Toxic Water Emissions and Economic Growth: A County Level Analysis of the United States

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I. Acknowledgements

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II. Executive Summary

Prior research has postulated that regional preferences for environmental degradation change over time with changing levels of income; as economies accumulate more wealth, they grow more environmentally conscientious, and abate pollutant intensive machinery or labor in favor of innovative technology that reduces emission levels, harmful toxins and hazardous pollutants (i.e. tertiary sectoral growth). The resulting functional form of environmental degradation is that of an inverted quadratic function, which has been applied across cross-country and national data sets. In economics, this functional form is widely known as the Environmental Kuznets Curve (EKC). This study builds on existent literature by analyzing consumption patterns of water pollution for all contiguous counties in the United States for 2010 to 2018 to determine whether water contamination at the county levels follows an inverted U-shaped pattern.

III. Project Objectives

The project implements applications of microeconomic theory and econometrics toward intensive research and the development of a research paper. Using ArcGIS software and OLS regression, the study examines whether the EKC pattern holds for toxic water contaminants at the county level across the contiguous United States after 2010. This study also discusses why specific regions choose to forgo environmentally sustainable economic activities, how industry/household characteristics and preferences affect decisions to enact pollution abatement, and what potential policy responses/proposals entail for regional economic growth if enacted.

IV. Project Approach

The project began with a literature review of environmental studies postulating the existence of an EKC across multiple locations and multiple pints in time. Grossman and Krueger's work (1991; 1995) have consistently been recognized among the first to apply Kuznets' original work to the study of environmental degradation; their findings point to the prevalence of an EKC pattern for urban air pollution, fecal and heavy metal contamination of river basins (two separate specifications), and the quality of oxygen regime at a cross-country level. While environmental quality does initially deteriorate in poorer countries, it improves after reaching a certain level of income. Stern et. al. (1996) note the challenges associated with analyzing the EKC for international datasets, as previous literature had used, remarking that data of such natures are often of poor quality and of 'patchy' availability, which makes analysis more difficult and diminishes the reliability of interpretation. Carson et. al. (1997) address this issue by limiting the scope of the EKC to a single country, the U.S., and analyzing the relationship between income distribution and per capita emission at the local boundary levels (50 U.S. states), providing sufficient variation among income levels to make analysis of the EKC relationship useful. Findings are consistent with previous literature and still hold when controlling for urban population and industrial composition. Rupasingha et. al. (2003) add to the literature by controlling for population density and urbanization, educational attainment, income inequality, and ethnic diversity (a newly introduced variable) for the USA for 1997. They find, as previous studies have, that the EKC is prevalent at the county level, with notable findings suggesting diversity plays an important role in levels of pollution. The specific application of the EKC to water contamination and usage has especially drawn the attention of empirical and theoretical research in more recent years. Paudel et. al. (2005) test for the EKC for water contaminants (dissolve oxygen, phosphorus, and nitrogen) at local parish levels for

Louisiana over a span of fourteen years. Though they find that the three pollutants of interest were not of statistical significance, they do find indication of an EKC relationship. In another study analyzing data for the Louisiana parishes, social capital is observed to play a significant role in determining consumption patterns for water pollution (nitrogen) (Paudel and Schafer, 2009). Farzin and Grogan (2013) also restrict their study to a single state: county level observations in California for a span of 13 years; they find that while the EKC does not hold for all water pollutants analyzed, education, agricultural intensity and land use, and monitoring intensity play a significant role in consumption patterns for water pollution. Many more articles are included in the paper (see literature review for full list).

Data for the regression model is collected across databases provided by the Environmental Protection Agency's Toxic Release Inventory, the Census Bureau, and the National Oceanic and Atmospheric Administration. Data is collected for all counties and independent cities across the contiguous United States for 2010 to 2017. Maps were developed using ArcGIS software to observe initial distribution of income and water contamination across the United States. Observations matched the expectations of releases of toxic water emissions and income, with wealthier counties, represented by per capita income adjusted for inflation, observed along Western-Pacific and Northeastern regions and poorer counties observed along Midwest and Southern regions. Conversely, counties that exhibit the most water contamination, represented by total toxic releases via surface water discharge and underground injections, are observed among the Midwest and Southern regions and counties that exhibit less water contamination among Western-Pacific and Northeastern regions.

Referencing previous literature and utilizing underlying assumptions of the Kuznets Curve, a regression model is built to estimate the impacts of economic growth on water contamination.

The model takes on the following form:

$$PerCapitaTE_{it} = \beta_0 + \beta_1 M_{it} + \beta_2 M_{it}^2 + \beta_3 Inequality_{it} + \beta_4 PopDen_{it} + \beta_5 Edu_{it} + \beta_6 Ethnic_{it} + \beta_7 Resource_{it} + \beta_8 Putnam_{it} + \beta_9 Olson_{it} + \beta_{10} Liquid_{it} + \beta_{11} Temp_{it} + \mathcal{E}_{it}$$

Where TE_{it} is per capita pounds of toxic chemicals emissions disposed of through surface water discharges and underground injections into wells by industries of the ith county for tth year; M_{it} is per capita income, adjusted for inflation, of the ith county for tth year; $Inequality_{it}$ is the ratio of mean household income to median household income of the ith county for tth year; $PopDen_{it}$ is the population density for ith county for tth year; Edu_{it} is the population with a Bachelor's degree or higher as a percentage of the total population of the ith county for tth year; $Ethnic_{it}$ is the percentage of African Americans and Hispanics, of any race, of the ith county for tth year; $Resource_{it}$ is the percentage of employed civilians in agriculture, forestry, fishing and hunting, mining, and manufacturing to the total labor force of the ith county for tth year; $Putnam_{it}$ and $Olson_{it}$ are an index for the number of non-rent seeking and rent seeking institutions in ith county for tth year; $Rain_{it}$ is the total liquid precipitation recorded for the preceding year of the ith county for tth year; $Temp_{it}$ is the average annual temperature in Fahrenheit recorded for the preceding year of the ith county for tth year.

V. Project Outcomes

Analysis included robustness analysis of data collected before running model specifications. Data for the $Putnam_{it}$ and $Olson_{it}$ variables were found to be multicollinear; as such, the $Olson_{it}$ variable was omitted from the model to not violate the assumption of OLS. Multicollinearity of residuals was also tested and accounted for. Individual regression models were run for each year (multiple cross-sectional analysis). SAS software and Excel were used to run regression analysis.

Results indicate that while water contamination follows an EKC pattern as a function of per capita income, the results are not significant. Results likely reflect concern and awareness of both markets and consumers of water contamination activities, regardless of resource intensity, as well as prevalent policy implementations by federal and state jurisdiction to control for contamination of our natural resources. Results are similar for various other explanatory variables, such as population density, the $Putnam_{it}$ index, education, and temperature (see Figure 3). Of the remaining variables, ethnicity components, resource intensive employment, and precipitation (except for one year) all follow expectations and significantly explain movements of per capita water contamination. This indicates that, despite policy efforts at the federal and state level, underrepresented minorities continue to take on much of the burden of water contamination. Similarly, additional resource intensive activities correlate with greater levels of per capita water contamination, indicating a need for continued advancement to production activities that promote resource efficiency. Precipitation (lagged by one year) also correlate with greater levels of per capita water emissions. This may reflect future expectations of markets given scarcity of inputs, especially as global temperatures increase every year.

The measure used for inequality did not meet expectations, yet it significantly influences per capita water contamination. This may be due to the way the variable was described or the omission of a variable form the regression model. An alternative explanation may be that though distribution of income is not consistent for all income levels (individuals with higher incomes hold more opportunities for social advancement than individuals with lower incomes), expectations of demand for water contamination is consistent. That is an individual with an exceptionally low income feels the same way about water contamination as an individual with an exceptionally high income.

Factors that were not considered were the unobservable, internal differences among separate entities and across time periods. Within one specific county, there may exist industries with abundant external and internal funds that allow for more rigorous supervision and preventive action to maintain clean resources than industries without the same amount of funding. Similarly, there may exist fundamental differences in future expectation, culture, and demand at the household level that influence income levels and the level of social capital accumulated for a given county. Such factors cannot be addressed with cross sectional analysis and requires the use of panel data for more robust results. Future work should take these factors into account when developing studies to address similar topics of environmental degradation.

VI. Conclusions

In preparation for graduate level study, this project took concepts and aspects of undergraduate economics coursework and applied them to the development of a research paper. Data was collected across federal agencies, a literature review was written, maps were created using ArcGIS software, and analysis was conducted using OLS regression. Results did not fully support initial expectations, yet they still provide sufficient discussion points. Further research projects of environmental degradation should use panel data to account for variability of internal factors across entities and time.

The experiential learning internship has positively impacted my career goals and plans. Not only have I had the opportunity to work alongside dedicated supervisor to tailor toward a career of intensive research activities, but I am now motivated to continue to build on this study and refine it with the recommendations discussed in the project outcomes. By continuing this type of work, I can continue to build my experience in preparation for engaging career opportunities as a research economist for USDA agencies.

VII. Appendices

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Figure I – Maps Created Using ArcGIS Software

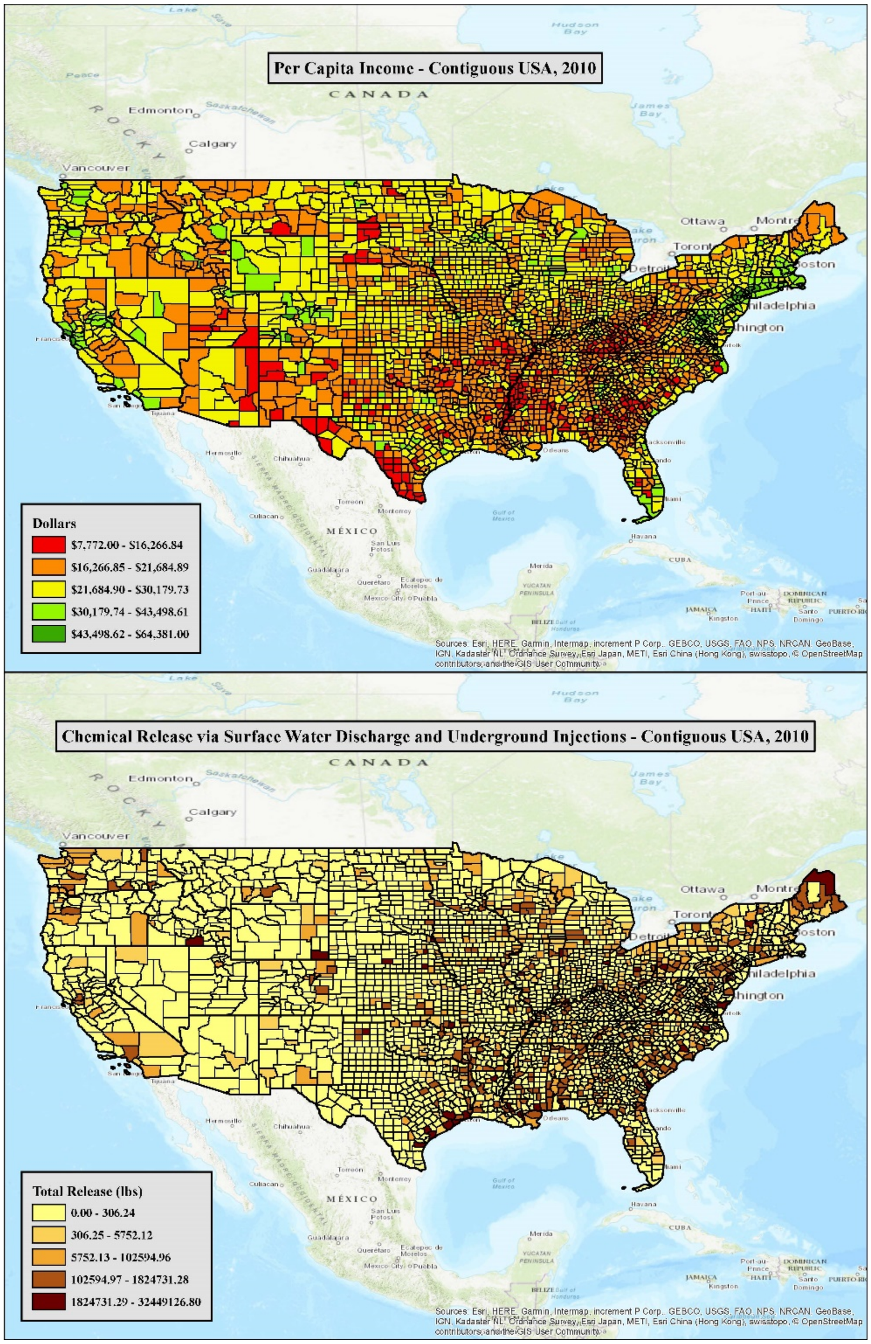
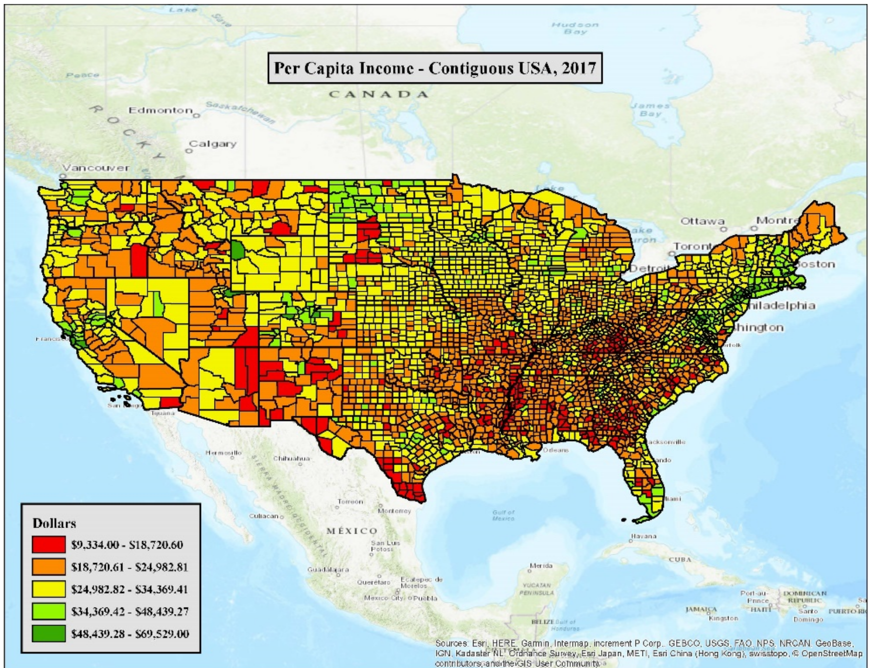


Figure I – Maps Created Using ArcGIS Software (continued)



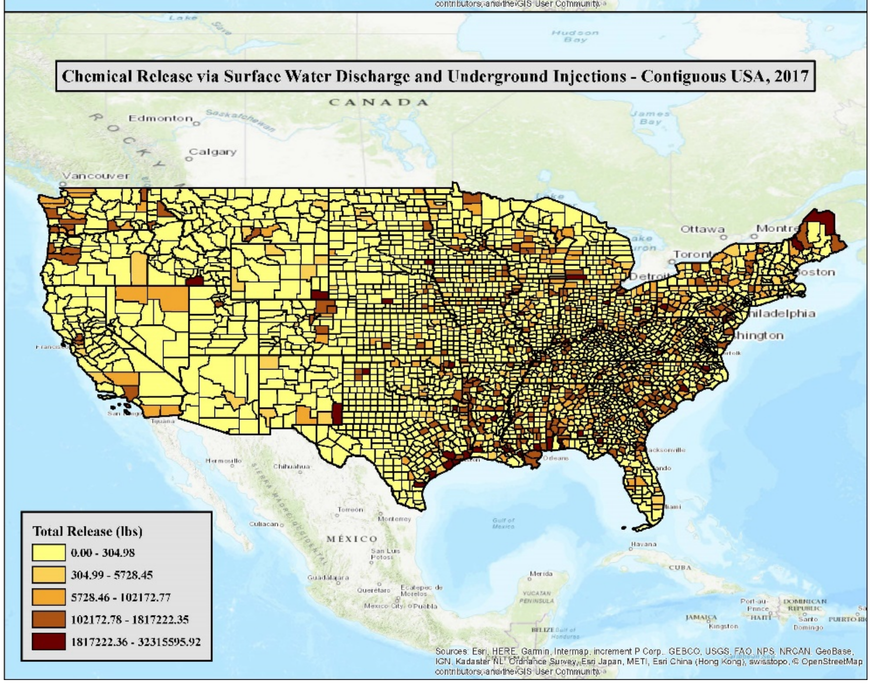


Figure II – Results of Cross-Sectional Analysis

Parameter Estimates																
	2010		2011		2012		2013		2014		2015		2016		2017	
Variable	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|	Parameter Estimate (Standard Error)	Pr > |t|
Intercept	-16.11708 (12.80804)	0.2084	-15.43894 (11.11493)	0.1649	-17.8031 (10.83008)	0.1003	-12.16045 (10.2461)	0.2354	-10.22748 (9.49411)	0.2815	-8.90372 (8.34044)	0.2858	-4.99288 (-0.59)	0.5566	-12.05028 (7.9029)	0.1274
M	0.00099664* (0.00055413)	0.0722	0.00072163 (0.00046814)	0.1233	0.00086535* (0.00046104)	0.0606	0.00079204* (0.00043302)	0.0675	0.000713* (0.00040699)	0.0799	0.000546 (0.00034265)	0.1112	0.00026336 (0.81)	0.4208	0.00042966 (0.00029919)	0.1511
M2	-0.0000000130659 (0.000000009481045)	0.1683	-0.0000000100948 (0.000000007999067)	0.207	-0.0000000123154 (0.000000007890561)	0.1187	-0.0000000102948 (0.000000007361261)	0.1621	-0.0000000099782 (0.000000006794422)	0.142	-0.00000000770516 (0.000000005641828)	0.1721	-0.00000000343426 (-0.65)	0.517	-0.00000000503192 (0.000000004598162)	0.2739
Inequality	-9.99177 (6.14532)	0.1041	-9.31296* (5.1909)	0.0729	-10.39859** (5.20246)	0.0457	-11.61157** (5.0099)	0.0205	-10.57754** (4.66384)	0.0234	-11.69798*** (4.07455)	0.0041	-9.37666** (-2.35)	0.0188	-6.75307* (3.72383)	0.0699
PopulationDensity	0.00014245 (0.00039738)	0.72	0.00012469 (0.00033697)	0.7114	0.00009127 (0.00032129)	0.7764	0.00013655 (0.00030702)	0.6565	0.00011483 (0.00028767)	0.6898	0.00010604 (0.00025247)	0.6745	0.00008117 (0.32)	0.748	0.00007483 (0.000232)	0.7471
Putnam	-0.00141 (0.00311)	0.6497	-0.00119	0.6535	-0.00139	0.5797	-0.00118 (0.00239)	0.6219	-0.0006754 (0.00223)	0.7619	-0.00059908 (0.00195)	0.759	0.00011275 (0.06)	0.9535	-0.00068739 (0.0018)	0.7028
Resource	0.31254*** (0.09144)	0.0006	0.30387*** (0.0791)	0.0001	0.33463*** (0.07598)	<.0001	0.3432*** (0.07331)	<.0001	0.28651*** (0.06824)	<.0001	0.30338*** (0.06044)	<.0001	0.22697*** (3.83)	0.0001	0.23785*** (0.05565)	<.0001
Edu	-0.06505 (0.12661)	0.6074	-0.01967 (0.10688)	0.854	-0.00551 (0.10152)	0.9567	-0.02253 (0.09609)	0.8147	-0.00955 (0.0893)	0.9148	0.02614 (0.07819)	0.7381	0.01525 (0.19)	0.8456	-0.00838 (0.07298)	0.9086
Ethnic	0.10375** (0.0424)	0.0145	0.0998*** (0.03551)	0.005	0.12579*** (0.03489)	0.0003	0.11959*** (0.03129)	0.0001	0.1077*** (0.03111)	0.0005	0.09112*** (0.02713)	0.0008	0.04372* (1.67)	0.096	0.07297*** (0.02453)	0.003
Precip	0.0405 (0.03851)	0.293	0.08759** (0.04519)	0.0527	0.07714** (0.03013)	0.0105	0.08921*** (0.03217)	0.0056	0.07305** (0.02982)	0.0144	0.08976** (0.02926)	0.0022	0.06925** (2.38)	0.0176	0.08988*** (0.02874)	0.0018
Temp	0.11401 (0.09567)	0.2335	0.12674 (0.08196)	0.1221	0.13513**	0.0483	0.07543 (0.07452)	0.3115	0.07172 (0.07067)	0.3102	0.0956 (0.05939)	0.1076	0.09741 (1.33)	0.1849	0.09021 (0.05974)	0.1311