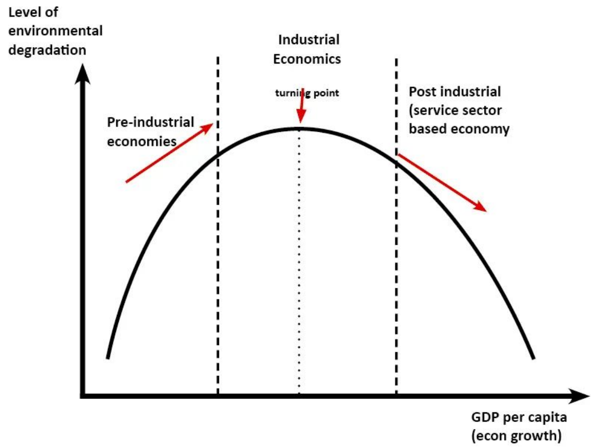
Analysis of the Relationship between Groundwater Pollution and Per Capita Income & Power Inequalities across Districts in India, 2011

Group 3

Vedant Bhatia, Ruhma Mehek Khan, Deepankar Aggarwal and Sounak Gupta

Background and Motivation



The Environmental Kuznets Curve (Kuznets, 1955)

- Put forward by Simon Kuznets in 1950s and 1960s.

As per-capita income of population increases:

  - Initially environment degradation takes place
  - With significant economic development, level of degradation sees a turning point followed by improving environment quality

Criticism of EKC

- Empirical evidence is mixed *(Scruggs, (1998))*

- Not simply a function of income, depends upon a variety of parameters such as effective government policies, population levels and other factors of power like distribution of wealth, race, literacy, gender etc

- ➔ Policies need to protect interest of those who bear effects of environment degradation against those that benefit from it
- ➔ Equitable distribution of power is necessary
- ➔ Power Inequalities with determinants such as race and ethnicity are also important along with income based inequality

Our Problem and Adaptation of Theory

Objectives:

- Empirically verify whether the EKC hypothesis holds for our model and whether power and income inequalities have significant effect on groundwater pollution
- Study the amount of nitrate, and iron present in ground water across districts of India for the year 2011.
- Understand how these concentrations vary with factors of income and power inequality
- Following (Boyce,(1994)), we set India-specific determinants of power inequality - gender and social classes (SC and ST)

Dependent Variables and their Descriptions

Dependent variable	Description	Maximum Safe Concentration*
Iron	Milligrams of iron present per litre of groundwater	1.0 mg/litre
Nitrate	Milligrams of nitrate present per litre of groundwater	45.0 mg/litre
Source : (Govt. of India. (2010)) **Data contains districts with readings above permissible concentrations*		

Independent Variables and their Descriptions

Independent Variable	Description (with units)	Remarks
Income and income inequality variables		
y	Per Capita income (in Rupees)	Income representative *Source: (Datanet India Pvt. Ltd.,(n.d.))*
y2	Square of per capita income (in rupees)	
y3	Cube of per capita income (in rupees)	
lr	Lorenz Ratio for the district	Income inequality representative *Source:(Chaudhuri, & Gupta, (2009))*

Independent Variable	Description (with units)	Remarks
Power Inequality Representatives		
latrines	The ratio of percentage of SC and ST households having access to latrines to percentage of general households having access to latrines	Amenities provided by the government; caste and tribe discriminants of power inequality. Biological waste and leakages from septic tanks and sewerage systems are common sources of Nitrate in Groundwater *Source (Census of India, (2011))*
water	Ratio of percentage of SC and ST households with access to tap water to percentage of general households with access to tap water	Amenities provided by the government; caste and tribe discriminants of power inequality. Strata of society which cannot afford alternatives would report higher usage % when polluted potable water provided (Eswar & Thomas, (2017)) *Source (Census of India, (2011))*
epp	Effective number of political parties. We use (Laakso, & Taagepera, (1979))'s formula $N = \frac{1}{\sum_{i=1}^{n} p_i^2}$ *n: number of parties with at least one vote* *p²: square of each party's proportion of all votes*	Capturing the diversity of represented political interests in a district *Source: (Election Commission of India,(2018))*
ngo	Number of water related NGOs (state wise)	Power inequality representative: measure of activism *Source: (ENVIS Centre, WWF-India, (2015))*

Independent Variable	Description (with units)	Remark
Control Variables		
rainfall	Rainfall in mm	Control variable for the amount of rainfall received by the district, as it could improve groundwater volumes and dilute concentration of contaminants *Source: (Census of India, (2011))*
forest	Ratio of forest area to the total district area	Forest cover promotes healthy water and nitrogen cycles and is beneficial to nitrate levels in the soil (Zhang & Hiscock (2011)) *Source: (Datanet India Pvt. Ltd., (n.d.))*
Note: All above data have been collected at district level for the year 2011 Data for NGOs is at the state level Number of districts studied: 90 (Nitrate), 95 (Iron)		

Data Summary Nitrate

Variable Acronym	N	Mean	Median	SD	Minimum	Maximum
Dependent						
Nitrate	90	122.70	109.60	59.51	48.00	306.80
Independent						
y	90	74768.00	70632.00	36778.27	13568.00	222099.00
lr	90	0.26	0.25	0.06	0.13	0.41
latrine	90	0.38	0.37	0.16	0.04	0.83
epp	90	4.10	3.98	1.19	2.21	7.01
rainfall	90	10858.90	7480.60	11859.97	365.10	74917.60
forest	90	0.16	0.09	0.16	0.01	0.60

Data Summary Iron

Variable Acronym	N	Mean	Median	SD	Minimum	Maximum
Dependent						
Iron	95	2.31	1.97	1.35	1.01	7.63
Independent						
y	95	78537.00	70648.00	49668.96	14192.00	222857.00
lr	95	0.26	0.25	0.06	0.15	0.46
water	95	0.77	0.75	0.33	0.05	1.69
rainfall	95	9349.6	7138.2	6573.274	365.10	29043.6
ngo	95	12.34	14.00	8.520534	3.00	34.00

General Model and Hypothesis

$$GWP = \beta + \alpha y + \gamma y^2 + \delta y^3 + \rho IE + \sigma PE + \lambda CV + u$$

Where:
GWP: groundwater pollution
Y: per capita income
IE: income equality
PE: power equality
CV: control variables

Hypothesis

There exists an inverted U shaped relationship between per capita income and groundwater pollution, and a more balanced distribution of power contributes to groundwater quality for pollution variables to have an inverted U shaped relationship with per capita income.

H^1_0: $\alpha > 0$ and $\gamma < 0$

H^1_a: $\alpha \leq$ or $\gamma \geq 0$

(there exists an inverted U shaped relationship between per capita income and groundwater pollution)

$H^2_0: \rho = 0$ $\quad$ $H^3_0: \sigma = 0$

$H^2_a: \rho < 0$ $\quad$ $H^3_a: \sigma < 0$

(A more balanced power distribution contributes positively to groundwater quality)

Model and Hypothesis (Nitrate)

$$nitrate = \beta + \alpha y + \gamma y^2 + \delta y^3 + \rho lr + \sigma latrines + \mu epp + \lambda rainfall + \eta forest + u$$

Hypothesis

There exists an inverted U shaped relationship between per capita income and groundwater pollution in terms of Nitrate pollutants, and a more balanced distribution of power contributes to groundwater quality for pollution variables that have an inverted U shaped relationship with per capita income.

H^1_0: **α > 0 and γ < 0**

H^1_a: **α ≤ or γ ≥ 0**

$H^2_0 : \rho = 0$	$H^3_0 : \sigma = 0$	$H^4_0 : \mu = 0$
$H^2_a : \rho < 0$	$H^3_a : \sigma < 0$	$H^4_a : \mu < 0$

(A more balanced power distribution contributes positively to groundwater quality)

We use rainfall and forest area per unit district area as control variables to account for geographical and population based differences across districts which might impact groundwater quality.

Model and Hypothesis (Iron)

$$iron = \beta + \alpha y + \gamma y^2 + \delta y^3 + \rho lr + \sigma water + \mu ngo + \lambda rainfall + u$$

Hypothesis

There exists an inverted U shaped relationship between monthly per capita expenditure and groundwater pollution in terms of Iron pollutants, and a more balanced distribution of power contributes to groundwater quality for pollution variables that have an inverted U shaped relationship with monthly per capita expenditure.

H^1_0: $\alpha > 0$ and $\gamma < 0$

H^1_a: $\alpha \leq$ or $\gamma \geq 0$

(there exists an inverted U shaped relationship between per capita income and groundwater pollution)

$H^2_0: \rho = 0$	$H^3_0: \sigma = 0$	$H^4_0: \mu = 0$
$H^2_a: \rho < 0$	$H^3_a: \sigma < 0$	$H^4_a: \mu < 0$

(A more balanced power distribution contributes positively to groundwater quality)

Regression Results (Nitrate)

Coefficients:				
	Estimate	Std. Error	Pr(>|t|)	
(Intercept)	1.38E+02	6.25E+01	3.06E-02	*
y	1.26E-03	1.33E-03	3.46E-01	
y2	-1.10E-08	1.50E-08	4.64E-01	
y3	2.87E-14	4.79E-14	5.50E-01	
lr	-1.62E+02	1.20E+02	1.81E-01	
latrines	4.09E+01	5.14E+01	4.28E-01	
forest	-1.36E+02	4.46E+01	3.18E-03	**
epp	-1.26E+00	7.28E+00	8.63E-01	
rainfall	-1.87E-04	9.15E-04	8.39E-01	
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Residual standard error: 55.29 on 82 degrees of freedom

Multiple R-squared: 0.213,

Adjusted R-squared: 0.1367

F-statistic: 2.78 on 8 and 82 DF,

p-value: 0.008

Regression Results (Iron)

Coefficients:				
	Estimate	Std. Error	Pr(>|t|)	
(Intercept)	4.40E+00	1.81E+00	1.73E-02	*
y	-4.39E-05	6.37E-05	4.93E-01	
y2	5.90E-10	8.25E-10	4.77E-01	
y3	-2.35E-15	3.04E-15	4.41E-01	
lr	-5.83E+00	4.77E+00	2.25E-01	
water	1.89E+00	8.44E-01	2.76E-02	*
rainfall	-5.29E-05	3.29E-05	1.11E-01	
ngo	-3.02E-02	2.61E-02	2.51E-01	
--- Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Residual standard error: 2.054 on 88 degrees of freedom

Multiple R-squared: 0.20

Adjusted R-squared: 0.13

F-statistic: 3.15 on 7 and 88 DF

p-value: 0.005

Conclusions

- We failed to get significant results in support of EKC for nitrate and iron contamination in groundwater, hence **we reject the EKC hypothesis**
- Including higher order terms of Y resulted in high VIF scores (Appendix)
- Variation in income across districts might be insufficient, resulting in high VIF/correlation among y terms and no significant results for income inequality
    - More than 75% districts had urban:rural ratio <= 0.25, more than 90% less than 0.5
- Trying to examine the relationship of pollution with only Y or Y^2 also did not yield significant results (experiments in appendix)

Conclusions - Inequality and Nitrate Contamination

- A significant relationship between groundwater pollution and power and income inequality could not be established
- The coefficient for income inequality suggests a positive relationship with pollution
- The coefficient for latrines access is positive; the contamination due to increased usage of septic tanks (McQuillan, D. (2004)) outweighs the benefits of reduced open defecation
- The coefficients for control variables suggest that they contribute as expected; forests have a significant (inverse) impact on nitrate levels, in agreement with literature (Zhang & Hiscock (2011))

Conclusions - Inequality and Iron Contamination

- A significant relationship between groundwater pollution and power and income inequality could not be established
- The coefficient for income inequality suggests a positive relationship with pollution
- The coefficient for water access is positive and significant; ‘lower’ strata of society may use polluted tap water when privileged strata can afford alternatives (Eswar & Thomas, (2017))
    - Data inspection shows that areas with higher access numbers for SC/ST than general households (water ratio >1) have higher iron contamination
- NGO activity has expected inverse impact on contamination, albeit insignificant
- The coefficients for control variables suggest that they contribute as expected

References

1. Chaudhuri, S., & Gupta, N. (2009). Levels of living and poverty patterns: A district-wise analysis for India. *Economic and Political Weekly*, 94-110.
2. Hlavac, Marek (2018). stargazer: Well-Formatted Regression and Summary Statistics Tables. R package version 5.2.2. https://CRAN.R-project.org/package=stargazer
3. Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets curve. *Ecological economics*, *25*(2), 147-160.
4. Boyce, J. K. (1994). Inequality as a cause of environmental degradation. *Ecological Economics*, *11*(3), 169-178.
5. Kuznets, S. (1955). Economic growth and income inequality. Am. Econ. Rev. 1, 1–28
6. Govt. of India. (2010). Ground Water Quality in Shallow Aquifers of India. Retrieved 2020, from http://cgwb.gov.in/documents/Waterquality/GW_Quality_in_shallow_aquifers.pdf
7. Laakso, M., & Taagepera, R. (1979). “Effective” number of parties: a measure with application to West Europe. *Comparative political studies*, *12*(1), 3-27.
8. Scruggs, L. A. (1998). Political and economic inequality and the environment. Ecological economics, 26(3), 259-275.
9. Eswar, M., & Thomas, B. K. (2017). Data Discrepancies. Economic & Political Weekly, 52(28), 29.
10. Zhang, H., & Hiscock, K. M. (2011). Modelling the effect of forest cover in mitigating nitrate contamination of groundwater: A case study of the Sherwood Sandstone aquifer in the East Midlands, UK. Journal of hydrology, 399(3-4), 212-225.

References

11. Datanet India Pvt. Ltd. (n.d.). District Books- Per Capita Income, Agricultural Production, Literacy Rate, Crime, Education | Books for All Indian Districts. Retrieved 2020, from https://www.datanetindia-ebooks.com/District_Factbook

12. Census of India (2011). Census of India | Office of the Registrar General & Census Commissioner, India. Retrieved 2020, from http://censusindia.gov.in/

13. ENVIS Centre, WWF-India. (2015). Directory of Environmental NGOs - 10th Edition. Retrieved 2020, from http://wwfenvis.nic.in/Database/NGOsDirectory2014_4328.aspx

14. McQuillan, D. (2004). Ground-water quality impacts from on-site septic systems. In *Proceedings, National Onsite Wastewater Recycling Association, 13th Annual Conference, Albuquerque, NM November* (pp. 7-10).

15. Election Commission of India. (2018). Election Results - Full Statistical Reports. Retrieved 2020, from https://eci.gov.in/statistical-report/statistical-reports/Select%20State

Appendix

VIF: Iron

y	y2	y3	water
9.73E+01	5.11E+02	1.98E+02	1.56E+00
lr	ngo	rainfall	
2.01E+00	1.19E+00	2.07E+00	

VIF: Nitrate

y	y2	y3	latrines
7.01E+01	3.98E+02	1.74E+02	2.11E+00
lr	epp	forest	rainfall
1.51E+00	2.23E+00	1.57E+00	3.46E+00

Correlation Matrix	Outlier Graphs: Iron	Outlier Graphs: Nitrate
Scatter plots : Iron	Scatter plots : Nitrate	More regression results: Iron
More regression results: Nitrate	Variable Selection	Description of other variables initially considered