifications, the initial state of environmental health (as measured by N91 and Z91) has a significant negative impact on rural population change. The magnitude of these effects is noteworthy. For example, in the long-run, a one percent (of sample range) difference in the initial NDVI is associated with a 3.2 to 3.7 percent reduction in rural population change; similarly, a one percent (of sample range) difference in the initial z-score is associated with a 10 to 15.3 percent reduction in rural population growth.

These results broadly support our Hypothesis 5.

2) *Urban fertility rises with environmental improvement* in most specifications (all except our long-run Model 7). These effects are statistically significant in most models, generally supporting our Hypothesis 6. (See the NC91T95 and ZC91T95 coefficients in Table 5B and the NC91T01 and ZC91T01 coefficients in Table 6B.) For example, consider our "base case" Models 1 and 5. In these cases, a one percent (of sample range) contemporaneous rise in the NDVI is associated with a 1.9 percent increase in short-run urban fertility and a 7.3 percent increase in long-run urban population growth; similarly, a one percent (of sample range) contemporaneous rise in z-score is associated with increases of 5.2 percent and 10.4 percent in short-run urban fertility and long-run urban population growth, respectively. Long-run impacts are expected to be

[19] One percent of the 1990-1991 NDVI sample range is .621. Multiplied by the coefficients on NC91T95 (Table 5A) and NC91T01 (Table 6A), and divided by average fertility (RBPOP94 for Table 5A) and rural population growth (RPCH91T01 for Table 6A) gives the indicated percentage changes.

greater because they incorporate the positive effects of environmental improvement on migration.

3) *Net migration falls with environmental scarcity*. In all specifications, net sown area (NSA) – our proxy for scarcity of common lands -- has a significant negative effect on migration (see Table 5C). For example, an increase in initial NSA by one percent of its sample range (approximately three-quarters of one percent of land area) is associated with a reduction in short-run net migration, as a proportion of initial population, of between approximately one half (.53) and .85 of a percent – that is, between 16.6 and 26.7 percent of average net in-migration. In addition, the initial environment has a positive impact on migration that is statistically significant in all but one case (Model 7). A one percent (of sample range) rise in the initial NDVI is associated with an increase in the short-run in-migration rate of between .46 and .7 percent; for a one percent (of sample range) rise in z-score, the corresponding increase in migration is between .53 (Model 7) and 2.2 percent of the initial population (Model 5). Overall, these results broadly support our Hypothesis 7.

4) *Increased rural fertility (short-run) and population growth (long-run) deplete the environment*. As indicated in Tables 5D and 6C, coefficients on the rural population growth variables (RBPOP94 and RPCH91T01) in the environmental change equations are negative and statistically significant in all Models. Assessing the quantitative significance of these coefficients is not straightforward. [20] However, we note that a one-standard-deviation increase in short-run rural fertility is associated with (i) a reduction in the average NDVI of between 2.3 and 3 – that is, 3.8 to 4.9 percent of the initial NDVI sample range and 60 to 77 percent of the standard deviation for the NDVI change – and (ii) a reduction in the z-score of .23, 2.5 percent of the initial z-score range and 65 percent of the standard deviation for the z-score change. Similarly, a one-standard-deviation

[20]We pattern our quantification here on Bohn and Deacon (2000) who, for example, report effects of a one-standard-deviation change in an ownership index on rates of deforestation.

increase in long-run rural population growth is associated with (i) a reduction in the average NDVI of 7.2, 19.5 percent of the initial NDVI sample range and 134 percent of the standard deviation for the NDVI change, and (ii) a reduction in the z-score of .48 to .72, 5.2 to 7.8 percent of the initial z-score range and 50 to 75 percent of the standard deviation for the z-score change. Overall, Hypothesis 1 is thus supported by our data, indicating that open access environmental resources are important in our study region.

5) *Increased urban fertility tends to spur environmental improvement.* In the short-run models (Table 5D), urban fertility has a positive impact on environmental change that is statistically significant in five of the eight specifications. In the long-run models (Table 6C), these conclusions are attenuated, with urban population change having a positive impact in all but one case (Model 7), but a statistically significant impact in only two models (Models 4 and 5). The magnitudes of these effects are substantially less than their rural counterparts. For example, in our base case short-run Models 1 and 5, a one-standard-deviation increase in urban fertility is associated with (i) an increase in the NDVI of 1.35 (for Model 1), which is 2.2 percent of the initial NDVI sample range and 34.7 percent of the standard deviation for the NDVI change, and (ii) an increase in the z-score of .09 (for Model 5), which is one percent of the initial z-score range and 25.5 percent of the standard deviation for the z-score change. It is not surprising that these magnitudes are relatively small. As indicated in Table 1A, there are competing effects of urban population growth on open access environmental resources. On net, our results suggest that positive effects, due to the political pull of urban populations for rural resource protection, dominate in our sample.

6) *Environmental scarcity spurs environmental improvement.* In all of the short-run equations (Table 5D), net sown area has a statistically significant positive impact on environmental change. In all of the long-run equations (Table 6C), as well as all short-run z-score equations (Table 5D), the initial environmental quality has a significant negative effect on environmental improvement. The magnitudes of the short-run effects

are quite small; for example, a one percent (of sample range) increase in the NSA is associated with a short-run change in average NDVI equal to only one-tenth to two-tenths of one percent of its (NC91T95) sample range and a z-score change of approximately one-tenth of one percent of its (ZC91T95) sample range. However, the magnitudes of the long-run effects are noteworthy. A unit difference in initial NDVI (N91) is associated with a long-run NDVI change of .23 to .29; in other words, approximately 23 to 29 percent of a district's relative initial environmental degradation is offset by subsequent environmental improvement. Effects of initial "z-score scarcity" are even more marked; a unit difference in initial z-score (Z91) is associated with a long-run z-score change of .7 to .92. Thus, in our sample, it appears that the stimulus for environmental improvement, stemming from environmental scarcity, takes some time to have its full impact.

7) *Population growth and environmental change are jointly determined*. Consonant with conventional wisdom, we find that fertility is affected by contemporaneous environmental change (Tables 5A, 5B, 6A, and 6B); conversely, environmental change is affected by contemporaneous population growth (Tables 5D and 6C). Failing to account for the joint endogeneity of these outcomes can thus lead to false inferences.

8) Our results provide some limited evidence on how income affects environmental change. *Higher rural consumption expenditures* -- *our proxy for rural incomes* -- *are estimated to have a negative impact on environmental change* in all of our specifications (see Tables 5D and 6C); these impacts are statistically significant in the short-run z-score estimations (Models 5-8) and most long-run NDVI estimations (Models 1-3), providing some limited support for the EKC (Environmental Kuznets Curve) Hypothesis 4. However, the magnitudes of some of these effects appear quite small, even when they are statistically significant. For example, a one percent (of sample range) change in 1994 rural consumption expenditure (PCER94) is associated with a change in short-run z-score of between .16 and 2.1 percent of its (ZC91T95) sample range.

Similarly, a one percent (of sample range) change in 2001 rural consumption expenditure (PCER01) is associated with a change in long-run average NDVI of between .03 and .3 percent of its (NC91T01) sample range. Urban consumption expenditures have mixed effects on the environment; however, the only statistically significant impacts (in the short-run Models 1 and 2) are positive. [21]

VI. Conclusion

In this paper, we study bi-directional links between population growth and environmental change using cross-sectional district-level data from South, Central and West India. On one hand, our results provide some support for the conceptual ingredients to the so-called "vicious cycle" theory. Under this Malthusian doctrine, population growth spurs environmental degradation; because child labor is in greater demand in environmentally degraded circumstances, the environmental depletion in turn fuels further population growth, and so on. We find evidence in our data that increased rural fertility indeed spurs depletion in biomass and forest resources, which in turn spurs increases in rural fertility. On the other hand, however, our results provide evidence of forces that counter the "vicious cycle." Whether through community or government or

[21] Although they are not the focus of our study, other socio-economic variables also have some statistically significant effects in our estimations. Female literacy (RFL/UFL) has a positive effect on fertility, controlling for income (see Tables 5A, 5B, 6A, and 6B). Consumption expenditures have a negative impact on rural fertility (Tables 5A and 6A) and, in the short-run, a positive effect on urban fertility (Table 5B). Urban infant death rates (UIDR) generally have a positive impact on long-run urban population change (Table 6B), and a negative effect on short-run urban fertility (Table 5B). Conversely, urban sex ratios (USR) generally have a negative effect on long-run population (Table 6B) and a positive effect on short-run fertility (Table 5B). Finally, short-run urban fertility is negatively related to the urban population share (UP) and female workforce participation (UFMW) (Table 5B). Some of these socio-economic effects are consistent with the traditional view of fertility decisions in poor households wherein higher literacy, greater female workforce participation, higher incomes, improved health (as implied by lower infant death rates), an improved status of women (for which the sex ratio is often thought to proxy), and a more open society (as measured by the extent of urbanization) all tend to raise the costs of having children and/or to reduce the demand for children as family workers. Other effects reflect different forces at work. For example, greater literacy may increase fertility by creating more awareness about neo-natal care, thus increasing the probability of live births; literacy may also improve social awareness, thus reducing instances of infanticide and sex-selective abortions. High infant mortality rates, particularly in urban areas where child bearing is more costly, can discourage family expansion plans. In urban areas, where the status of women tends to be better, a higher sex ratio implies a larger number of child bearers and, hence, may yield a higher fertility rate. And if children are consumption goods -- as is more likely to be the case in urban areas -- fertility can rise with income.

individual action, we find evidence that environmental scarcity spurs environmental improvement. Environmental degradation also spurs out-migration; to the extent that this out-migration is from rural areas, it can fuel long-run environmental improvements. Finally, we find some evidence that a "counter-vicious" cycle may be at work, with urban population growth spurring environmental improvement that in turn fuels further increases in urban populations. Urban populations have incentives to protect proximate natural environments from open access exploitation, and may demand more children as complements to environmental "goods."

Pieces of these conclusions are contained in prior work. For example, a number of scholars identify negative effects of rural population growth on the environment (Panayotou, 2000) and positive effects of environmental degradation on rural fertility (Aggarwal, et al., 2001; Filmer and Pritchett, 2002) and out-migration (Amacher, et al., 1998; Chopra and Gulati, 1997). However, the links that we identify in this paper account for the joint determination of population and environmental outcomes that is ignored elsewhere. Indeed, consonant with conventional wisdom, we find strong evidence that population and environmental outcomes are jointly determined in our sample, implying that a failure to account for simultaneity, at least in our sample, would lead to biased and inconsistent parameter estimates and, as a result, false inferences. In addition, by virtue of an empirical model that accounts for distinct urban and rural populations, distinct effects of fertility and migration, and the joint endogeneity of population growth and biomass / forest resources in a complete system of relationships, we are able to identify forces countering the "vicious cycle" that are missed elsewhere. To a great extent, identification of these offsetting forces confirms the "Boserupian" conjecture that environmental scarcity breeds creativity, innovation and policy that conserves natural resources.

Our findings also shed light on the relevant paradigm for thinking about forest policy in countries like India. Foster and Rosenzweig (2003) argue that trends and policies that increase local demand for forest products will spur an increase in the local supply of forests. We loosely term their argument a "market resource" paradigm, driven by the presence of protected rights for forest resources. Juxtaposed to this logic is the "open access" paradigm wherein forests are common property resources; contrary to the "market resource" paradigm, an increased demand for forest products will lead to increased exploitation of open access forests and, hence, deforestation. As Foster and Rosenzweig (2003, p. 633) point out, the latter effects can be mitigated if demand increases spur the adoption of policies that protect previously unprotected public forests. However, this policy mechanism for aforestation is quite different than the market mechanism implied by the market resource paradigm. We find, for example, that rural population and income growth lead to resource degradation in our sample. These findings are inconsistent with the "market resource" perspective, suggest that much of our measured natural resource base is of the open access variety, and imply that policy responses to rural population and income growth do not compensate for their direct environmental depletion effects. Urban population growth, on the other hand, can lead to environmental improvement, most likely due to a combination of induced policy responses that protect public forests and induced increases in private forest supply (the market resource effect). These results suggest that policies targeted to reduce rural population growth, even though they reduce the rural demand for forest products, may promote aforestation in India. They also stress the importance of environmental / forest policy to the achievement of aforestation objectives.

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Table 1

(A) Potential Effects of Population Growth (P) on Environmental Change (E)

When the Environment Is A

Non-Market Open-Access Resource		Market Resource
(-) P ⇒ increased demand for environmental goods		(+) P ⇒ increased demand for environmental goods (Foster and Rosenzweig)
Urban P	Rural P	
(+) P ⇒ increased per per capita resource scarcity ⇒ political will for resource protection	(-) P ⇒ increased political weight to rural population that benefits from open access	

(B) Potential Effects of Increased Income (I) on Environmental Change (E)

When the Environment Is A

Non-Market Open-Access Resource	Market Resource
(-) I ⇒ increased demand for the products of local environmental resources (if normal) ⇒ environmental depletion (+) I ⇒ increased demand for the environment as a public good (if normal)	(+) I ⇒ increased demand for products of local environmental resources (if normal) ⇒ increased equilibrium supply of environmental resources (Foster and Rosenzweig)

Notes: Signs in parentheses denote expected effects. In Table 1(A), population growth includes growth from both net fertility and net migration.

Table 1 (continued)

(C) Potential Effects of Environmental Improvement (E) on Fertility

Costs of Children (Supply)

(+) E ⇒ lower costs of resource-intensive inputs in child maintenance (food, water, fuel)

(-) E ⇒ better health / higher productivity of care-givers ⇒ higher time costs of children

Benefits of Children (Demand) When Children Are A

Factor of Household Production	Consumption Good
(-) Resource scarcity ⇒ increased benefits of children as resource gatherers, labor in animal husbandry (Dasgupta, Nerlove) (-) E ⇒ improved child health ⇒ more productive children ⇒ fewer children needed for income security	(+)/(-) The environment and children may be complements / substitutes in consumption

(D) Potential Effects of Environmental Improvement (E) on Net In-Migration

(+) E ⇒ increased health / consumption benefits of the environment as a public good

(+) E ⇒ increased labor demand for production of environmental goods (when the environment is a market resource)

(+) E ⇒ reduced cost of local environmental goods supplied in local markets

(+) E ⇒ increased value for rural resident exploitation of open access environmental resources (Amacher, et al.)

Table 2. Variables Definitions

Variable Name	Description
RBPOP94	Rural births (from 1991 to 1994) per thousand 1991 rural population
UBPOP94	Urban births (from 1991 to 1994) per thousand 1991 urban population
RDPOP94	Rural deaths (from 1991 to 1994) per thousand 1991 rural population
UDPOP94	Urban deaths (from 1991 to 1994) per thousand 1991 urban population
MIPOP94	Net Migration (from 1991 to 1994) per thousand 1991 district population
RPCH91T01	Percentage change in rural population from 1991 to 2001
UPCH91T01	Percentage change in urban population from 1991 to 2001
RPD	Rural population density (per square kilometer) in 1991
UPD	Urban population density (per square kilometer) in 1991
N91	Equal –weighted average of one-year (1991) and two-year (1990-91) average NDVI
NC86T90	Change in average NDVI from 1986 to 1990
NC91T95	Change in average NDVI from 1990-91 to 1993-95 (2 year averages)
NC91T01	Change in average NDVI from 1990-91 to 1999-2001 (2 year averages)
Z91	Equal –weighted average of one-year (1991) and two-year (1990-91) z-score
ZC86T90	Change in z-score from 1986 to 1990
ZC91T95	Change in z-score from 1990-91 to 1993-95 (2 year averages)
ZC91T01	Change in z-score from 1990-91 to 1999-2001 (2 year averages)
NSA	Net sown area as a proportion of total district area (1991)
ADR91T94	Average annual deviation from normal rainfall for 1991 to 1994
ADR86T90	Average annual deviation from normal rainfall for 1986 to 1990
ADR91T00	Average annual deviation from normal rainfall for 1991 to 2000
RN	Normal rainfall
PCER94	Per capita average annual rural consumption expenditure (1994)
PCEU94	Per capita average annual urban consumption expenditure (1994)
PCER01	Per capita average annual rural consumption expenditure (2001)
PCEU01	Per capita average annual urban consumption expenditure (2001)

RFMW	Rural percentage female workforce participation (1991)
UFMW	Urban percentage female workforce participation (1991)
RIDR	Rural infant death rate (1991)
UIDR	Urban infant death rate (1991)
RSR	Rural sex ratio (females per thousand males) (1991)
USR	Urban sex ratio (females per thousand males) (1991)
RFL	Rural female literacy rate (1991)
UFL	Urban female literacy rate (1991)
RTL	Rural total literacy rate (1991)
UTL	Urban total literacy rate (1991)
RMPOP	Percentage of Muslim population in rural areas (1991)
UMPOP	Percentage of Muslim population in urban areas (1991)
RHS	Average household size in rural areas (1991)
UHS	Average household size in urban areas (1991)
UP	Urban population percentage in district (1991)
KD	Kerala dummy
MD	Metropolitan district dummy
PMD	Dummy for districts proximate to metropolitan districts

Table 3. Sample Statistics

	Min	Max	Mean	Std. Dev.
RPCH91T01	-561.913	2595.334	166.597	240.596
UPCH91T01	-401.333	3024.309	327.446	428.254
UBPOP94	6.205	257.136	95.360	45.096
UDPOP94	0.920	46.949	18.172	6.675
RBPOP94	2.330	108.819	35.624	22.955
RDPOP94	2.083	32.741	14.216	7.024
MIPOP94	-486.515	7115.408	31.831	521.190
RPD	7.000	1236.000	222.710	191.292
UPD	267.350	27490.642	3196.841	3157.946
PCER94	20426.641	86463.232	35519.701	9082.827
PCEU94	29285.763	125890.240	48183.783	11780.523
PCER01	26262.892	125313.136	54464.312	15483.674
PCEU01	41537.161	160102.828	78632.998	21368.063
RFL	4.200	93.960	32.616	20.692
UFL	32.540	94.160	61.895	12.450
RTL	13.740	95.670	46.651	17.496
UTL	51.050	95.910	72.605	9.018
RSR	786.000	1230.000	960.259	56.636
USR	764.000	1685.000	930.817	74.931
RIDR	0.906	88.601	23.114	17.340
UIDR	0.108	86.207	17.964	12.791
RFMW	2.180	59.500	28.904	13.962
UFMW	1.980	26.610	9.641	3.925
RHS	3.740	7.070	5.417	0.693
UHS	4.120	7.470	5.359	0.580
RMPOP	0.101	67.068	5.899	7.066
UMPOP	0.682	70.365	17.164	9.289
UP	3.410	100.000	25.771	16.621
ADR91T00	-1160.460	2059.920	-51.125	773.721
ADR91T95	-1026.280	2093.120	-27.042	771.898
ADR86T90	-1279.390	2008.900	-74.615	770.054
RN	313.000	3502.000	1173.861	730.389
NSA	0.054	0.826	0.511	0.160
NC86T90	-1.826	14.096	4.474	3.475
NC91T95	-10.754	28.619	5.423	3.895
ZC86T90	-2.783	13.897	0.851	2.023
ZC91T95	-0.218	2.950	0.482	0.354
ZC91T01	-0.865	8.058	0.267	0.959
NC91T01	-13.864	16.470	-2.917	5.391
Z9091	-7.985	1.248	-0.750	1.177
N9091	133.329	195.405	168.616	11.554
N91	87.595238	194.130953	167.4364044	12.5422076
Z91	-10.721247	1.06959759	-0.93161145	1.39312672

Note: Our sample contains 194 districts of Central, West and South India. Three of these districts are entirely urban (Madras, Hyderabad, and Mumbai) and one is entirely rural (The Dangs in Gujarat). In this table, statistics for rural (urban) variables exclude the entirely urban (rural) districts.

Table 4. Correlation Coefficients Between Environmental Measures

	NSA	*Z9091*	*N9091*	*NC91T95*	*NC91T01*
FA	-0.5236	0.505104	0.5866		
NSA	1	-0.00173	-0.15287		
Z9091		1	0.925189		
ZC91T95				0.273728672	
ZC91T01					0.494105

Note: "FA" represents forest area as a percent of district land, "NSA" represents percentage net sown area, N9091 and Z9091 represent average NDVI and z-score values for 1990-1991, and NC91T95 / NC91T01 and ZC91T95 / ZC91T01 represent changes in average NDVI and z-score values between 1990-1991 and 1993-1995 / 1999-2001, respectively.

Table 5. Short Run 3SLS Results

A) Rural Fertility Equation
(Endogenous Variable: RBPOP94)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	-14.06 (-0.31)	-41.11 (-0.99)	15.73 (0.34)	11.5 (0.24)	-36.79 (-1.13)	-19.82 (-0.58)	-11.69 (-0.35)	-34.1 (-1.11)
Population	*UBPOP94*	0.20*** (4.02)	0.13*** (3.13)	0.2*** (4.16)	0.16*** (3.44)	0.14*** (2.94)	0.16*** (3.51)	0.14*** (3.09)	0.18*** (4.15)
	RDPOP94	1.99*** (7.12)	2.25*** (8.85)	2.25*** (8.85)	2.25*** (8.83)	2.14*** (8.4)	2.23*** (8.7)	2.16*** (8.4)	2.25*** (9.29)
	RPD	-0.01 (-0.47)	-0.03*** (-2.83)	-0.02* (-1.95)	-0.02** (-2.03)	-0.02 (-1.56)	-0.03** (-2.48)	-0.03*** (2.85)	-0.02** (-2.36)
Environment	*NC86T90*	-0.63 (-1.21)	0.19 (0.42)		0.03 (0.06)				
	NC91T95	-5.62*** (-6.98)	-3.06*** (-4.15)	-4.43*** (-6.09)	-3.53*** (-4.72)				
	N91	-0.22 (-1.21)	-0.09 (-0.68)	-0.31* (1.9)	-0.27* (-1.71)				
	NSA	27.95** (2.44)	25.63** (2.54)	22.15** (2.19)	19.07* (1.85)	27.96*** (2.93)	29.35*** (3.15)	28.39*** (2.94)	30.21*** (3.28)
	ZC86T90					1.82 (1.36)	1.88 (1.45)		2.13* (1.68)
	ZC91T95					-62.99*** (-6.89)	-59.22*** (-6.4)	-61.39*** (-6.4)	-61.96*** (-7.29)
	Z91					-11.38*** (-4.22)	-10.94*** (-3.98)	-13.69*** (-6.18)	-11.09*** (-4.41)
Urban Effects	*UP*	0.2 (1.47)	0.104 (0.98)	0.26** (2.11)	0.21* (1.89)	0.03 (0.27)	0.06 (0.52)	0.09 (0.71)	0.11 (0.96)
	MD	-70.99*** (-3.11)		-67.44*** (-2.95)	-53.99** (-2.38)	-17.62 (-0.93)		-26.77 (-1.41)	-16.43 (-0.95)
	PMD	8.05 (0.9)		7.17 (0.8)	4.48 (0.54)	8.18 (0.92)		14.53* (1.64)	15.61* (1.83)
Income	*PCER94*	-0.0004* (-1.95)	-0.0004** (-2.28)	-0.001* (-1.64)	-0.0004** (-2.47)	-0.001 (-1.2)	-0.001 (-1.37)	-0.001** (-2.55)	-0.001*** (-3.4)
Socio-economic Effects	*RIDR*	0.05 (0.52)	-0.06 (-0.56)	0.01 (0.11)	-0.008 (-0.08)	0.04 (0.42)	0.002 (0.02)	0.02 (0.19)	-0.01 (-0.14)
	RFL	0.32** (2.15)	0.23* (1.91)	0.22 (1.48)	0.26* (1.94)	0.42*** (2.74)	0.28* (1.85)	0.43*** (2.99)	0.23* (1.86)
	RSR	0.03 (1.26)	0.02 (0.72)	0.01 (0.25)	-0.005 (-0.17)	0.014 (0.5)	0.002 (0.08)	0.004 (0.13)	0.01 (0.56)
	RFMW	0.002 (0.02)	0.008 (0.08)	0.09 (0.79)	0.1 (0.93)	0.046 (0.41)	0.11 (0.88)	0.04 (0.34)	0.09 (0.92)
	RHS	5.26** (2.46)	7.62*** (3.22)	6.47*** (2.78)	7.49*** (3.13)	4.22* (1.86)	3.33 (1.39)	3.98* (1.69)	3.98* (1.94)
	RMPOP	-0.13 (-0.86)	-0.29 (-1.87)	-0.13 (-0.68)	-0.18 (-0.94)	0.17 (0.85)	0.03 (0.16)	-0.03 (-0.17)	-0.03 (-0.2)
	KD	-35.08*** (-3.08)				-22.63** (-2.38)			

Note: Figures in brackets are t-statistics. Number of Observations = 194.
The *, **, *** represent significance at 10%, 5% and 1% (two-sided) respectively.

Table 5. Short Run 3SLS Results (continued)

B) Urban Fertility Equation
(Endogenous Variable: UBPOP94)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	-47.88 (-0.83)	-49.45 (-0.96)	-165.5** (-2.54)	5.44 (0.1)	-218.84*** (-3.6)	-207.71*** (3.95)	-195.77*** (-3.64)	-14.33 (-0.34)
Population	*RBPOP94*	0.09 (0.79)	-0.02 (-0.16)	0.09 (0.84)	-0.07 (-0.59)	0.04 (0.35)	0.07 (0.63)	0.07 (0.61)	-0.04 (-0.36)
	UDPOP94	3.47*** (9.23)	3.59*** (9.98)	2.87*** (6.13)	3.88*** (10.23)	3.25*** (7.43)	3.39*** (8.39)	3.49*** (8.4)	3.82*** (10.68)
	UPD	-0.0002 (-0.17)	-0.0002 (-0.2)	-0.0003 (-0.32)	-0.0004 (-0.41)	0.0001 (0.1)	-0.00004 (-0.05)	0.0002 (0.22)	-0.0001 (-0.13)
Environment	*NC86T90*	1.05 (1.63)	0.8 (1.34)		-0.57 (0.91)				
	NC91T95	2.88** (2.36)	2.45** (2.26)	4.66*** (3.49)	1.61 (1.42)				
	N91	-0.13 (-0.61)	-0.15 (-0.78)	-0.16 (-0.68)	-0.13 (-0.67)				
	ZC86T90					3.51 (1.58)	3.62* (1.68)		1.94 (1.01)
	ZC91T95					53.69*** (3.78)	51.62*** (3.63)	45.62*** (3.16)	30.44*** (2.58)
	Z91					14.27*** (3.22)	14.06*** (3.21)	8.42** (2.54)	7.19** (1.96)
Urban Effects	*UP*	-0.79*** (-4.72)	-0.71*** (-4.58)	-0.84*** (-4.31)	-0.74*** (-4.56)	-0.82*** (-4.31)	-0.88*** (-5.11)	-0.75*** (-3.98)	-0.71*** (-4.31)
	MD	23.51 (1.01)		1.47 (0.06)	19.84 (0.87)	-17.59 (-0.75)		-27.73 (-1.21)	12.08 (0.61)
	PMD	-4.86 (-0.39)		-34.1** (-2.12)	-1.9 (-0.15)	-13.63 (-1.18)		-31.78** (-2.08)	-3.1 (-0.24)
Income	*PCEU94*	0.001*** (4.59)	0.001*** (3.92)	0.002*** (5.53)	0.0002 (1.0)	0.002*** (5.38)	0.002*** (6.05)	0.003*** (5.79)	0.0002 (1.25)
Socio-economic Effects	*UIDR*	-0.82*** (-5.13)	-0.82*** (-5.06)	-0.68*** (-3.59)	-0.89*** (-5.39)	-0.7*** (-3.7)	-0.75*** (-4.08)	-0.76 (-4.05)	-0.84*** (-5.3)
	UFL	0.75** (2.38)	1.003*** (4.04)	0.58* (1.93)	1.11*** (4.38)	0.47 (1.31)	0.35 (1.25)	0.33 (1.18)	0.97*** (4.14)
	USR	0.06* (1.93)	0.06** (2.0)	0.09** (2.45)	0.04 (1.36)	0.09*** (2.81)	0.1*** (2.95)	0.09*** (2.75)	0.04 (1.35)
	UFMW	-1.52*** (-2.74)	-1.64*** (-2.96)	-0.91 (-1.38)	-1.88*** (-3.32)	-0.74 (-1.1)	-0.84 (-1.27)	-1.16* (1.78)	-1.66*** (-2.97)
	UHS	-4.18 (-0.84)	-4.35 (-0.94)	1.81 (0.35)	-8.31* (-1.71)	7.39 (1.29)	7.09 (1.36)	4.93 (0.93)	-7.59 (-1.61)
	UMPOP	0.59** (2.44)	0.66*** (2.77)	0.36* (1.69)	0.86*** (3.34)	0.25 (1.15)	0.16 (0.75)	0.18 (0.83)	0.92*** (3.8)
	KD	14.3 (1.15)				-5.34 (-0.42)			

Table 5. Short Run 3SLS Results (continued)

C) Migration Equation
(Endogenous Variable: MIPOP94)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	-403.43 (-0.32)	-626.55 (-0.61)	-103.18 (0.09)	-718.73 (-0.67)	2434.4** (2.27)	2016.3** (2.29)	1742.4* (1.95)	1326.93* (1.72)
Population	*RBPOP94*	3.62 (0.82)	6.45 (1.6)	4.83 (1.09)	7.53** (1.97)	7.53 (1.46)	6.54 (1.38)	4.76 (1.05)	10.23*** (2.5)
	UBPOP94	2.82 (1.23)	0.15 (0.06)	-2.02 (-0.73)	0.83 (0.38)	-2.06 (-0.71)	-0.28 (-0.11)	-1.47 (-0.54)	0.16 (0.07)
	RDPOP94	-7.07 (-0.61)	-17.61 (-1.55)	-18.98 (-1.55)	-16.59 (-1.56)	-24.29* (-1.81)	-22.79* (-1.81)	-17.41 (-1.42)	-26.6** (-2.42)
	UDPOP94	-15.45 (-1.55)	-9.28 (-0.94)	-4.63 (-0.41)	-14.07 (-1.42)	-5.29 (-0.45)	-9.72 (-0.89)	-6.38 (-0.57)	-12.66 (-1.24)
	RPD	-0.16 (0.62)	-0.06 (-0.21)	-0.19 (-0.57)	-0.08 (-0.27)	-0.19 (-0.53)	-0.02 (-0.05)	-0.09 (-0.26)	0.04 (0.14)
	UPD	-0.04 (-0.18)	-0.003 (-0.17)	-0.01 (-0.41)	-0.009 (-0.48)	-0.005 (-0.28)	-0.01 (-0.56)	-0.01 (-0.47)	-0.002 (-0.13)
Environment	*NC86T90*	17.83 (1.26)	21.19 (1.62)		23.03* (1.67)				
	NC91T95	-1.33 (-0.04)	36.99 (1.35)	31.04 (1.07)	31.001 (1.18)				
	N91	10.92** (2.24)	7.48* (1.8)	9.38* (1.78)	11.35** (2.47)				
	NSA	-683.5* (-1.94)	-1050.1*** (-3.04)	-844.67** (-2.31)	-864.8** (-2.53)	-1100.1*** (-2.86)	-930.4*** (-2.62)	-925.1** (-2.52)	-952.9*** (-2.82)
	ZC86T90					76.33 (1.43)	57.05 (1.18)		18.36 (0.46)
	ZC91T95					461.93 (1.23)	226.28 (0.64)	29.5 (0.08)	512.19 (1.6)
	Z91					235.6** (2.23)	171.9* (1.75)	57.44 (0.69)	189.93** (2.22)
Urban Effects	*UP*	1.24 (0.32)	0.9 (0.24)	-0.74 (-0.17)	-0.65 (-0.17)	0.44 (0.1)	-1.02 (0.25)	-0.82 (-0.19)	-1.25 (-0.32)
	MD	882.13 (1.35)		-78.99 (-0.1)	1149.6* (1.78)	-853.42 (-1.14)		-573.05 (-0.82)	127.04 (0.24)
	PMD	-133.54 (-0.51)		-290.53 (-0.89)	-195.64 (-0.75)	-303.96 (-0.95)		-219.45 (-0.69)	-244.94 (-0.91)
Income	*PCER94*	-0.006 (-0.93)	-0.006 (-1.06)	-0.05*** (-2.9)	-0.003 (0.51)	-0.05*** (-2.8)	-0.03* (-1.9)	-0.04 (-2.47)	-0.002 (-0.24)
	PCEU94	-0.002 (-0.53)	-0.001 (-0.34)	0.02 (1.53)	-0.002 (-0.34)	0.02 (1.28)	0.004 (0.36)	0.01 (1.08)	-0.001 (-0.24)
Socio-economic Effects	*RHS*	196.76** (2.02)	99.2 (1.2)	251.49** (2.29)	180.65* (1.88)	202.001** (1.91)	158.42 (1.62)	152.19 (1.55)	66.04 (0.77)
	UHS	-220.57** (-1.86)	-64.37 (-0.66)	-226.6* (-1.75)	-197.76* (-1.79)	-231.45 (-1.61)	-190.92 (-1.63)	-164.68 (-1.32)	-101.58 (-0.92)
	RTL	5.56 (0.98)	5.66 (1.05)	20.81** (2.47)	6.22 (1.14)	18.42** (2.05)	13.94 (1.59)	17.18** (2.1)	3.23 (0.59)
	UTL	-13.02 (-1.34)	-4.67 (-0.49)	-17.24 (-1.56)	-11.08 (-1.17)	-18.67 (-1.6)	-9.67 (-0.91)	-11.95 (-1.11)	-6.77 (-0.73)
	KD	-3.24 (-0.01)				461.24 (1.46)			

Table 5. Short Run 3SLS Results (continued)

D) Environmental Change Equation
(Endogenous Variable: NC91T95 for Models 1-4, and ZC91T95 for Models 5-8)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	1.52 (0.28)	-1.99 (-0.37)	5.86 (0.94)	7.98 (1.34)	0.36 (1.42)	0.27 (1.08)	0.39* (1.72)	0.08 (0.4)
Population	*RBPOP94*	-0.13*** (-6.97)	-0.11*** (-5.22)	-0.1*** (-4.53)	-0.1*** (-4.51)	-0.01*** (-6.38)	-0.01*** (-6.51)	-0.01*** (-6.38)	-0.01*** (-8.52)
	UBPOP94	0.03** (2.72)	0.02 (1.52)	0.04*** (2.7)	0.04** (2.31)	0.002** (2.06)	0.002 (1.39)	0.001 (0.79)	0.003*** (3.38)
	RDPOP94	0.23*** (4.18)	0.25*** (4.01)	0.23*** (3.18)	0.23*** (3.26)	0.02*** (4.28)	0.02*** (4.39)	0.02*** (3.95)	0.02*** (6.08)
	UDPOP94	0.03 (0.65)	0.06 (1.13)	0.02 (0.31)	0.01 (0.18)	-0.004 (-0.83)	-0.003 (-0.63)	-0.002 (-0.42)	-0.003 (-0.86)
	MIPOP94	-0.001 (-0.89)	0.001 (1.41)	0.0002 (0.19)	0.001 (0.86)	-0.00004 (-0.71)	-5.44E-7 (-0.01)	-0.0001 (-1.11)	0.0001 (1.38)
	RPD	-0.001 (-0.8)	-0.003 (-1.6)	-0.003 (-1.28)	-0.003 (-1.25)	-0.0003* (-1.79)	-0.0003** (-2.29)	-0.0004*** (-2.78)	-0.0003** (-2.33)
	UPD	0.0001 (0.67)	0.0001 (0.58)	0.00004 (0.39)	0.0002 (1.52)	1.51E-6 (0.25)	4.76E-10 (0.00)	9.75E-7 (0.16)	1.85E-6 (0.32)
Environment	*NC86T90*	-0.13 (-1.54)	-0.14 (-1.61)		-0.15 (-1.66)				
	N91	-0.01 (-0.17)	0.01 (0.27)	-0.01 (0.42)	-0.02 (-0.67)				
	NSA	4.86*** (2.63)	9.38*** (4.62)	5.52*** (2.67)	6.42*** (2.39)	0.27** (2.10)	0.37*** (2.72)	0.31** (2.22)	0.44*** (3.5)
	ZC86T90					0.02 (1.03)	0.02 (1.06)		0.01 (0.78)
	Z91					-0.19*** (-6.3)	-0.19*** (-6.41)	-0.22*** (-13.76)	-0.19*** (-7.58)
	ADR86t90	-0.001 (-0.29)	0.001 (0.45)	0.0004 (0.17)	-0.002 (-0.68)	-0.0002 (-1.39)	-0.0002 (-1.32)	-0.0003** (-2.22)	-0.0001 (-1.04)
	ADR91t95	0.001 (0.61)	0.0002 (0.08)	0.0004 (0.19)	0.003 (0.99)	0.0003* (1.68)	0.0003 (1.6)	0.0004** (2.53)	0.0002 (1.28)
	RN			0.0004 (0.65)				7.69E-6 (0.19)	
Urban Effects	*UP*	0.02 (0.95)	-0.02 (-0.75)	0.038 (1.37)	0.02 (0.73)	0.0002 (0.08)	-0.001 (-0.41)	-0.001 (-0.54)	0.001 (0.45)
	MD	-7.64 (-2.38)		-4.52 (-1.08)	-7.48** (-2.16)	-0.07 (-0.25)		-0.25 (-0.95)	0.03 (0.12)
	PMD	1.99 (1.21)		3.09 (1.57)	2.39 (1.32)	0.19 (1.5)		0.23* (1.76)	0.27** (2.25)
Income	*PCER94*	-0.0001 (-1.58)	-0.00002 (-0.6)	-3.14E-7 (-0.00)	-0.0001* (-1.85)	-0.0001** (-2.01)	-0.00002** (-2.55)	-0.00002*** (-3.47)	-7.59E-6*** (-3.16)
	PCEU94	0.00004** (2.47)	0.0001*** (4.31)	-0.0001 (-1.55)	0.00001 (0.47)	9.42E-7 (0.18)	3.88E-6 (0.81)	6.08E-6 (1.24)	2.18E-7 (0.16)
Socio-economic Effects	*RTL*	0.01 (0.47)	-0.01 (-0.31)	-0.03 (-0.68)	0.01 (0.27)	0.01** (2.22)	0.007** (2.09)	0.01*** (3.07)	0.003 (1.61)
	UTL	-0.01 (-0.14)	-0.04 (-0.78)	0.02 (0.29)	-0.05 (-0.82)	-0.002 (-0.51)	-0.002 (-0.42)	-0.003 (-0.7)	-0.001 (-0.37)
	KD	-4.03** (-2.22)				-0.11 (-0.73)			
System-Weighted R-Square		0.5951	0.6016	0.6200	0.5532	0.6865	0.6747	0.6800	0.6978

Table 6. Long Run 3SLS Results

A) Rural Population Change Equation
(Endogenous Variable: RPCH91T01)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	1953.4*** (3.65)	1676.1*** (3.96)	2024.4*** (4.17)	1511.5*** (3.32)	-435.97 (-1.5)	-358.12 (-1.4)	17.05 (0.07)	-255.19 (-0.99)
Population	*UPCH91T01*	0.13** (1.97)	0.08 (1.46)	0.12** (2.06)	0.17** (2.36)	0.07 (0.79)	0.01 (0.12)	-0.1 (-1.52)	0.05 (0.72)
	RPD	0.19 (1.34)	0.13 (1.06)	0.21* (1.68)	0.12 (0.93)	-0.01 (-0.07)	-0.003 (0.02)	0.05 (0.42)	0.002 (0.01)
Environment	*NC86T90*	-3.45 (-0.61)	-2.33 (-0.43)		-3.17 (-0.59)				
	NC91T01	-32.47*** (-7.49)	-31.57*** (-8.91)	-32.85*** (-8.75)	-32.19*** (-8.44)				
	N91	-9.82*** (-4.33)	-8.47*** (-4.61)	-9.91*** (-4.77)	-8.47*** (-4.1)				
	NSA	11.92 (0.09)	59.98 (0.47)	-20.86 (-0.17)	-12.44 (-0.1)	-52.17 (-0.4)	22.93 (0.19)	-30.03 (-0.25)	-9.11 (-0.07)
	ZC86T90					-65.8*** (-3.42)	-56.81*** (-3.02)		-64.48*** (-3.4)
	ZC91T01					-370.4*** (-7.87)	-381.4*** (-9.24)	-333.1*** (-10.56)	-393.6*** (-9.3)
	Z91					-337.9*** (-7.04)	-332.5*** (-7.56)	-230.4*** (-9.14)	-353.4*** (-7.9)
Urban Effects	*UP*	-0.46 (-0.32)	-2.002* (-1.64)	-0.36 (-0.26)	-0.42 (-0.3)	-0.97 (-0.66)	-2.39* (-1.93)	-1.13 (-0.78)	-1.12 (-0.77)
	MD	-421.62 (-1.63)		-369.73* (-1.76)	-308.02 (-1.39)	-340.9 (-1.46)		-263.43 (-1.24)	-329.3 (-1.56)
	PMD	-64.48 (-0.85)		-76.13 (-1.05)	-56.71 (-0.5)	-129.39 (-1.12)		-70.91 (-0.78)	-111.6 (-0.94)
Income	*PCER01*	-0.003 (-1.59)	-0.01*** (-2.83)	-0.004** (-2.3)	-0.001 (-0.55)	-0.001 (-0.23)	-0.002 (-1.01)	-0.003* (-1.76)	-0.001 (-0.4)
Socio-economic Effects	*RIDR*	0.17 (0.24)	0.38 (0.65)	0.03 (0.05)	0.25 (0.53)	0.49 (0.67)	0.07 (0.12)	0.15 (0.29)	0.08 (0.15)
	RFL	1.97 (1.31)	2.71** (2.11)	2.18* (1.71)	0.96 (0.78)	2.6 (1.59)	2.58* (1.73)	1.86 (1.41)	2.11 (1.52)
	RSR	-0.08 (-0.38)	-0.03 (-0.18)	-0.11 (-0.65)	-0.03 (-0.19)	0.26 (1.05)	0.29 (1.43)	0.15 (0.83)	0.18 (0.82)
	RFMW	-0.65 (-0.77)	-0.99 (-1.33)	-0.59 (-0.89)	-0.62 (-0.9)	-0.87 (-0.77)	-0.42 (-0.47)	-0.11 (-015)	-0.15 (-0.16)
	RHS	-15.34 (-0.63)	0.15 (0.01)	-15.05 (-0.7)	-1.26 (-0.08)	36.38 (1.44)	32.99 (1.5)	11.96 (0.58)	12.25 (0.71)
	RMPOP	-0.23 (-0.16)	-0.2 (-0.19)	-0.05 (-0.05)	-0.49 (-0.47)	-0.001 (-0.00)	-0.89 (-0.7)	0.10 (0.10)	-0.31 (-0.23)
	KD	0.2 (0.0)				-38.15 (0.28)			

Note: Figures in brackets are t-statistics. Number of Observations = 194.
The *, **, *** represent significance at 10%, 5% and 1% (two-sided) respectively.

Table 6. Long Run 3SLS Results (continued)

B) Urban Population Change Equation
(Endogenous Variable: UPCH91T01)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	-859.5 (-0.53)	1357.53 (1.22)	86.15 (0.07)	106.84 (0.09)	1404.9 (1.2)	2710.97*** (3.7)	2973.4*** (3.84)	2623.4*** (3.65)
Population	*RPCH91T01*	1.09* (1.83)	0.58 (1.11)	1.28** (2.21)	1.18** (2.05)	0.15 (0.39)	-0.29 (-0.82)	-0.83** (-1.99)	-0.13 (-0.34)
	UPD	-0.02 (-1.46)	-0.01 (-1.08)	-0.02 (-1.43)	-0.02 (-1.29)	-0.02 (-1.36)	-0.01 (-1.02)	-0.02 (-1.23)	-0.12 (-1.1)
Environment	*NC86T90*	-2.04 (-0.18)	-4.15 (-0.43)		1.63 (0.15)				
	NC91T01	54.62*** (3.45)	42.39*** (3.12)	61.26*** (4.0)	59.08*** (3.84)				
	N91	13.6*** (2.64)	8.38** (2.08)	14.45*** (3.09)	13.59*** (2.8)				
	ZC86T90					77.24* (1.84)	28.72 (0.78)		44.76 (1.2)
	ZC91T01					368.03** (2.48)	147.73 (1.12)	-67.8 (-0.51)	229.7* (1.75)
	Z91					358.8** (2.51)	145.22 (1.19)	-35.68 (-0.38)	220.9* (1.78)
Urban Effects	*UP*	1.05 (0.36)	3.28 (1.29)	2.34 (0.84)	1.99 (0.73)	0.76 (0.27)	1.84 (0.73)	1.14 (0.41)	1.87 (0.7)
	MD	493.04 (1.17)		732.96* (1.85)	623.28 (1.58)	92.97 (0.27)		14.81 (0.04)	121.84 (0.37)
	PMD	105.29 (0.49)		148.28 (0.7)	110.92 (0.51)	61.49 (0.3)		-5.3 (-0.03)	75.75 (0.36)
Income	*PCEU01*	0.002 (0.39)	-0.003 (-0.91)	-0.003 (-1.2)	-0.002 (-1.28)	0.003 (0.57)	-0.004 (-1.28)	-0.007** (-2.19)	-0.003* (-1.65)
Socio-economic Effects	*UIDR*	6.42** (2.47)	7.05*** (2.71)	6.76** (2.55)	6.94*** (2.62)	5.18** (2.11)	5.31** (2.21)	4.85** (1.97)	5.31** (2.19)
	UFL	1.98 (0.5)	1.78 (0.49)	1.77 (0.47)	1.24 (0.36)	1.73 (0.44)	1.92 (0.48)	5.32 (1.37)	0.66 (0.19)
	USR	-1.26** (-2.37)	-1.65*** (-3.26)	-1.56*** (-3.03)	-1.54*** (-3.02)	-1.01* (1.88)	-1.32*** (-2.69)	-1.36*** (-2.73)	-1.24** (-2.51)
	UFMW	-1.47 (-0.14)	-5.27 (-0.52)	-1.67 (-0.16)	-2.89 (-0.28)	-8.98 (-0.9)	-7.89 (-0.79)	-7.64 (-0.77)	-9.02 (-0.93)
	UHS	-48.97 (-0.45)	-164.39* (-1.95)	-131.14 (-1.53)	-121.59 (-1.4)	-56.53 (-0.52)	-166.08** (-2.07)	-194.47** (-2.34)	-156.36** (-2.00)
	UMPOP	0.41 (0.1)	1.28 (0.3)	0.68 (0.17)	0.41 (0.1)	0.77 (0.19)	1.15 (0.29)	1.18 (0.29)	0.73 (0.19)
	KD	-341.07 (-1.23)				-468.9 (-1.61)			

Table 6. Long Run 3SLS Results (continued)

C) Environmental Change Equation
(Endogenous Variable: NC91T01 for Models 1-4, and ZC91T01 for Models 5-8)

Categories	*Variables*	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Constant	51.65*** (4.46)	43.78*** (4.78)	52.21*** (5.13)	43.67*** (4.75)	0.02 (0.06)	-0.02 (-0.06)	0.5 (1.39)	-0.22 (-0.72)
Population	*RPCH91T01*	-0.03*** (-7.83)	-0.03*** (-9.16)	-0.03*** (-9.13)	-0.03*** (-9.98)	-0.002*** (-8.81)	-0.002*** (-9.91)	-0.003*** (-10.12)	-0.002*** (-10.02)
	UPCH91T01	0.001 (0.65)	0.001 (0.71)	0.002 (1.17)	0.004* (1.81)	0.0004* (1.8)	0.0002 (1.06)	-0.0001 (-0.57)	0.0003 (1.46)
	RPD	0.006 (1.56)	0.004 (1.35)	0.006* (1.87)	0.004 (1.19)	0.00002 (0.08)	0.0001 (0.35)	0.0002 (0.69)	0.0001 (0.38)
	UPD	-2.93E-6 (-0.03)	-0.00002 (-0.32)	0.00001 (0.16)	0.00002 (0.27)	4.53E-6 (0.59)	-1.02E-6 (-0.14)	2.18E-6 (0.28)	1.83E-6 (0.23)
Environment	*NC86T90*	-0.14 (-0.96)	-0.09 (-0.71)		-0.12 (-0.84)				
	N91	-0.29*** (-4.96)	-0.23*** (-4.92)	-0.29*** (-5.38)	-0.24*** (-5.01)				
	NSA	0.28 (0.08)	1.84 (0.59)	-0.96 (-0.28)	-0.45 (-0.14)	-0.19 (-0.76)	-0.04 (-0.16)	-0.1 (-0.31)	-0.09 (-0.37)
	ZC86T90					-0.18*** (-4.74)	-0.16*** (-4.07)		-0.17*** (-4.35)
	Z91					-0.92*** (-16.39)	-0.89*** (-15.48)	-0.7*** (-17.92)	-0.91*** (-15.73)
	ADR86t90	0.0001 (0.02)	-0.001 (-0.49)	-0.0002 (-0.07)	-0.001 (-0.28)	0.0002 (0.76)	-0.0001 (-0.42)	0.0001 (0.17)	0.0001 (0.37)
	ADR91t00	0.001 (0.29)	0.002 (0.86)	0.0009 (0.36)	0.001 (0.54)	-0.0002 (-0.76)	0.0001 (0.36)	-0.0001 (-0.17)	-0.0001 (-0.39)
	RN			-0.00002 (-0.04)				0.0001 (0.99)	
Urban Effects	*UP*	-0.03 (-0.67)	-0.062* (-1.91)	-0.02 (-0.52)	-0.02 (-0.47)	-0.002 (-0.71)	-0.01** (-2.08)	-0.004 (-0.94)	-0.003 (-1.06)
	MD	-13.97** (-2.41)		-13.87*** (-2.53)	-9.97** (-2.02)	-0.66 (-1.6)		-0.71 (-1.38)	-0.71* (-1.72)
	PMD	-1.6 (-0.93)		-1.86 (-1.0)	-1.36 (-0.46)	-0.29 (-1.28)		-0.3 (-1.07)	-0.29 (-1.14)
Income	*PCER01*	-0.0001** (-2.02)	-0.0001* (-1.74)	-0.0001** (-2.23)	-0.00001 (-0.4)	-2.72E-6 (-0.54)	-3.08E-6 (-0.64)	-8.41E-6 (-1.47)	-1.71E-6 (-0.55)
	PCEU01	0.00005 (0.86)	-0.00002 (-0.39)	0.00003 (0.64)	-7.07E-6 (-0.59)	-4.8E-6 (-1.12)	-2.9E-6 (-0.81)	-9.93E-7 (-0.22)	1.17E-7 (0.1)
Socio-economic Effects	*RTL*	0.09* (1.73)	0.09** (1.98)	0.09* (1.91)	0.05 (1.32)	0.01* (1.67)	0.01* (1.93)	0.01 (1.27)	0.007** (2.08)
	UTL	-0.04 (-0.64)	-0.03 (-0.57)	-0.04 (-084)	-0.04 (-0.94)	0.002 (0.3)	0.001 (0.27)	-0.001 (-0.24)	-0.001 (-0.12)
	KD	-0.71 (-0.21)				0.34 (1.28)			
System-Weighted R-Square		0.6101	0.5900	0.6139	0.6242	0.7795	0.7727	0.7177	0.7662