Economic Growth, Safe Drinking Water and Ground Water Storage: Examining Environmental Kuznets Curve (EKC) in Indian Context

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Economic Growth, Safe Drinking Water and Ground Water Storage: Examining Environmental Kuznets Curve (EKC) in Indian Context

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Abstract:

The trade-off between economic growth and environmental sustainability is very tough to a faster growing developing country like India. The Environmental Kuznets Curve (EKC) hypothesis proposes, environmental degradation increases with income growth first, and then it declines with income rise. The present study is an endeavor to find out the EKC relation in the arena of access to safe drinking water, ground water development and utilisation, and waterborne diseases during 2001-2012 in 32 Indian States/Union Territories (UTs). The panel analysis results reveal that no EKC relationship is found in the Indian context and income growth has no significant effect on all of the indicators. Income growth in lower income States/UTs immensely helps to improve the access to safe drinking water compared to the higher income States/UTs. Rapid expansion of irrigated agriculture and obsoleted regulation related to the abstraction overexploit the ground water. Moreover, lack of proper technological investment or abatement measures and its implication in Indian industry deteriorate the indicators of environmental quality. The contribution of technological input and its progress infer the poor design of environmental policies and its implementation in India. Apart from these, climatic and geomorphological heterogeneity widely influence the distribution and utilisation of water resources. The huge population pressure also exerts a negative effect on the environment.

Key words: Environmental Kuznets Curve (EKC), Environmental Sustainability, Safe Drinking water, Ground Water, Waterborne diseases, Economic Growth.

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1. Introduction:

Indian has experienced remarkable economic growth during last two-three decades. The growth rate of income per capita (Net State Domestic Product) tripled from 1.5 percent during 1951-81 to 4.2 percent during 1981-2009 (Subramanian and Kumar 2011, p.2). Within the latter period, the 2000s was the best ever decade for Indian macroeconomic performance with growth rate 6.1 percent per annum, which had increased from 4.2 percent in 1990s and almost all major states recoded growth performance (Subramanian and Kumar 2011, p.2). The impetus has come actually from the rapid industrial and service sector growth. Although the growth of the agricultural sector has been diminished, it has continued its economic expansion during that period.

With the robust growth trajectory in India the demand and availability of the factors of production as well as quality of the environment is the matter of concern. Environmental degradation is seriously undermining the India's economic prospects. It is estimated that the financial costs of environmental damage in India around Rs 3.75 trillion (US$80 billion) equivalent to 5.7 percent of Gross Domestic Product (GDP) per year (World Bank 2013, p.1). Air pollution, emission of greenhouse gases, surface and ground water pollution, depletion of ground water storage and deforestation have serious economic and public health impact that ultimately downplaying the quality of life. Nearly 23 percent child mortality in India is linked to environmental degradation, especially for air pollution and inadequate water supply, sanitation and hygiene (World Bank 2013, p.1). Near about 37.7 million Indian is estimated to be affected by waterborne diseases annually (Khurana and Sen 2011, p.4). Near about 200 million person days of work are wasted and the country loses about Rs 366 billion each year due to the ill effects of water pollution and poor sanitation facilities (Parikh 2004 cited in IDFC 2011, p.228). The total amount of estimated expenditure for lack of safe drinking water, sanitation and its related diseases is nearly 470-610 billion Rs per annum (World Bank 2013, p.16).

Diminishing per capita water availability from 1816 cubic meters (CM) in 2001 from 1588 cubic meters in 2011 (MOSPI 2013, p.184) accompanied with increasing population, urbanisation and industrialisation augment the burden of the crisis. Moreover, due to contamination of the sources of water, especially through industrial effluent and domestic sewage discharge, and poor water treatment facility, it is often difficult to get safe drinking water (CAG 2011; PIB 2012). The water quality of most of the Indian rivers crossed the desired standard. The monitoring result during 2011 of the Central Pollution Control Board (CPCB) reported that the organic pollution in terms of Biochemical Oxygen Demand (BOD) and Coliform bacterial count continues to be the predominant pollution of aquatic resources in different parts of the country. Another finding by CPCB (2009), 43 industrial areas/clusters out of the 88 are found to be critically polluted as per Comprehensive Environmental Pollution Index (CEPI). Critically polluted industrial areas are not only just an environmental challenge, but they are a public health challenges also. Nearly 85 percent of big industrial clusters in India are facing health hazards where air, water and land pollution levels are not fit for human habitants (PIB 2009).

It is very tough trade-off between economic growth in one hand and environmental sustainability on the other hand, in faster growing developing countries like India. It is widely recognised theory that in the early stages of income growth, degradation and pollution increases, but beyond a threshold of income, pollution drops down with the growth increase (Fig. 1). It is known as Environmental Kuznets Curve (EKC) hypothesis. The EKC concept is traced from the original hypothesis of Kuznets in 1955 that is income equality rises first and then falls with economic development proceeds. The argument behind the EKC hypothesis is that the country assimilates new technologies, policies and programmes to its growth trajectory over the time that helps to reduce environmental degradation to a great extent. Implementation of new technologies and effective policies need a substantial amount of investment or expenditure that crucially linked with the pattern of higher economic growth. Most probably that is why, the policy makers of developing countries keep environmental consideration as second objectives, prioritise 'grow first, clean up later'. However, there is wide contradiction regarding the validation of the hypothesis while it confronts with the emerging idea of sustainable economic development promulgated by the Brundtland Commission (1987) in 'Our Common Future'.

The EKC concept first draws its root from the path breaking studies by Grossman and Krueger (1991), World Bank Development Reports (1992) and its background study by Shafik and Bandhyopadhya (1992). The Grossman and Krueger's study was based on three air pollutants, viz. sulfur dioxide (SO_2), smoke and suspended particulate of urban areas located in 42 countries during the time period 1977-1988. The study reveals that the concentration of two pollutants, such as SO_2 and smoke, increase with per capita GDP at low levels of national income, but decrease at higher levels of the same. Shafik and Bandhyopadhya (1992) began studying with ten diversified indicators[1] of environmental quality of 149 countries during 1960-90. Income has the most consisting significant effect on all chosen indicators of environmental quality and most of these (except access to safe drinking water and urban sanitation) deteriorate initially as the incomes rise and higher incomes assist to resolve the problem better ways. Only two indicators out of the ten, such as suspended particulate matter and ambient $SO_{2,}$ follow the EKC hypothesis. The study also expresses that in most of the cases, high investment and rapid economic growth, create pressure on natural resources resulting in high levels of pollution. Trade, debt and other macroeconomics policy variable exert little generalise effects on the environment. Apart from these, a plethora of studies on different aspects of environmental indicators (Hetteig et al. 1992; Selden and Song 1994) in various parts of the world and its critical evaluation (Bruyn et al. 1998; Dinda 2004; Stern 2004;) have also been carried on during the last couple of decades.

There are also few of studies in Indian context. Most appreciated one, Managi and Jena (2007), has brought out the EKC relation between environmental productivity of three pollutants, such as SO_2, nitrogen dioxide (NO_2) and suspended particulate matter, and income with the analysis of state level industrial data during 1991-2003. The results of the panel analysis unveil that the scale effect dominates over the technique effect and combined effect of income on environmental productivity is negative. The study of Mythili and Mukherjee (2011) denies the EKC kind of relationship between river effluents and per capita net state domestic

[1] Shafik and Bandhyopadhya's (1992) study includes wide range of environmental indicators such as lack of safe drinking water, lack of urban sanitation, annual deforestation, total deforestation, dissolved oxygen (DO), fecal coliform, ambient suspended particulates matter, ambient SO_2, municipal waste per capita, carbon emission per capita.

product (NSDP) when dealing with three river effluents, such as BOD, dissolve oxygen (DO) and pH, during the period 1990-91 to 2005-06 in 14 Indian states. This study also expresses that the policy ordinance has not been implemented in many cases and government should take mix measures such as command and control instruments, economic instruments like price based and quality based, and hybrid instrument. The Barua and Hubacek's (2008) study focus on the watershed level of the 12 states based on two parameters of riverine water quality, BOD and chemical oxygen demand (COD). The study has found the EKC relationship only four states out of the 12. A distinctive kind of study has been carried by Kumar and Viswanathan (2003) on indoor air pollution and income relationship at household level based on the National Sample Survey (NSS) over the period from 1983 to 2000. The result shows the validation of EKC hypothesis, especially for the rural households.

However, whatever studies have been carried on Indian context are limited either on air pollution, such as CO_2, SO_2, NO_2 and suspended particulate matter, or riverine water pollution, such as BOD, DO, COD, pH and Coliform. None of the study has been done on the quality of drinking water, waterborne diseases and ground water utilisation and development, even if these have not been explored beyond India except lack of safe drinking water and urban sewage generation. The present study, therefore, is an endeavour to insight into the arena of drinking water and its related diseases and ground water storages with respect to a rapid growth trajectory in India.

2. Status of drinking water and ground water storage

Before entering into the main study, it is very important to briefly introduce regarding the condition of drinking water and ground water storages in India. According to the periodical assessment of Central Water Commission (CWC 2012-13, p.14) total utilisable water potential is 1,121 billion cubic meters (BCM) against current water demand of 813 BCM in India. The current demand will rise 1,093 BCM by the year 2025 and it will be double (1,447BCM) in 2050 (Table 1). Therefore, India will face a water crisis in the near future, if precaution is not taken immediately. Moreover, recent (in 2011) per capita water availability is 1588 CM which has declined from 1816 CM in 2001 (MOSPI 2013, p.184) and it is estimated further decline to 1140

CM by the year 2050 (CPCB 2010, p.23). As per Falkenmark (1989) indicator, 1,000-1,700 CM per capita water usages considered as 'stress' water conditions in an area where India has already entered into 2010 onward.

The requirement of drinking water of the total demand in a country is small, but it should be clean. In India, it is around six percent of the total fresh water consumption (T.1). Universal coverage of safe drinking water is one of the basic provisions of a nation. India would not able to provide to its cent percent households (HHs) till now, in spite of implementing a plethora of policies and programmes since the beginning of the Five Year Plan. But India has improved a lot (Table 2). Nearly 87 percent HHs enjoy the provision of safe drinking water[2] in the 2011 Census. The figure of National Sample Survey (NSS) in 2012 is a bit higher; about 91 percent HHs use improved source[3] of drinking water (Table 2).

Provision of safe drinking water within the premises is a sign of more gender empowerment as well as an indicator of a good quality of living status. A substantial proportion of HHs (18 percent) travel away from the premises[4] to fetch water in the 2011 Census and it has increased from the previous Census, 2001 (Das and Mistri 2013, p.156). The regional picture is far different from the gross. In West Indian States, namely Rajasthan, Central Indian States, namely Madhya Pradesh and Chhattisgarh, and East Indian States, namely Bihar, Odisha, Jharkhand and West Bengal, and North-Eastern States, namely Tripura, Manipur and Nagaland, where more than 25 percent HHs have to face water away from the premises (Das and Mistri 2013). Moreover, on an average nearly 20 percent rural HHs in Western and Central Indian states do not get sufficient amount of water for maintaining their activities throughout the year (NSS 2012).

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[2] Safe drinking water includes the sources like tap water from treated and un-treated sources, covered well, hand pump and tube well/borehole in the 2001 and 2011 Census of India.

[3] 'Improved source' of drinking water includes: 'bottled water', 'piped water into dwelling', 'piped water to yard/plot', 'public tap/standpipe', 'tube well/borehole', 'protected well', 'protected spring', and 'rainwater collection' in the different round of NSS such as 58th round (2002), 65th round (2008-09) and 69th Round (2012).

[4] Away from the premises refers to a water source located beyond 100 metres from the premises in urban areas and 500 metres in rural areas (Census of India, 2001 & 2011).

India is the largest ground water user in the world, estimated usages 245.05 BCM per annum (CGWB 2014, p.88); more than a quarter of the global total (World Bank 2010). For the drinking water purpose India highly relies on the storage of ground water and it is considered as a safe source also. More than 50 percent HHs directly[5] extract ground water for drinking in various rounds of NSS and Census of India. According to the World Bank (2010, p.ix) estimation, nearly 85 percent drinking water supply depends on ground water and especially rural Indian high depends on it.

The periodical assessment (in 2011) of the ground water in India by Center Ground Water Board (CGWB) reported that total ground water drafting (per annum) is 245.05 BCM, of these only 22.71 BCM (9.27 Percent) is used for domestic and industrial purpose and the rest 222.36 BCM equal to 90.74 percent of total drafting is used for irrigation (Table 3). The World Bank (2010, p.1) estimates that more than 60 percent irrigated agriculture depends on ground water withdrawal. Other sources like remote sensing data and NSS suggest that this figure would be much higher as 75-80 percent of the total irrigated area in India is served by groundwater (Shah 2009, p.4). With the rapid expansion of gross irrigated area of 38.2 million hectares (ha) in 1970-71 to 91.5 million ha in 2011-12 that is more than two fold (DOES 2014), the stress on ground water has also been amplified. Since the 1970s, ground water irrigation has expanded at a very rapid pace (UNICEF 2013). During last eight years (2004-11), the ground water drafting for irrigation has been near about five percent increased (Table 3). Therefore, it is clear that when most of the Indian people depend on ground water for drinking and so-called for the safe also, the maximum amount of that is allocated for irrigation.

Furthermore, according to the World Bank (1998) estimation India uses nearly 13 percent of the total fresh water withdrawal for industrial usages[6], and the industrial demand along with energy production is expected to grow at the rate of 4.2 percent per year, rising

[5] Directly extract refers to using the sources of covered and uncovered well/protected and unprotected well, hand pump, borehole and tube well, etc., by the differs Census of India and NSS rounds

[6] In India, there is no accurate estimation of water demand in industrial sector. NCIWRD estimates (T.1), industry including energy production consumes 7.9 percent of the total demand and CPCB estimates, the figure may be eight percent.

from 67 BCM in 1999 to 228 BCM by 2025 (cited in CSE 2004, p.2). The industrial demand, therefore, is not negligible in India and it is bound to grow in the coming years.

Ground water is a renewable resource. But the question is how much India is prepared for that in terms of replenishment and its management. The outcomes are far from satisfactory. 'Stages of ground water development'[7] that is a percentage of utilisation with respect to recharge has gradually increased to 62 percent in the latest assessment, 2011 from 58 percent in first assessment, 2004 (Table 3). It indicates extraction is higher than recharge processes. The regional figure is too uneven. In Punjab (172 percent), Delhi (137 percent), Rajasthan (137 percent) and Haryana (133 percent), indiscriminate withdrawal of ground water leading to overexploitation. In 12 States/Union Territories (UTs) out of the 35, stage of ground water development is higher than national average (62 percent).

The expert group on ground water assessment categorises the administrative blocks/watersheds/mandals/firkas into four assessment units such as 'safe', 'semi-critical', 'critical' and 'overexploited' areas based on two criteria viz. stage of ground water development and long term trend (10 years) of pre and post monsoon ground water levels. In the last assessment (in 2011), total 1985 units (30 percent) out of the 6607 assessment units in various States/UTs are categorised as assessment units under thereat (semi-critical + critical + overexploited) where people suffer different shorts of ground water crisis (Table 3). Among these, 1071 units equal to 16 percent of the total assessment units are defined as 'over exploited'. There is no sign of improvement of assessment units in the different assessments (Table 3).

Therefore, the unsustainable level of exploitation put the ground water resources at a great peril. Gradual depletion of ground water accompanied with population growth, rapid urbanisation and pollution of the surface water sources by industrial and domestic effluents, it is a very tough challenge for India to provide safe drinking water universally. Moreover, increasing prevalence rate of waterborne diseases, especially diarrhea and typhoid (MOHFW

[7] The stage of Ground water Development is computed as – (Existing Gross Draft For All Uses/Net Annual Groundwater Availability)*100

2005-13[8]), and the huge environmental damage cost related to it that is 0.8 percent of the GDP equal to Rs 470-610 billion (World Bank 2013) really pose questions on existing safe and sanitised drinking water in India.

Actually, the outright expansion of gross irrigated areas, rapid industrial growth and high energy consumption along with huge industrial effluent, and faster pace of urbanisation, all are the catalyst of faster economic growth in India which abruptly decline both the quantity and quality of fresh water in the country. As a result, different shorts of water related issues have been intensifying gradually. The growth India has been experiencing, how much it is appreciated while considering the quality of environmental indicators as well as social and financial costs of environmental damage, is the basic concern to the policy makers. In this context the argument of EKC hypothesis could be supportive or not at all. The present study, therefore, is an attempt to explore the relationship, especially for the quality of drinking water, prevalence of waterborne diseases and ground water utilisation and crisis, with income growth in India during the best ever growth decade after independence, 2000s.

3. Objectives of the study

The scope of the present study is to examine the relationship between per capita Net State Domestic Product (NSDP) and five selective indicators related to drinking water, ground water and waterborne diseases such as lack of safe drinking water, stage of ground water development, administrative units (blocks/watersheds/mandals/firkas) under threats in terms of ground water crisis and the prevalence of waterborne disease, especially for typhoid and diarrhea. These relationships help to investigate whether any EKC hypothesis exist or not in the arena of drinking water and its related disease, and ground water storages in Indian context. How the relationship varies across different States/UTs for different indicators and how demographic factors and macroeconomic policies affect the evolution of the environmental indicators are also brought in the gamut of the study. Total 32 out of the 35 States/UTs are included, only excluded Dadara and Nagar Havel, Daman and Diu, and Lakshadweep due to the

[8] As per the statistics of National Health Profile, 2005 to 2013 by Directorate of General of Health Service, Ministry of Health and Family Welfare (MOHFW)

lack of availability of proper date sets over the years. The study is carried on the time frame 2001 to 2012.

4. Data sources

The income data, per capita NSDP is at factor cost and constant prices of the year 2004-05 from the Central Statistical Organisation (CSO), Ministry of Statistics and Programme Implementation (MOSPI), Government of India (GOI). The data for all the years (2001 to 2012) of all the indicators are not available, there are some gaps. Hence, it is an unbalance panel data. For the access to safe drinking water, five time point data, such as 2001 and 2011 from Census of India and 2002, 2008 and 2012 from different rounds of NSS, are available. For the NSS data, weight cases are considered to make these comparable to the Census figures. Lack of safe drinking water is measured by percentage of households (HHs) without access to drinking water from safe sources or improved sources[9]. In case of waterborne diseases, such as Diarrhea and Typhoid, continuous eight years data from 2005 to 2012 are taken from Directorate General of Health Services, Ministry of Health Family and Welfare (MOHFW), GOI. Both cases and deaths are included to compute the disease prevalence in a year. Three time data, such as 2004, 2009 and 2011, for stage of ground water development and administrative units under threats, are available from the Central Ground Water Board (CGWB), Ministry of Water Resources (MOWR). Both the indicators are in percentage terms. For administrative units under threats, the cumulative percentage of semi-critical, critical and overexploited units out of the total assessment units under different States/UTs are considered.

Apart from these, two demographic factors, such as density and literacy, are taken from the Census of India 2001 and 2011. Three macroeconomic policy variables, such as percentage growth (year of year) of gross state domestic product (GSDP) at constant price, outstanding public debt as percentage of GSDP and annual government expenditure as percentage to GSDP are accumulated from the CSO, MOSPI.

[9] For more details regarding the indicators, refers to the section, 2. 'Status of drinking water and ground water storage'

5. Methodology

Basic three models are tested- log-log, quadratic and cubic to explore the relation between income and each environmental indicator (EI).

$$ln\ (EI) = \alpha + \beta_1\ ln(NSDP/Capita) + \beta_2\ (Year)$$

$$ln\ (EI) = \alpha + \beta_1\ ln(NSDP/Capita) + \beta_2 ln\ (NSDP/Capita)^2 + \beta_3(Year)$$

$$ln\ (EI) = \alpha + \beta_1\ ln(NSDP/Capita) + \beta_2 ln\ (NSDP/Capita)^2 + \beta_3 ln\ (NSDP/Capita)^3 + \beta_3(Year)$$

In the study, five environmental indicators (EIs) or dependent variables are investigated. All dependent and independent variables are in logarithms. Time and entity fixed effect model that is dummy for the 32 States/UTs and time trend are incorporated in the right hand side of the equation to capture the State/UTs specific effect and time specific effect is adopted. It helps to explore the net effect of per capita NSDP on the outcome variable/EI. The time trend is added as a proxy of improvement in technology or measures and its implementation. The basic relation between income and each dependent variable is examined first based on above mentioned three models (Table 4). The estimated parameters of the best fits models/equations help to assess the various forms of economic-environment relationship (Bruyn et al. 1998). It is mentioned as follows.

$\beta_1 > 0, \beta_2 = \beta_3 = 0; represent\ a\ monotonically\ incereasing\ relationship$

$\beta_1 < 0, \beta_2 = \beta_3 = 0; represent\ a\ monotonically\ decereasing\ relationship$

$\boldsymbol{\beta_1 > 0, \beta_2 < 0, \beta_3 = 0;\ represent\ a\ quadriatic\ relationship\ (i.e. EKC)}$

$\beta_1 < 0, \beta_2 > 0, \beta_3 = 0;\ represent\ a\ quadriatic\ relationship\ (i.e. U - shaped)$

$\beta_1 > 0, \beta_2 < 0, \beta_3 > 0;\ represent\ a\ cubic\ relationship\ (i.e. N - Shaped)$

$\beta_1 < 0, \beta_2 > 0, \beta_3 < 0;\ represent\ a\ cubic\ relationship\ (i.e. tilted\ S - shaped)$

Next, the consequences of other factors like demographic and policy are examined one by one based on best fits models (basic relation models) where effect of income is controlled and the functional forms of the hypothesised relationship between income and dependent variables are maintained. Finally, the concluding remarks are incorporated.

6. Basic relationship

6.1 Access to safe drinking water

After controlling time and States/UTs specific effects in panel regression, the relation between per capita NSDP and each indicator as follows. Lack of safe drinking water indicates that it has improved first with incomes rise, and then deteriorated with higher incomes (Table 4). The relation is significant. The quadratic model fits the best than linear or cubic because, these do not add considerable explanatory power to the lack of safe drinking water. The curve is U-shaped, $\beta_1<0$, $\beta_2>0$, $\beta_3=0$; hence, the EKC hypothesis is not followed. The deterioration of the quality of safe drinking water at higher incomes begins (turning point) at per capita NSDP of around Rs 53,400. The Fig. 2 is the elasticity graph of the lack of safe drinking water with respect to per capita NSDP. The graph indicates the change of the lack of safe drinking water in respect to the change of per capita income less than one percent that means the lack of safe drinking water is found to be inelastic with respect to per capita income in the whole range. From the economic viewpoint, though it is inelastic the slope of the curve indicates that the changes are higher in lower income states compared to middle and high income states. The problem has improved at a faster pace in low income states with income rise.

It is not surprising that the problem of access to safe drinking water is essentially solved with higher income as it helps to more invest for supplying water from safe/improve sources and better maintains. Households can also take own measures. But surprising is, in some high income States/UTs worsening the problem. It could be attributed by the issues related to management and technological inputs. If it is followed the States/UTs specific effect, some states, such as Kerala, Jharkhand, Manipur, Meghalaya, Mizoram and Nagaland, where the problem of access to safe drinking water have significantly increased during 2001-2011 with per capita income rise. During 2001-2012, Kerala, Jharkhand, Meghalaya, Mizoram, Nagaland and

Manipur have recorded on an average 6.9, 6.0, 5.5, 5.5, 5.0 and 4.0 percent per year NSDP per capita growths respectively, where the national average is 5.6 percent per year (CSO 2014). Actually, in geographical viewpoint, these are either hilly or plateau regions. Manipur, Meghalaya, Mizoram and Nagaland are North-Eastern hilly States and part of the Himalayan system; Kerala is in the Western Ghats system and Jharkhand is the part of the Chota Nagpur Plateau. Due to such geomorphological setup, the ground potentiality is very less. They highly rely on either the sources of unprotected spring, pond/tank, unprotected well or other surface water sources. In Kerala and Jharkhand, near about 61 and 26 percent HHs use unprotected well for drinking respectively (NSS 2012). In the North-Eastern states, a substantial proportion of HHs use unprotected spring and well, tank/ponds and other surface water sources. However, it is obviously a question of management and technological investment, because with the implementation of proper programme and technological investment at household and community level could solve the problem easily. For an example in Kerala, 61 percent unprotected well users could be brought under the safe brigade, only needs some basic technological intervention at HHs level, such as the use of filters, using after boiling or chemically treated and so on so forth.

6.2 Ground water: utilisation and availability

Two measures of ground water, stage of ground water development and administrative units under threat, tend to decrease with rising per capita NSDP. The quadratic and cubic models are not best fit to describe the relationships (Table 4). Both the relation is not statistically significant. But the time trend is significantly different from zero and both the slope coefficients are positive.

Time trend is a proxy of improvement in technology. Owing to incorporate more technology with the time, the exploitation of ground water becomes higher than previous. Long-term exploitation results in the depletion of water table and runs the ground water crisis. Moreover, exploitation is highly associated with government policy and management. In India, ground water is considered as private resource and mutated with the land right. The Government has no direct control over it. Therefore, overwhelming exploitation is continuing. Since 1970 onward ground water irrigation has been expanded with rapid stride (Shah 2009;

UNICEF 2013). Until 1960, Indian farmers owned just a few tens of thousands of mechanical pumps using diesel or electricity to pump water; today India has over 20 million modern water extraction structures (Shah 2009, p.4). According to the last Agricultural Census of India 2010-11, near about 9.8 million and 11.1 million wells and tube wells with pump sets (both electric and diesel) respectively, a total 20.95 million pump sets are used to extract ground water. Total 6.57 million pump sets are newly added from the Agricultural Census 2000-01. Moreover, during last two-three Five Year Plans, there were wide coverage of electricity in most of the rural villages that make easier to explore the ground water with electrical pump sets. According to the 2001 population Census of India, only about 44 percent rural HHs enjoyed the electricity facility, now (in 2011) it has increased to 55 percent. Total electrical pump sets have been increased about four million during 2000-01 to 2010-11, where diesel pump sets have been increased 2.5 million. Besides, governmental investment in irrigation during the last two to three decades has helped the farmers to use or install water abstraction technology as well as enhance the purchasing power. Every fourth cultivator HH has a tube well, and two of the remaining three use purchased irrigation service supplied by tube well owners (Shah 2009, p.4).

Like agriculture or domestic ground water uses in India, obsolete law related to the ground water extraction often remains un-priced and unregulated for the industrial establishment compared to the supply from surface water sources through the municipality/corporation/local bodies. It is absolutely absurd for industrial and commercial use. Furthermore, this poor pricing act as an incentive to extract more ground water for the industrial unit in the country.

The stage of ground water development and administrative units under threats, both have two facets, one extraction and another recharge and replenish. Punjab, Haryana, Delhi and western Uttar Pradesh where though replenishable resources are abundant, but there have been excessive withdrawals of ground water leading to overexploitation (CGWB 2014) resulting into very high level of ground water development and more blocks under threats. On the other hand, arid climatic influence states, namely Rajasthan and Gujarat where chances of replenish are very low. In peninsular India like Kerala, Karnataka, Andhra Pradesh and Tamil Nadu where due to poor aquifer both availability and recharge is very low. Therefore climatic and geomorphological set up influence a lot to the storages of ground water.

6.3 Waterborne diseases: Typhoid and Diarrhea

The main health impact of unclean water and poor hygiene are typhoid and diarrhea. More than ten million cases are reported each year in India and its numbers have been increasing over the years. In 2013, 10.8 million and 1.5 million cases are reported for diarrhea and typhoid respectively, which have been increased from 9.0 million and 0.6 million in 2005 respectively (MOHFW 2005-13). Though the deaths related to the typhoid and diarrhea has been declined, still these are the one of the top five causes of death in India (ORGI 2009, p.11). The children (under 5 years) are highly susceptible to the waterborne diseases. According to the reporting of the Office of Registrar General of India (2009), 13.8 percent of child mortality is caused due to Diarrheal diseases. The estimated morbidity cost of these two diseases is nearly 480 billion Rs and aversive cost/ cost of the health risks of environmental burdens is about 55 billion Rs, a total 470-610 billion Rs per year contributes to the dominating share of the health cost in India (World Bank 2013, p.16).

Present study considered the total effected persons that are the sum of the cases and deaths for each disease. The models indicate (Table 4) that both the diseases decline with income growth; only typhoid is significantly related to the income. The time trend shows significant relation with both the diseases, but the direction of the relationship is opposite compared to income relationship. It is very straight forward that higher income means higher access to safe drinking water, sanitation and so on so forth, ultimately decline of waterborne diseases. But, when income is controlled the relation between time and waterborne diseases are positive and highly significant (one percent level). State specific effect indicates that the waterborne diseases are significantly increasing in all the States/UTs. It is most probably an indication of the management issues. Leakages or contamination from the out sources, recharge though industrial and domestic effluent, neat and clean collecting site, sanitised storages in households or public, sterilised container for carrying, etc., are important aspects of management both in community and household level. It should not only be the target to use safe/improved sources, but the quality of water should also be the concern of people; need time to time checking for this.

Besides, rural people in India think that ground water means safe drinking water. The ground water in different parts of India highly contaminated with Arsenic, Nitrate and Fluorides. The highly arsenic prone state is West Bengal accompanied with other States, namely Assam, Bihar, Chhattisgarh and Uttar Pradesh[10]. Rajasthan, Karnataka, Gujarat and Andhra Pradesh highly affected by Fluorides. Apart from the ground water, surface water pollution is the pathetic condition in India. Almost 70 percent surface water is contaminated by biological, toxic, organic, and inorganic pollutants (IDFC 2011, p.285). The monitoring result during 2011 by CPCB reports that Biochemical Oxygen Demand (BOD) and Coliform bacterial count are predominant pollutant and these have been increasing continuously in different parts of the country. Meanwhile, the generated waste water by domestic and industrial sector is hardly treated before discharged. According to the report of the Comptroller and Auditor General of India (CAG 2011, p.2), near about 10 percent of the waste water is treated at present in India; the rest is discharged into water bodies and these enter into river, ground water and lakes. Therefore, with proper management, more investment and technological intervention are needed to incorporate to curb the high prevalence of waterborne diseases in India.

7. Demographic factor

The above discussions have focused on the changes of the water indicators with respect to per capita NSDP changes. In this section and the subsequent sections, it is examined how demographic and policy differences across the States/UTs affect the environmental indicators when income and other time-invariant factors remain constant over the years. The best fits from the table-4 are the core models around which the subsequent discussions are continued so that the functional forms of the hypothesised relationship with income are not affected by adding additional factors.

[10] Ground water quality scenario. Central Ground Water Board (CGWB), http://cgwb.gov.in/GW_quality.html . Accessed 5 September 2014

Now India is the residence of 1.2 billion people (Census 2011) expected to be top ranked with 1.7 billion population by the year 2050 (PRB 2010, p.2). Huge population is the important factor for the Indian economy. Two demographic factors, such as population density and literacy rate, are selected for the study purpose (Table 5). Population density helps to understand the pressure on common resources in an area. Higher density means higher utilisation of common resources, like ground water and other sources of water, and more environmental degradation as well as pollution. With the population growth, density has also increased to 382 people per sq km in 2011 Census from 342 people per sq km in 2001. But it is not uniformly distributed among the States and UTs. It varies ranges from higher density 1,102 people per sq km in Bihar to lowest 17 people per sq km in Arunachal Pradesh among the States and from higher 11,297 people per sq km in Delhi to lowest 46 people per sq km in Andaman and Nicobar Islands among the UTs. Therefore, population pressure highly varies states to states. On the other hand, literacy is a proxy of environmental consciousness. It helps to better understand the management of resources and improve the environmental quality. India achieves a lot in terms of literacy during the last decade. It has increased to 74 percent in 2011 from 65 percent in 2011 (Census 2011).

In the model of quality of drinking water (Table 5), higher density has an additional effect on it that cannot be explained by the per capita net income in the best fits model in table-4. One percent increase of density significantly increases nearly four percent lack of safe drinking water that means additional four percent households will suffer the problem to access of safe drinking water. Likewise, one percent density rising affects the Diarrhea prevalence by increasing nearly two percent. Apart from two, density has no additional effect on ground water development, administrative units under threat and Typhoid, but higher density is positively associated with the rests except stage of ground water development.

The literacy rate has additional effects on none of the indicators and the direction of the relationship far from the assumption. The reason may be the inability to capture the environmental conscious by the proxy. According to Indian Census, the ‘literate’ refers to the both ability to read and write in any Indian scheduled languages. Therefore, finest indicator is needed to be incorporated to capture the effect.

8. Economic policy

Three macroeconomic policy variables are incorporated to the study such as the growth rate of GSDP, public debt and annual government expenditure (Table 6). The Indian economy has been experiencing rapid economic growth. Investment is also in higher proportion. Rapid economic growth and investment may worsen the environmental quality compare to the average for their income level if policies and regulations are slow to respond to the changing circumstances. On the other hand, if the investment is in pollutant abatement equipment and technology, the effect would be positive; then high investment and rapid growth may have better environmental quality than average growing economy. There is a dual argument regarding the public debt on economic growth. First one, traditional view considers the increasing debt is a burden on the economy in the log-run period. It forces people to be more relay on natural resources and rapid exploitation of the same. Another one, Ricardian view (Ricardian equivalence hypothesis) considers debt is equivalent to future taxes which implies the neutrality of domestic debt to growth. Studies (Bhattacharya and Guha 1990; Singh 1999; Barik 2011; MOF 2013) suggest that Indian domestic debt is intensively used for investment purpose to achieve rapid growth.

The growth of GSDP has no additional effects on drinking water and ground water compare to the best fits models (Table 6). Waterborne diseases are influenced by the higher economic growth. The diarrhea prevalence significantly increases by one percent with the economic growth rise at the rate of 10 percent. With Typhoid, high economic growth rates are insignificant, but it is clearly associated with the higher disease prevalence. There is also another positive, but insignificant association is found between economic growth and water crisis at administrative units. Public debt has additional and significant effect with none of the water indicators. But, higher public debt indicates the improvement of the indicators except access to safe drinking water. Government expenditure significantly affects the ground water development. Near about one percent ground water improvement is associated with the increase of government expenditure nearly two percent point of the GSDP. Though government expenditure has no significant effect on the rests, but all except typhoid are negatively related to it; that means more public expenditure helps to improve the indicators.

Overall the macroeconomic policy variables have no such significant effects; these imply mixed effect in the models. When higher economic growth indicates the deterioration of environmental quality, public debt and expenditure help to improvement the same. The direction of relationships is not clear.

9. Conclusion

Finally, it is concluded that no EKC kind of relation is found in drinking water, ground water and waterborne diseases in Indian context. Income has no significant effect on all of the indicators. It has only consistently significant effect on two indicators such as access to unsafe drinking water and typhoid. Although all the indicators are not significantly related to the income, the best fits models suggest that all the indicators improve with income rising except drinking water. The problem of the access to safe drinking water rapidly declines with incomes rising first, but again begins to increase in higher incomes. The reason could partially be the incapability to manage the effects of regional climatic and geomorphological diversity properly. The population pressure (density) has a clear negative impact on all of the indicators except stage of ground water development. There is no strong evidence that rapid economic growth puts greater pressure on natural resources, meanwhile these is no such robust evidence that the economy with higher investment and public expenditure help to improve the environmental condition. The overall effects of the macroeconomic policies are ambiguous. It infers two thinks, one, there is a very meager amount of investment and expenditure for environmental degradation abatement technologies and measures in India. Second, the latter (technologies and measures) is hardly properly implemented with the rapid economic growth during 2000s. If both had been properly, there would obviously have an imprint of the consistently significant positive effect of all of the policy variables. Moreover, government expenditure and investment highly depend on the government policy (Peacock and Wiseman 1961). The contribution of technological inputs and its progress depend on how well environmental policies are designed and implemented (Jaffe et al. 2003; Managi and Jena 2007). Most probably that is why, technological improvement or abatement measures, and its implementation proxied by 'time trend' clearly works throughout the models (Table 4-7) in the support of gradual degradation of environmental resources and its worst consequences.

Apart from these, safe drinking water and ground water are highly influenced by climatic and physiographical heterogeneity. When one part of the India suffers flood, and a huge proportion of water are wasted through run-off, another part of India suffers draught and acute water shortages. Owing to lack of sufficient rainfall or run-off, replenish of ground water is not possible in Western India. In spite of having abundant rainfall, in North-Eastern and Peninsular India, ground water potentiality is very less due to hard rock formation. In some States both the climatic condition and geological set up are favorable for ground formation, but due to voracious extraction the stage of development is very high resulting into most of the administrative units under threats. On the other hand, when most of the people depend on ground water for safe drinking, maximum proportion of that is used by agriculture and Industry. Moreover, discharge of huge untreated (more the 90 percent) industrial and domestic effluent pollute the surface water sources (almost 70 percent) and deteriorate ground water quality as well as supplies resulting into gradual increasing the prevalence of waterborne diseases. All these issues could be handled by proper management, policy implementation and investment. Its indication has been got from consistently significant time trend in the models.

A plethora of policies and programmes have been implemented during different Five Year Plans in India since Fifth Five Year Plan (1974-79) to the present for universal coverage of safe drinking water. At a glance, these are Minimum Need Programme (MNP) and Accelerated Rural Water Supply Programme (ARWSP) during Fifth Five Year Plan, Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1991–92, 'Nirmal Bharat Abhiyan' (NBA) in 1991, the formation of new department, the Department of Drinking Water Supply (DDWS) under Ministry of Rural Development in 1999 and another important programme is 'Swajaldhara' in 2000. Owing to rigorous exercise, though it is far from universal coverage, the provision of safe drinking water has improved substantially. Besides, there are lots of acts and regulations in different arena of environment such as the Water (Prevention and Control of Pollution) Act 1974, the Water (Prevention and Control of Pollution) Cess Act 1977, the Air (Prevention and Control of Pollution) Act 1981, the India Wildlife (Protection) Act 1972, and the Environment (Protection) Act 1986 and so on so forth.

But, in case of ground water, there are hardly found such kind of policies, programmes and acts. One law, a person who owns the land also owns ground water below it, exists related to ground water extraction. It is outright absurd both in terms of domestic and commercial use. All the regulation related to ground water is included under the overall Environment (Protection) Act, 1986. The Central Ground Water Authority (CGWA) has been constituted under sections 3(3) of this act. Its exercises of power are limited. It manly deals with quality and quantity, and status of ground water in the country. But they have no mandate to charge different sectoral uses. Besides, water is the subject matter of the State Government as per Indian Constitution, where Center has no exclusive power to make laws with respect it. Till now, six States out of the 29, namely Andhra Pradesh, Goa, Tamil Nadu, Kerala, West Bengal, Himachal Pradesh and two UTs out of the seven, namely Lakshadweep and Pondicherry, have enacted and implemented ground water legislation. But those States, such as Punjab, Haryana, Delhi, Rajasthan, Gujarat and Uttar Pradesh, exploit the most are far away from the formation of legislation. Therefore, a strong regulation is also needed in all the States and UTs to manage the ground water properly.

Therefore, water conservation in agriculture should be highly prioritised in India. The Government should follow the mixed approaches**,** such as different constructive measures include water supply management through construction of dams, reservoirs and other surface water storages, rain water harvesting, river linkages or channelised excess water to the deficit regions; command and control (CAC) measures through not only introducing the polices, restriction, licensing or permitting, but also effectively implementation of these which is very tough in Indian context; and the economic instruments like various taxes, and non-compliance charges or fees. Moreover, persuasive instruments or voluntary commitments of the Indian people are also very important.

Better the management of the surface water helps to develop the ground water as aquifers are hydraulically connected with surface water bodies. In this context, India should get experience from the United States of America (USA), how its different parts have made over the regenerative ability of the aquifers through sustainable utilisation strategies and adopting innovative approaches. Innovative approaches typically involve some combination of the use of aquifers as storage reservoirs, conjunctive use of surface water and ground water, artificial recharge of water through wells or surface spreading, and use of recycled or reclaimed water (Alley et al. 1999). Meanwhile, India should take effective endeavour in water efficiency in domestic as well as industrial usages. All these will help to resolve the problem of access to safe drinking water as well as curb the waterborne diseases.

The above mentioned recommendations are not so easy to achieve, because these are not only very expensive, but these also place certain requirements on institutional funding. India will have also to ensure the same.

References

1. Agricultural Census of India (2000-01; 2005-06; 2010-11). Agricultural Census data base. http://agcensus.dacnet.nic.in/nationalcharacterstic.aspx. Accessed 21 August 2014.

2. Alley, W. M., Reilly T. E., & Franke, O. L. (1999). Sustainability of Ground-Water Resources, U.S. Geological Survey Circular 1186. Colorado: U.S. Geological Survey.

3. Barik, A. (2011) Government debt and economic growth in India. http://www.punjabiuniversity.ac.in/cdeiswebsite/papers/31%20Anirudha%20Barik%20 Punjabi%20University%20Paper-.pdf. Accessed 12 September 2014.

4. Barua. A., & Hubacek, K. (2008) Water pollution and economic growth: an Environmental Kuznets Curve analysis at the watershed and state level. International Journal of Ecological Economic and Statistics, 10(8), 1-25.

5. Bhattacharya, B. B., & Guha, S. (1990) Internal public debt of Government of India growth and composition. Economic and Political Weekly, 25(15), 780-788.

6. Brundtland Commission (1987) Our common future, report of the World Commission on Environment and Development. United Nations. http://conspect.nl/pdf/Our_Common_Future-Brundtland_Report_1987.pdf. Accessed 15 September 2014.

7. Bruyn, S. M. de, van den Bergh, J. C. J. M., & Opschoor, J. B. (1998). Economic growth and emissions: reconsidering the empirical basis of Environmental Kuznets Curves. Ecological Economics, 25, 161–175

8. Census of India (2001; 2011) Office of the Registrar General and Census Commissioner, Ministry of Home Affair, Government of India. (CD ROM).

9. Central Ground Water Board (CGWB) (2006; 2011; 2014) Dynamic ground water resources of India 2004, 2009, 2011. Ministry of Water Resources, Government of India. http://cgwb.gov.in/GW_assessment.html. Accessed 5 September 2014.

10. Central Pollution Control Board (CPCB) (2009) Comprehensive environmental assessment of industrial clusters. New Delhi: The Energy and Resources Institute Press.

11. Central Pollution Control Board (CPCB) (2010) Status of water quality in India- 2010. Ministry of Environment and Forests, Government of India. http://cpcb.nic.in/WQSTATUS_REPORT2010.pdf. Accessed 24 October 2013.

12. Central Pollution Control Board (CPCB) (2011) Status of water quality in India- 2011. Ministry of Environment and Forest, Government of India.

http://cpcb.nic.in/upload/NewItems/NewItem_198_Status_of_WQ_in_India_2011.pdf. Accessed 20 September 2014.

13. Central Statistical Organisation (CSO) (2014) Complete data table. Ministry of Statistics and Programme Implementation, Government of India. http://planningcommission.nic.in/data/datatable/0814/comp_databook.pdf. Accessed 20 August 2014.

14. Central Water Commission (CWC) (2012-13) Annual report 2012-13. Ministry of Water Resources, Government of India. http://www.cwc.gov.in/main/downloads/ANNUAL%20REPORT%202012-13%2009_12_13.pdf. Accessed 22 August 2014.

15. Centre for Science and Environment (CSE) (2004) It isn't agriculture. A Down to Earth: Supplement. http://www.cseindia.org/dte-supplement/industry20040215/agriculture.htm. Accessed 13 October 2014.

16. Comptroller and Auditor General of India (CAG) (2011) Performance Audit of Water Pollution in India. Government of India. http://www.environmental-auditing.org/Portals/0/AuditFiles/India_f_eng_Water-Pollution-in-India.pdf. Accessed 21 October 2013.

17. Das, B., & Mistri, A. (2013) Household quality of living in Indian states: analysis of 2011 Census. Environment and Urbanization Asia, 4(1), 151–171.

18. Dinda, S. (2004) Environmental Kuznets Curve hypothesis: a survey. Ecological Economics, 49, 431–455

19. Directorate of Economic and Statistics (DOES) (2014) Land use statistics at a glance-state wise. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. http://eands.dacnet.nic.in/LUS_1999_2004.htm. Accessed 16 March 2014.

20. Falkenmark, M. (1989) The massive water scarcity now threatening Africa: why isn't it Being addressed? Ambio, 18(2), 112-118.

21. Grossman, G. M., & Krueger, A. B. (1991) Environmental impacts of a North American free trade agreement. National Bureau of Economic Research, Working Paper 3914, NBER, Cambridge MA.

22. Hettige, H., Lucas, R., & Wheeler, D. (1992) The toxic intensity of industrial production: global patterns, trends and trade policy. The American Economic Review, papers proceedings 82(2), 478–481.

23. Infrastructure Development Finance Company (IDFC) (2011) India infrastructure report 2011, Water: policy and performance for sustainable development. New Delhi: Oxford University Press.

24. Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2003) Technological change and the environment. Working paper 7970. National Bureau of Economic Research. http://www.nber.org/papers/w7970.pdf. Accessed 22 September 2014.

25. Khurana, I., & Sen, R. (2011) Drinking water quality in rural India: issues and approaches. Background Paper, WaterAid. http://www.wateraid.org/uk/google-search?query=rinking+water+quality+in+rural+India%3A+Issues+and+approaches. Accessed 15 September 2014.

26. Kumar, K. S. K., & Viswanathan, B. (2003) Does Environmental Kuznet's Curve exist for indoor air pollution? Evidence from Indian household level data. Working Paper 3, Madras School of Economics. http://www.mse.ac.in/pub/wp_kavi.pdf. Accessed 5 September 2014.

27. Kumar, U., & Subramanian, A. (2011) Indian's growth in the 2000s: four facts. Working paper 11-17, Peterson Institute for International Economics. http://www.iie.com/publications/wp/wp11-17.pdf. Accessed 15 March 2014.

28. Managi. S., & Jena, P. R. (2007) Environmental productivity and Kuznets curve in India. Ecological Economics, 65(2), 432-440.

29. Ministry of Finance (MOF) (2013) Government debt: status paper. Department of Economic Affairs, Government of India. http://www.finmin.nic.in/reports/GOVT_DEBT_July2013.pdf. Accessed 20 September 2014.

30. Ministry of Health and Family Welfare (MOHFW) (2005-13) National health profile 2005 onwards. Directorate General of Health Services, Government of India. http://cbhidghs.nic.in/index1.asp?linkid=267. Accessed 27 August 2014.

31. Ministry of Statistics and Programme Implementation (MOSPI) (2013) Compendium of environment statistics India. Central Statistics Office, Government of India. http://www.indiaenvironmentportal.org.in/files/file/compendium%20environment%20statistics%20india%202013.pdf. Accessed 5 September 2014.

32. Mythili, G., & Mukherjee, S. (2011) Examining Environmental Kuznets Curve for river effluents in India. Environ Dev. Sustain, 13, 627–640.

33. National Sample Survey (NSS) (2002; 2008; 2012) National Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India. (CD ROM).

34. Office of Registrar General of India (2009) Report on causes of death in India 2001-03. Ministry of Home Affair, Government of India. http://www.cghr.org/wordpress/wp-content/uploads/Causes_of_death_2001-03.pdf. Accessed 6 October 2014.

35. Parikh, J. (2004) Environmentally Sustainable Development in India. http://scid.stanford.edu/events/India2004/JParikh.pdf. Accessed 22 August 2010.

36. Peacock, A. T., & Wiseman, J. (1961) The Growth of Public Expenditure in the United Kingdom. United Kingdom: Princeton University Press.

37. Population Reference Bureau (PRB) (2010) 2010 World population data sheet. http://www.prb.org/pdf10/10wpds_eng.pdf. Accessed 15 September 2014.

38. Press Information Bureau (PIB) (2009) Environmental assessment of industrial clusters. Ministry of Environment and Forest, Government of India. http://pib.nic.in/newsite/erelease.aspx?relid=56483. Accessed 10 September 2014.

39. Press Information Bureau (PIB) (2012) Per capita water availability. Ministry of Water Resources, Government of India. http://pib.nic.in/newsite/erelease.aspx?relid=82676. Accessed 10 September 2014.

40. Selden, T. M., & Song, D. (1994) Environmental quality and development: is there a Kuznets curve for air pollution emissions? Journal of Environmental Economics and Management, 27, 147–162.

41. Shafik, N., & Bandyopadhyay, S. (1992) Economic growth and environmental quality: time series and cross country evidence. Background paper for the World Development Report 1992, Washington, DC: World Bank.

42. Shah, T. (2009) India's groundwater irrigation economy: the challenge of balancing livelihoods and environment. In Badarayani, U., Kulkarni, H., & Upasani, D. (Ed.) Groundwater management: typology of challenges, opportunities and approaches. Pune: ACWADAM.

43. Singh, C. (1999) Domestic debt and economic growth in India. Economic and Political Weekly, 34(23), 1445-1453.

44. Stern, D. I. (2004) The rise and fall of the Environmental Kuznets Curve. World Development, 32(8), 1419–1439.

45. UNICEF (2013) Water in India: situation and prospects. UNICEF, FAO, SaciWATERs. http://www.unicef.org/india/Final_Report.pdf. Accessed 1 October 2014.

46. World Bank (1992) World Development report: development and the environment. New York: Oxford University Press.

47. World Bank (1998) India-water resources management sector review: report on the irrigation sector. World Development Sources, WDS 1998-3. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/1998/09/442139/india-water-resources-management-sector-review-report-irrigation-sector. Accessed 25 October 2014.

48. World Bank (2010) Deep well and prudence: towards pragmatic action for addressing groundwater overexploitation in India. Washington, DC: World Bank.

49. World Bank (2013) An analysis of physical and monetary losses of environmental health and natural resources. Vol. 1 of India - Diagnostic assessment of select environmental challenges. Washington DC: World Bank. http://documents.worldbank.org/curated/en/2013/06/18009327/india-diagnostic-assessment-select-environmental-challenges-vol-1-3-analysis-physical-monetary-losses-environmental-health-natural-resources. Accessed 15 September 2014.

Appendix

Figure 1: The Environmental Kuznets Curve (EKC)

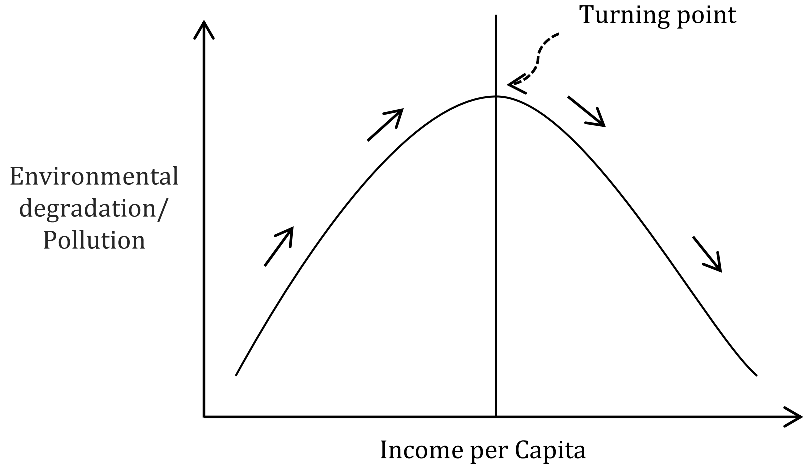

Figure 2: Elasticity of lack of safe drinking water with respect to income per capita

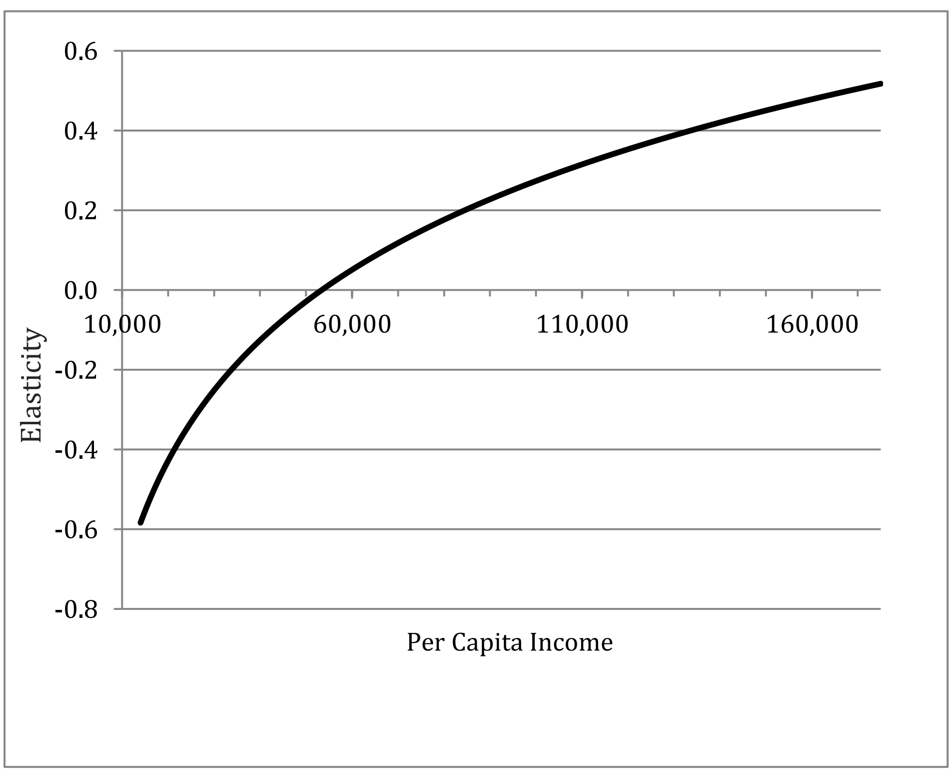

Table 1: Projected water demand (BCM) of India by different use

Sector	Standing Sub-Committee of MOWR			National Commission on Integrated Water Resource Development					
	2010	2025	2050	2010		2025		2050	
	Total	Total	Total	Low	High	Low	High	Low	High
Irrigation	688	910	1072	543	557	561	611	628	807
Drinking water	56	73	102	42	43	55	62	90	111
Industry	12	23	63	37	37	67	67	81	81
Energy	5	15	130	18	19	31	33	63	70
Other	52	72	80	54	54	70	70	111	111
Total	813	1093	1447	694	710	784	843	973	1180
Source: Report of the Standing Sub-Committee on 'Assessment of Availability & requirement of Water for Diverse uses-2000'cited on MOSPI, 2013 p. 184.									

Table 2: Households having source of drinking water

Years	Improved/safe sources (%)	Unimproved/unsafe sources (%)
NSS 69, 2012	90.6	9.40
Census, 2011	87.2	12.8
NSS 65, 2008	88.0	12.00
NSS 58, 2002	82.8	17.20
Census, 2001	77.9	22.08
Source: compute from different NSS rounds and Census of India		

Table 3: Ground water availability, utilisation and development

Assessment Years	Annual Ground Water Draft (BCM/Year)			Stage of Ground Water Development (%)	Assessment units under threats (%) (no./out of)
	Irrigation	Domestic & industrial uses	Total		
2004	212.51	18.09	230.62	58.0	29.0 (1615/5723)
2009	221.42	21.89	243.32	61.0	26.0 (1494/5842)
2011	222.36	22.71	245.05	62.0	30.0 (1985/6607)
Source: Central Ground Water Board (CGWB), 2006, 20011 and 2014					

Table 4: Water indicators and per capita Net State Domestic Product (NSDP)

Dependent Variable	Intercept	NSDP/ Capita	(NSDP/ Capita)^2	(NSDP/ Capita)^3	Time (year)	Adjusted R^2	N	Curve Shape
Lack of safe drinking water	3.059 (0.993)	-0.009 (-0.027)	-	-	-0.070** (-2.133)	0.847	157	
	28.451 (2.492)	-4.746** (-2.284)	0.218** (2.306)	-	-0.044 (-1.291)	0.852		U- Shaped
	23.006 (0.233)	-3.160 (-0.111)	0.065 (0.023)	0.005 (0.056)	-0.044 (-1.287)	0.851		
Stage of ground water development	7.697 (2.172)	-0.482 (-1.356)	-	-	0.054** (2.181)	0.985	93	Monotonically decrease
	3.359 (0.186)	0.310 (0.096)	-0.036 (-0.245)	-	0.051 (1.855)	0.984		
	92.132 (0.730)	-25.241 (-0.700)	2.411 (0.700)	-0.078 (0.700)	0.052 (1.870)	0.984		
Administrative units under threats	10.933 (1.750)	-0.928 (-1.487)	-	-	0.093** (2.151)	0.943	96	Monotonically decrease
	-23.145 (-0.759)	5.329 (0.966)	-0.285 (-1.142)	-	0.074 (1.595)	0.943		
	-278.397 (-1.249)	78.649 (1.236)	-7.294 (-1.202)	0.223 (1.156)	0.070 (1.508)	0.943		
Typhoid	21.500 (3.585)	-1.321** (-2.208)	-	-	0.227*** (5.330)	0.881	239	Monotonically decrease
	27.681 (0.772)	-2.458 (-0.376)	0.052 (0.175)	-	0.229*** (5.110)	0.880		
	-881.774 (-2.371)	252.467** (2.428)	-23.745** (-2.450)	0.740** (2.456)	0.206*** (4.561)	0.883		
Diarrhea	15.171 (4.471)	-0.349 (-1.031)	-	-	0.056** (2.316)	0.943	242	Monotonically decrease
	-6.500 (-0.321)	3.637 (0.986)	-0.182 (-1.085)	-	0.047 (1.867)	0.943		
	-859.305 (-4.200)	242.689*** (4.243)	-22.498*** (-4.219)	0.694*** (4.187)	0.026 (1.049)	0.947		

Note: *** Significant at 1%; ** significant at 5%; t-Statistics are in parentheses.

Table 5: Water indicators, per capita NSDP and demographic factors

Dependent Variable	Intercept	NSDP/ Capita	(NSDP/ Capita)^2	Time (year)	Density	Literacy	Adjusted R^2	N
Lack of safe drinking water	12.022 (0.964)	-5.523*** (-2.712)	0.263*** (2.822)	-0.120*** (-2.830)	3.558*** (2.881)	-	0.861	157
	29.282 (2.546)	-5.732** (-2.286)	0.265** (2.290)	-0.056 (-1.468)	-	1.027 (0.706)	0.852	157
Stage of ground water development	8.197 (1.509)	-0.484 (-1.349)	-	0.056 (1.804)	-0.087 (-0.122)	-	0.984	93
	8.518 (1.668)	-0.495 (-1.364)	-	0.058 (1.876)	-	-0.166 (-0.225)	0.984	93
Administrative units under threats	5.603 (0.579)	-0.907 (-1.446)	-	0.069 (1.265)	0.918 (0.722)	-	0.942	96
	3.869 (0.445)	-0.847 (-1.353)	-	0.058 (1.118)	-	1.499 (1.162)	0.943	96
Typhoid	16.764 (1.478)	-1.330** (-2.218)	-	0.215*** (4.418)	0.861 (0.492)	-	0.880	239
	19.875 (1.916)	-1.327** (-2.210)	-	0.223*** (4.699)	-	0.398 (0.192)	0.880	239
Diarrhea	24.532 (3.916)	-0.335 (-0.994)	-	0.079*** (2.893)	1.693** (2.268)	-	0.944	242
	10.824 (1.871)	-0.364 (-1.073)	-	0.045 (1.680)	-	1.058 (0.928)	0.943	242

Note: *** Significant at 1%; ** significant at 5%; t-Statistics are in parentheses.

Table 6: Water indicators, per capita NSDP and macroeconomic policies

Dependent Variable	Intercept	NSDP/ Capita	(NSDP/ Capita)^2	Time (year)	GSDP Growth	Annual Expenditure	Public debt	Adjusted R^2	N
Lack of safe drinking water	31.943 (2.452)	-5.376** (-2.270)	0.246** (2.292)	-0.040 (-1.109)	-0.028 (-0.275)	-	-	0.849	148
	-4.792 (-0.388)	1.515 (0.664)	-0.070 (-0.665)	-0.091** (-2.584)	-	-0.063 (-0.508)	-	0.845	140
	-0.705 (-0.057)	0.464 (0.205)	-0.018 (-0.172)	-0.081** (-2.395)	-	-	0.273 (1.936)	0.849	
Stage of ground water development	6.171 (3.736)	-0.316 (0.379)	-	0.043 (0.027)	-0.086 (0.069)	-	-	0.985	91
	12.196 (2.789)	-0.888** (-2.082)	-	0.105*** (3.015)	-	-0.392** (-2.140)	-	0.985	84
	7.707 (1.972)	-0.455 (-1.193)	-	0.051 (1.978)	-	-	-0.077 (-0.717)	0.984	88
Administrative units under threats	11.572 (1.729)	-1.009 (-1.491)	-	0.100** (2.137)	0.051 (0.406)	-	-	0.940	94
	18.578 (2.244)	-1.636** (-2.026)	-	0.169** (2.562)	-	-0.498 (-1.436)	-	0.934	84
	13.276 (1.837)	-1.113 (-1.579)	-	0.100** (2.112)	-	-	-0.127 (-0.639)	0.936	88
Typhoid	21.633 (3.606)	-1.334** (-2.212)	-	0.223*** (5.125)	0.026 (0.268)	-	-	0.888	236
	17.755 (2.580)	-0.958 (-1.422)	-	0.186 (3.538)	-	0.151 (0.549)	-	0.879	211
	21.652 (3.274)	-1.261** (-1.972)	-	0.208*** (4.638)	-	-	-0.161 (-0.783)	0.873	223
Diarrhea	16.806 (4.968)	-0.533 (-1.568)	-	0.068*** (2.779)	0.113** (2.044)			0.946	239
	12.234 (3.100)	-0.040 (-0.105)	-	0.034 (1.114)	-	-0.000 (-0.002)		0.943	213
	13.470 (3.690)	-0.124 (-0.351)	-	0.030 (1.227)	-	-	-0.104 (-0.917)	0.942	225

Note: *** Significant at 1%; ** significant at 5%; t-Statistics are in parentheses

Table 7: Summary model: water indicators, per capita NSDP, demographic factors and macroeconomic policies

Dependent Variable	Intercept	NSDP/ Capita	(NSDP/ Capita)^2	Time (year)	Density	Literacy	GSDP gr	Annual Expend.	Public debt	R^2	Adj.R^2	N
Lack of safe drinking water	-15.376 (-1.015)	0.688 (0.232)	-0.021 (-0.156)	-0.136*** (-2.979)	1.823 (1.234)	0.784 (0.503)	-0.030 (-0.299)	-0.083 (-0.579)	0.274 (1.853)	0.888	0.847	131
Stage of ground water development	12.643 (1.784)	-0.868 (-1.836)	-	0.100** (2.286)	0.293 (0.298)	-0.386 (-0.397)	-0.107 (-1.407)	-0.423** (-2.189)	-0.091 (-0.808)	0.991	0.985	83
Administrative units under threats	16.958 (1.250)	-1.966** (-2.174)	-	0.158 (1.887)	-0.284 (-0.151)	1.752 (0.942)	0.067 (0.460)	-0.630 (-1.707)	-0.209 (-0.972)	0.959	0.930	83
Typhoid	17.865 (1.397)	-1.180 (-1.713)	-	0.167*** (2.682)	-2.271 (-0.887)	3.639 (1.222)	0.049 (0.477)	0.154 (0.568)	-0.264 (-1.333)	0.906	0.888	208
Diarrhea	19.325 (2.759)	-0.388 (-1.019)	-	0.052 (1.497)	4.768*** (3.372)	5.337*** (3.239)	0.130** (2.263)	-0.042 (-0.279)	-0.159 (-1.447)	0.958	0.950	210

Note: *** Significant at 1%; ** significant at 5%; t-Statistics are in parentheses