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HAS SURFACE WATER QUALITY IMPROVED SINCE THE CLEAN WATER ACT?

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ABSTRACT

On the fortieth anniversary of the Clean Water Act this paper reports the first quantitative assessment of the aggregate trends in water quality in the U.S. using a single standard over the years 1975 to 2011. The analysis suggests that fresh water lakes for the nation as a whole are about at the same quality levels as they were in 1975. In short, viewed in the aggregate, nothing has changed. An assessment of the factors influencing the aggregates also suggests that water quality appears to be affected by the business cycle. This result calls into question the simple descriptions of the change in environmental quality with economic growth that are associated with the Environmental Kuznets Curve.

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1. Introduction

Forty years ago, in 1972, the Clean Water Act (more formally the Federal Water Pollution Control Amendments) was passed. There have not been major changes in the legislation governing national water quality goals or the rules used to achieve them since this early legislation. National water policy was intended: "to restore and maintain the chemical, physical, and biological integrity of the nation's waters". To realize this objective operational goals were part of the legislation. They called for: (1) eliminating all discharges of pollutants into navigable waters by 1985; and (2) achieving "fishable and swimmable" waters by 1983. Technology standards on dischargers were the primary methods used to realize these goals.[1]

To our knowledge, there have been no attempts to consider what was accomplished using a single, consistent, index of water quality conditions at the national level.[2] Instead, the U.S. Environmental Protection Agency compiles, at periodic intervals, the data from state reports on the quality of surface and ground waters in each state.[3] The activities associated with monitoring and assessing water quality conditions can be defined independently by each state. This approach was authorized by several sections of the act. A requirement for a national assessment is described as part of the Section 305(b) process. It calls for a summary of the states' reports and corresponds to the way EPA evaluates whether U.S. waters at a national level meet water quality standards.

[1] See Freeman [1990] for a more detailed description and evaluation of water pollution policy.

[2] Hayward is a notable exception. He identified these issues in a number of annual reports on environmental quality trends since 1994 (see Hayward [1996]). In his most recent report (Hayward [2011]) he aptly summarized the situation noting that "Since 1970 the United States has spent more than 1 trillion on behalf of water quality. However, we lack reliable, systematic measurements of general water quality trends to match our consistent trend data for air quality" p. 131. His 2011 assessment uses EPA information to describe the current state of streams and U.S. Geological Survey Data to describe stream flows from 1961 to 2000. He does not attempt, as we do, an overall assessment.

[3] Reports are available for 1992, 1994, 1996, 1998, 2000, 2002 and 2004. The last of these for 2004 was available in 2009 and is the most recent assessment.

This paper reports the first quantitative assessment of the trends in water quality for freshwater lakes in the U.S. using a single standard over the years from 1975 to 2011.[4] With data from the U.S. Geological Survey's National Water Information System (NWIS) we find average water quality in U.S. lakes is at about the same level in 2011 as it was in 1975 with over eighty percent of the lakes in the NWIS database consistent with fishable conditions based on measures of the levels of dissolved oxygen present in them. Thus, for freshwater lakes one could conclude nothing has changed. We do not have conditions that are closer to quality levels that support fishable and swimmable lakes uniformly throughout the U.S. as mandated in the act. Of course, this does not imply lakes were unaffected. We do not know what water quality conditions would have been without the legislation. Moreover, our database is not ideally situated to answering the question we posed. However, it is important to also acknowledge that neither is the one used by EPA.[5] The legislation never included a serious requirement for evaluation. However this general conclusion may well be the least important outcome of this effort to develop an assessment of the national trend in water quality.

Three additional important observations were derived in the process: (1) There is no generally accepted economic definition for a national index for any spatially delineated environmental amenity. The conventional economic theory of quantity indexes relies on the presence of prices to construct an aggregate for the heterogeneous goods that are defined to be part of each aggregate group. There is no comparable logic for non-market amenities. (2) An examination of the record suggests there is <u>no</u> trend. Rating lakes by dissolved oxygen consistent with requirements to support sport fishing has the weighted proportion with fishable conditions

[4] The EPA process acknowledges that each state is free to adopt its own approach for measuring and monitoring water quality. We use a single metric for all the lakes sampled to assure a consistent evaluation.

[5] They do not attempt to evaluate progress over time. Statistics on the acres of assessed lakes that are judged to be good or threatened are provided in each of these reports. However the reports also note that the conditions of monitoring and evaluating lakes are based on each state and tribal authority's decisions.

varying between 73 percent and about 87 percent over the thirty seven years in our sample, with no apparent pattern. Moreover, the use of a set of fixed weights in an attempt to reflect differences in recreation use patterns, based on measures of water based recreation in each state, does not change the qualitative conclusions about trends in lakes' water quality. Finally (3) when the aggregate indexes we constructed for fishable and swimmable lakes are compared to the national unemployment rate over the same period our results suggest the indexes of national water quality respond to the business cycle. As the unemployment rate rises, all the national indexes for water quality improve and the reverse seems to accompany improving economic conditions. This finding calls into question simple stories of how aggregate environmental conditions evolve as an economy develops. The most popular of these descriptions is associated with the Environmental Kuznets Curve (EKC). This theory hypothesizes as the average level of household income (measured by GDP per capita) increases so does environmental quality.[6]

The next section provides a brief summary of the economic theory of index numbers and considers how this logic might be used for the task of measuring national water quality trends. Section III describes the data used for our analysis and the construction of our indexes. Section IV discusses the resulting indexes and their relationship to aggregate measures of economic activity. Section V discusses the implications of our analysis as a first step in developing measures for trends in national indexes of environmental quality.

[6] See Carson [2010] for a review and Smith [2012] for a critique of models of the EKC process.

2. Economic Index Numbers for National Water Quality

Frisch [1936] offered one of the first general descriptions of the problem that index numbers seek to resolve. He noted that: "the index number problem arises whenever we want a quantitative expression for a *complex* that is made up of individual measurements for which no common *physical* unit exists."[7] In most economic situations the physical measures available do not capture the variations in all the attributes that could describe the elements in what Frisch labeled a "complex" (or set of heterogeneous elements). The economic approach to price and quantity indexes defines them as solutions to optimization problems.[8] Price indexes follow from the definition of the cost (or expenditure) functions and implicitly view the quantity elements involved as based on that minimization criterion. An economic quantity index can also be defined as a solution to an optimization problem. In this case the characterization is in terms of a distance function that selects the largest deflator to a vector of quantities for heterogeneous items that yield equivalent utility as a reference vector. Classic aggregation rules for the case of proportional changes of either prices (Hicks aggregation) or quantities (Leontief aggregation) usually evaluate the performance of aggregates based on their ability to yield conclusions for choice problems that are no different from analysis that would be undertaken in disaggregated terms (Green [1964]).

All of this structure relies on exogenous prices for the elements to be aggregated. For the case of time series analysis, there is usually a further implicit assumption that the law of one price can be maintained over spatially defined elements in the aggregate. None of these

[7] Frisch [1936] p.1.
[8] Diewert [1993] provides the details underlying each of these arguments (see p. 11-18).

conditions would be satisfied for environmental amenities. So aggregate indexes for them cannot be based on the conventional theoretical foundation used for price and quantity indexes.[9]

Two types of indexes have been proposed for non-market amenities. Neither fits the specific needs for a national analysis of environmental quality trends for resources that are outside the areas where households live. The first is associated with quality of life comparison across metropolitan areas. First introduced by Blomquist et al [1998], the most comprehensive assessment by Biere, Kuminoff and Pope [2012] describes the method as "…estimating the expenditures on amenities the consumers implicitly make when they choose to pay higher rents and/or accept lower wages in order to live in higher amenity locations."[10] Their analysis defines the relative differential using national level hedonic property value (with housing prices expressed as rents) and wage equations. The estimated contributions of amenities to the relative implicit expenditures (i.e. the sum of the higher rents and the magnitude of the reduced wages) are used to construct their estimates. This logic follows the Rosen-Roback ([1979] [1982]) framework. Each location is compared to the least expensive alternative to construct their real expenditure differential required to live in that area. This logic is comparable to the economic approach for price indexes. Indeed, if we defined the ratio of a location's implicit expenditure to the reference value it would be a spatial analog to an economic price index for local amenities. It seems most appropriate for amenities available through residence in specific communities such as air quality.[11] Thus, this logic could supply a set of weights for a time series analysis of national trends for amenities available through the locations households select by matching the

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[9] One of the early leaders in the modern literature on index numbers, Pollak [1989] discusses the role of amenities in index numbers. However, his focus is on cost of living indexes and place to place comparisons. As a result he incorporates amenities in the cost function approach.

[10] Biere, Kuminoff and Pope p. 2.

[11] To incorporate recreational resources one needs the counterpart to the Rosen-Roback logic used for jobs and houses to consider how recreation opportunities would be integrated into the hedonic model. See Phaneuf et al [2008] for discussion.

net expenditures estimates implicitly made for spatially delineated amenities. If the objective is to construct an index for one of these amenities, the appropriate weight would presumably be based only on the contribution of the specific non-market service to these net expenditures.[12]

The second index for environmental goods parallels the Malmquist [1953] logic that our earlier discussion used to describe economic quantity indexes. In proposing it Färe, Grosskopf, and Hernandez-Sancho [2004] derive a relative distance function as a quantity index for non-market goods. Their application is to pollution and measures the relative ability of a source of pollution to contract its polluting outputs while holding the market outputs produced and inputs used at the same levels observed for the reference situation.[13] The most direct application would be for consistent economic quantity indexes of emissions that could be compared across countries. This is the example these authors use in their paper. Generalization of their proposal for an index of environmental quality would require consideration of how the environmental diffusion effects are treated in defining the relative distance functions. To our knowledge this extension has not been considered.

Overall then, while there are potential strategies for developing economic indexes for national trends in environmental amenities that would be closer to the ideal, neither of these approaches would fit the situation that arises with a national index for surface water quality. Adaptation of the expenditure differential measures to develop indexes for non-market services would be best suited for situations where the services are conveyed by the locational choices households make. The extensions to Malmquist's distance function logic are best suited for characterizing trends in national emissions from point sources.

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[12] There are several alternatives. One could derive a price index based on the relevant component of the implicit expenditures over time and then use the Fisher condition for consistent aggregates to derive a quantity index from the aggregate price index.

[13] The approach meets the four Fisher [1972] tests for consistent index numbers.

Our analysis demonstrates the importance of addressing these issues using the types of indexes that can be defined with available data.[14] Our quantity indexes are weighted averages of a water quality indicator that is based on one of the goals of the legislation—to support recreational uses of surface water bodies. There are two steps in defining the index. The first translates the most common measure of surface water quality, dissolved oxygen (DO), into a use related indicator. This step follows the convention adopted in the early efforts to estimate the benefits from surface water quality improvements and uses Vaughan's [1981] DO thresholds for sport fishing and swimming.[15] Our scheme identifies a lake as supporting fishing with a discrete indicator equal to unity if the dissolved oxygen exceeds the threshold for sport fishing and zero otherwise. The same practice is followed for swimming with higher DO thresholds required for this type of recreation. The specific details associated with developing the thresholds are explained in the next section.

Aggregates of these indexes over all the sampled lakes in the United States by year is our first index. This measure is the proportions of lakes with dissolved oxygen levels consistent with the thresholds for each activity. A second index can be defined from these same data by using the proportions of lakes satisfying each water quality criteria in each state and then averaging these proportions across states for each year. These two indexes are the closest to physical measures. They are distinguished based on how one takes account of the availability of lakes for recreation.

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[14] This issue is different from the estimates of Gross External Damages developed in Muller et al [2011]. They use a partial equilibrium integrated assessment model to derive shadow values for pollution emissions for each source location and then aggregate across source locations to develop a national measure of the damages. Their objective is to develop an expenditure equivalent. Unfortunately the partial equilibrium orientation implies they are assuming the equivalent of a law of one price for the constituent elements entering the marginal damage used to construct source specific damages. The variations in the marginal damages arise from the air diffusion system inherent in their integrated assessment model and not the actual differences in the components of damages by receptor location. See Muller and Mendelsohn [2009] for discussion of the details of the model.

[15] The most influential national assessment of surface water quality benefits to date by Mitchell and Carson [1981] was the early stated preference survey that focused attention on water quality indicators that would be understood by the general public. A published paper based on this survey is Carson and Mitchell [1993].

The overall average treats each lake as equally accessible to any person regardless of where the lake is. The state specific average implicitly defines the extent of the market for the lakes available to each person to be his or her state.

To weight quality in a way more consistent with the requirements of an economic index, the analysis would need to allow the index of aggregate quality to reflect the importance of quality differences for people. One way to meet this goal would be to weight quality by the amount of recreation being supported by water quality. The revealed preference approach for estimating the tradeoffs recreationists would make to improve water quality relies on weak complementarity. This restriction assures that changes in water quality could be represented in equivalent terms as price changes for the commodity serving as the weak complement to that quality (Smith and Banzhaf [2007]). Using this relationship a natural candidate would be to weight the water quality indicator for each lake by the quantity of each type of recreation undertaken. Ideally this would involve measures of fishing (and swimming) activity at each lake over time. Unfortunately, this level of detail does not exist for a large enough sample of lakes for the nation as a whole. Most of the literature on recreation use patterns consists of "one time" studies of recreation at individual lakes (or sets of lakes) or national surveys of recreational activities.[16] The national surveys often do not identify the recreation sites used and are undertaken at infrequent intervals.

These limitations imply that our effort to develop weights based on recreational activities should be considered illustrative. We use measures of fishing and swimming activities in each state to weight the statewide average quality measure. These aggregates construct national weighted proportions of lakes meeting the fishable and swimmable criteria based on the average

[16] The surveys associated with the Iowa Lakes Project are notable exceptions. See Evans, Herriges and Kling [2009] for more details.

proportion of lakes meeting each standard in a state and the amount of recreational activity in each state. The weights for quality levels that support recreational fishing are held across the 1975-2011 period based on estimates of use for 2006. For recreational swimming we developed weights based on a recreation survey in 2001 but ultimately rejected them because we did not have a basis for defining the representative swimming levels in each state. In constructing the weighted aggregate indexes only the quality indicators for sample lakes in each state change from year to year.

3. Data and Implementation

The U.S. Geological Survey collects information on the chemical, physical and biological properties of surface and ground water sites in the U.S. We assembled the data for this analysis from the National Water Information System (NWIS).[17] Table 1 summarizes several features of the data. The count of observations available by year and the average number per lake are given in columns two and three. Columns four and five report the states with the largest number of samples per lake each year and the states with the smallest number in each year. Beside the abbreviation for each state's name (in parentheses) is the count of the number of observations in each case. The last two columns in this table provide the average number of lakes sampled per state and the number of distinct lakes sampled for the lower 48 states overall per year. A total of 8,130 lakes were sampled over this time span. Over the full sample, these records provide 12 to 40 observations on average per lake in each state.

The records were not intended to provide a representative sample of either the lakes or their conditions throughout the year. As the summary in columns three and four suggests, some states

[17] See http://nwis.waterdata.usgs.gov/nwis/qwdata

have a large number of samples while many others only have one sample per lake per year. On average, each state has between 7 and 23 lakes sampled with over 300 sampled in total most years. There is a sharp drop in coverage from 2009 to 2011. We could not determine the reasons for the decline, whether budget cutbacks or some other issue.

To construct the indicator variable for water quality we used dissolved oxygen. Our measure is based on the dissolved oxygen thresholds Vaughan identified for sport fishing and swimming.[18] This is 64% saturation at 85 degrees F and atmospheric pressure of 770 ppsi. Converted to milligrams per liter (mg/l) it is 4.99 mg/l. For swimming the threshold is 83% or 6.47 mg/l. The three types of quality indexes we developed are defined as follows:

$$I_{1t}^{k} = \frac{1}{N_t} \sum_{j=1}^{S} \sum_{i \in L_{jt}} l\left(WQ_{it} \geq C_k\right) \qquad (1)$$

l(.) = an indicator function that equals unity when dissolved oxygen (WQ_{it}) for lake *i* in period *t* exceeds the threshold for the recreational activity (C_k, with *k* defined separately for sport fishing and swimming)

L_{jt} = the set of dissolved oxygen readings for lakes in state *j* in period *t*

N_t = the total number of readings in period *t* across all 48 states and lakes with readings

S = the number of states included (the lower 48)

The second index computes these proportions for the lakes in each state and then averages over the states in each year as in equation (2).

[18] We also used the Vaughan criteria to develop an index for "boatable" water quality conditions. This index is not as stringent as the quality required for sport fishing and has results that are comparable to those reported for the fishable index.

$$I_{2t}^{k} = \frac{1}{s}\sum_{j=1}^{S}\frac{1}{n(L_{jt})}\sum_{i\in L_{jt}} l\left(WQ_{it} \geq C_k\right) \qquad (2)$$

$n(L_{jt})$ = the number of water quality readings across lakes in state j in period t

The last index weights the statewide averages by measures of fishing and swimming recreations in each state. The index for sport fishing is in equation (3a) and for swimming in (3b).

$$I_{3t}^{k} = \frac{\sum_{j=1}^{S}\left(\frac{1}{n(L_{jt})}\right)\left(\sum_{i\in L_{jt}} l\left(WQ_{it} > C_k\right)\right)\cdot\sum_{s\in r_j}\upsilon_s \cdot w_s}{\sum_{j=1}^{S}\sum_{s\in r_j}\upsilon_{s\cdot} w_s} \qquad (3a)$$

υ_s = the number of days fishing by respondent s in the set of respondents (r_j) for state j

w_s = the sample weight for respondent s in set of respondents for state (j)

The information on fishing days in 2006 is developed from the National Survey of Fishing, Hunting and Wildlife Associated Recreation (NSFHW). For swimming we used the National Survey on Recreation and the Environment (NSRE). The NSRE did not report sampling weights. As a result, the weighted average in this case simply reflects the relative number of survey respondents who indicated they had days with swimming in freshwater bodies in 2001 in each state.

$$I_{3t}^{k'} = \frac{\sum_{j=1}^{S} \left(\frac{\sum_{i \in L_{jt}} \left(I\left(WQ_{it} > C_{k'} \right) \right)}{n\left(L_{jt} \right)} \cdot \sum_{s \in R_j} d_s \right)}{\sum_{j=1}^{S} \sum_{s \in R_j} d_s} \tag{3b}$$

d_s = the number of days of swimming that respondent s in the set of respondents (R_j) for state j had in 2001

At present, none of these indexes would meet rigorous standards that should be used in an official measure that is used to gauge water quality at the national level. The data required to construct such a measure do not exist. The only systematic study that links water quality measurement of lakes to recreational use is the Iowa Lakes Study (see http://www.card.iastate.edu/lakes/ and Evans, Herriges and Kling [2011]).[19] Unfortunately the Iowa initiative was limited to these four years. The most recent effort conducted in 2009-2010 focuses on people's preferences for cleaner lakes with greater fishing opportunities.

This systematic approach contrasts with the EPA Section 305(b) report to Congress where the coverage and monitoring criteria can vary by state. The report issued in 2009 for readings in 2004 is the most recent one available. There is no clear pattern in the percentage of

[19]This project gathered data of recreation trips made by households to 130 primary lakes in Iowa to estimate the economic tradeoffs households would make for improvements in water quality. The first phase of the project involved mailed surveys in four consecutive years from 2002 to 2005 and links the data to on-site measures of water quality.

assessed lakes that are rated as having good conditions between the 1992 and the 2004 reports.[20] Table 2 provides a summary from these Section 305(b) reports. The percentage of assessed acreage that was rated as good was highest in 1994 and lowest in the most recent assessment in 2004.

4. Results

Figures 1 and 2 display our water quality indexes. In figures 1a and 1b we present the indexes describing water quality conditions using two different criteria. Swimmable requires higher dissolved oxygen readings than a fishable rating. In each case the three sets of indexes are presented. The solid line (with circles) in each graph corresponds to the overall national proportion of lakes meeting each standard. The dashed line with squares uses the means at the state level and the last line, tight dots with triangles, uses the recreation use weighted to scale the state level averages. If we were to base our assessment on the national mean index (equation (1)) using either the swimmable or the fishable water quality indexes, the descriptions would imply the lowest ratings of water quality conditions. The index based on use related weights for fishable conditions (equation (3a)) tracks the state average index reasonably closely. In this case the weights used in constructing the index are based on the population weights from the

[20] A separate EPA effort, the National Lakes Assessment (NLA), was reported in April 2010. The NLA was intended to provide unbiased estimates of the condition of natural and man-made freshwater lakes, ponds and reservoirs greater than 10 acres and at least one meter in depth. Lakes were selected at random to represent the condition of a larger population of lakes in the 48 states. The analysis included 1,028 lakes sampled during the summer of 2007. The criteria for the evaluation is to support healthy biological communities. The overall results for the first assessment rated quality as follows: (values are percentages)

	All Lakes	Natural	Man-Made
Good (less than 20% taxa loss)	56	67	40
Fair (20-40% taxa loss)	21	16	30
Poor (> 40% taxa loss)	22	17	29

In 2012 EPA designed a second assessment of 904 natural lakes, ponds and reservoirs. They must be at least 2.5 acres and one meter deep. The results from the survey are expected to be available in 2014.

NSFHW. These weights were designed to construct consistent estimates for the national recreation usage of fresh water fishing activities. For the case of swimmable conditions, the use weighted index is much more volatile. The weights here are based on the actual sample responses to the NSRE by state. The variation reflects the pattern of survey responses without appropriate weighting to reflect how the sample patterns would translate to the overall population or users. We presented it here to illustrate how the weighting scheme, even when it is constant over time, can create the appearance of wide swings in the trends over time. In the remainder of the discussion we focus on three indexes. We use the two based on average of the state-level readings for both swimming and fishing, and in the case of sport fishing we include the recreation weighted indexes.

Figure 2a considers the two fishable quality indexes in comparison to the national unemployment rate (with the axes for unemployment on the right side of the graph). Here the circles correspond to the state-wide average, triangles (with dashed line), to the recreation weighted average, and the diamonds with tight dots plot the unemployment rates. The graph suggests that there are more periods in which low unemployment corresponds to low water quality than any other pattern. Nonetheless, this finding may well over emphasize a few clusters of observations. As a result, we also use simple regression models to consider the relationship. Before discussing these we consider one more set of overlaps. Figure 2b plots the recreational weighted average for water quality along with the national unemployment rate and overlap the NBER Business Cycles as grey panels. As unemployment is rising it seems clearer in this graph that the water quality index increases as well.

These informal insights are confirmed with some simple regressions. Table 3 uses the average-by-state indexes for both the swimmable and fishable water quality indexes and the recreation use weighted average. Two models are presented for each index. A simple regression of the index on the national unemployment rate and a regression with a quadratic term in the unemployment rate confirms a positive relationship between the unemployment rate and water quality indexes. It would appear that the slowdown in economic activity lead to improved water quality on average over this period. In five of the six estimated models we find a statistically significant relationship with unemployment. Only the average index for swimmable quality would be judged insignificant. All of the quadratic unemployment terms have a statistically significant negative effect on water quality. The explanatory power for the regressions is modest. Nonetheless the association is striking. The water quality indexes were assembled using individual readings for water quality in each lake. It is difficult to speculate about a mechanism that would imply this is a spurious correlation and thus offer an alternative basis for explaining these findings.

The last aspect of our results considers whether our water quality indexes would support an EKC hypothesis. Table 4 provides these regression models. In general there is no clear evidence of a relationship between the fishable and swimmable water quality indexes using the state averages and real per capita GDP. Only in the case of the recreation weighted index do we find marginal support (see equation (3) in Table 4). As a final issue we considered whether the effect would be more apparent including the unemployment rate. We report only one set of results using the recreation weighted index in equation (4) in table 4. There were also modest improvements in the models for the other water quality indexes but nothing to suggest a change in our overall conclusion. This is the most supportive case. In this case, both the GDP per capita terms and the unemployment variables are significant. At best, these findings would suggest that responses consistent with the EKC hypothesis cannot be detected unless there is explicit consideration of the short term effects of the business cycle on aggregate environmental quality measures.[21]

5. Implications

Our water quality indexes are far from ideal. Nonetheless they provide a vehicle for raising two important issues. First, new rules intended to improve some aspect of environmental quality should build into the implementation process a specific strategy for evaluating whether they do what is intended. At present they do not! Greenstone [2009] has argued forcefully for a change.[22] Our results support the argument for built-in evaluation. While the goals are national these evaluations need indexes of national quality. The NWIS data highlight the importance of collecting micro data on quality and recreation use consistently to evaluate national policies. For now we are left with a conjecture. Our findings could be interpreted as suggesting the forty years of experience with the surface water quality of freshwater lakes in the U.S. implies federal policies did not meet their stated objectives. Of course, in the end this conclusion depends on the degree to which our samples provide a representative picture of the water quality in lakes in the U.S. over time. The data collected by the 305(b) process do not allow us to answer this question.

Second, and equally important, we have at least sixty years of evidence suggesting that environmental quality is important to people. There is now a host of micro-economic evidence

[21] This is consistent with some unpublished research by Sheldon [2012] for the case of CO_2 emissions.

[22] His suggestions call into question conventional practices of benefit-cost analysis, arguing that ex ante assessment is not possible. Instead he would call for experiments that "try out" policies on a limited scale, perhaps in a small region or set of industries before national mandates. In most cases this strategy will not be feasible due to the properties of environmental systems as interrelated mechanisms, the ways households and firms adjust to temporary versus permanent changes, and the prospects for selective targeting of regions or sectors for policies as experiments. Nonetheless, the call for his "built in" evaluation should be a key element in all large scale regulatory programs.

confirming its impacts on human health, productivity, and consumption choices. The economic tradeoffs people are willing to make to improve quality are significant. Environmental quality needs to be directly integrated into modern dynamic general equilibrium macro models of how economic policies can be designed to reflect market and non-market behaviors. To meet this goal we need to develop aggregate indexes for spatially delineated environmental services. This research has illustrated the data requirements and conceptual challenges in responding to this goal.

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Table 1: Description of U.S. Geological Survey's NWIS Sample of Freshwater Lakes: 1975-2011

Year	Number of Obs. per year used in analysis	Average number of obs. per lake	State with highest average number per year	State with lowest average number per year	Average number lakes sampled	Number of lakes per year
1975	5403	12.33	MO (54.2)	AR (1)	22.20	555
1976	6648	15.79	NH (69.4)	OR (1)	23.67	639
1977	6857	24.71	GA (131.5)	WI (1)	19.15	498
1978	8317	22.95	NV (153)	WI (1)	23.08	577
1979	9308	22.61	NV (155)	WI (1)	20.54	534
1980	8884	19.33	NV (168)	ID (1)	21.00	567
1981	8661	21.15	NV (125)	MI (1)	21.52	538
1982	7018	28.86	MT (285.7)	MI (1)	17.08	444
1983	8648	16.86	MT (114.6)	NC (1)	21.54	560
1984	12301	28.03	MT (274.2)	MA (1)	15.22	411
1985	11356	28.26	MT (196.2)	OH (1)	16.93	457
1986	12036	28.61	MT (174.9)	WY (1)	14.59	423
1987	13727	31.84	MT (242.7)	DE (1)	18.04	469
1988	10941	21.77	MT (315.9)	TN (1)	17.45	541
1989	10731	27.67	MT (276.9)	DE (1)	14.97	434
1990	9356	22.87	MT (170.7)	UT (1)	15.18	425
1991	11937	16.03	WI (80.0)	MI (1)	16.38	475
1992	10869	13.21	WI (62.6)	OK (1)	15.48	480
1993	10960	17.42	MT (159.3)	AZ (1)	22.19	599
1994	11897	18.41	MT (175.3)	PA (1)	17.47	524
1995	13926	12.99	WI (58.6)	OH (1)	20.83	604
1996	11105	22.92	MT (122.7)	IN (1)	18.64	522
1997	11117	25.33	MT (155)	NY (1)	18.00	450
1998	11552	26.17	MT (164)	PA (1.5)	18.87	434
1999	10305	28.23	MA (218)	IN (1)	17.84	446
2000	8782	24.99	MT (156)	TN (1)	12.31	357
2001	11733	31.53	AR (296)	UT (1)	17.03	511
2002	10659	25.39	MT (169.7)	MD (1)	17.47	524
2003	12250	23.39	MT (166.7)	SD (1)	20.28	588
2004	11109	21.04	MT (136.7)	SD (1)	19.25	539
2005	9796	17.90	AR (112)	AZ (1)	18.41	589
2006	10088	18.52	WI (70.9)	MD (1)	19.07	515
2007	9230	17.74	CO (58.2)	NM (1)	16.96	424

2008	9334	19.37	KS	(65)	WV	(1)	12.93	362
2009	7884	28.35981	CO	(153.7)	NY	(1)	8.23	181
2010	6784	28.81433	CO	(117.6)	NY	(1)	8.86	186
2011	6402	41.01092	OK	(194)	ID	(1)	7.24	152

Table 2: Summary of EPA Section 305(b) Reports

Year	Total Acres Reported (thousands of acres)	Acres Assessed (thousands of acres)	% Assessed	Water Quality Assessment (%) [a] Good	Impaired
1992	39,920	18,300	46	43	- [b]
1994	40,826	17,134	42	63	37
1996	41,685	16,820	40	39	61
1998	41,594	17,390	42	55	45
2000	40,604	17,339	43	55	45
2002	40,600	18,832	37	48	47
2004	41,666	16,230	39	35	64

[a] Percentages do not add to 100% for rounding and in some years other categories identified but not continued.
[b] This category was not reported.

Sources: U.S. Environmental Protection Agency, Section 305(b) reports in 2000, 2002, 2003, 2007, 2009

Table 3: Water Quality and Unemployment[a]

Independent Variables	Swimmable Index-State Average (1)	(2)	Fishable Index-State Average (3)	(4)	Fishable Index-Recreation Weighted Average (5)	(6)
Unemployment Rate	.005	.137	.009	.087	.010	.084
	(1.05)	(4.06)	(2.76)	(3.69)	(2.59)	(2.72)
(Unemployment Rate)^2	-	-.009	-	-.006	-	-.005
		(-3.94)		(-3.34)		(-2.41)
Constant	.700	.270	.778	.524	.749	.509
	(22.08	(2.41)	(36.84)	(6.70)	(28.75)	(4.94)
R^2	.03	.33	.18	.38	.16	.28
No. of Obs.	37	37	37	37	37	37

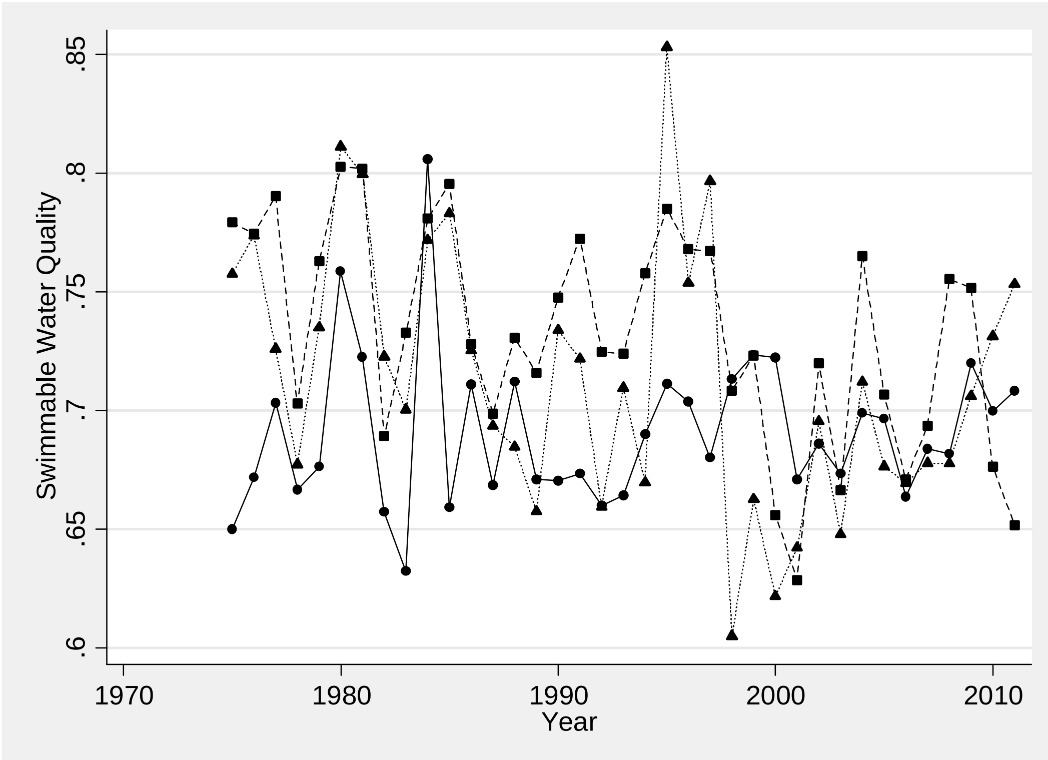
[a] The numbers in parentheses are t-statistics for the null hypothesis of no association.

Table 4: EKC Hypothesis and Water Quality[a]

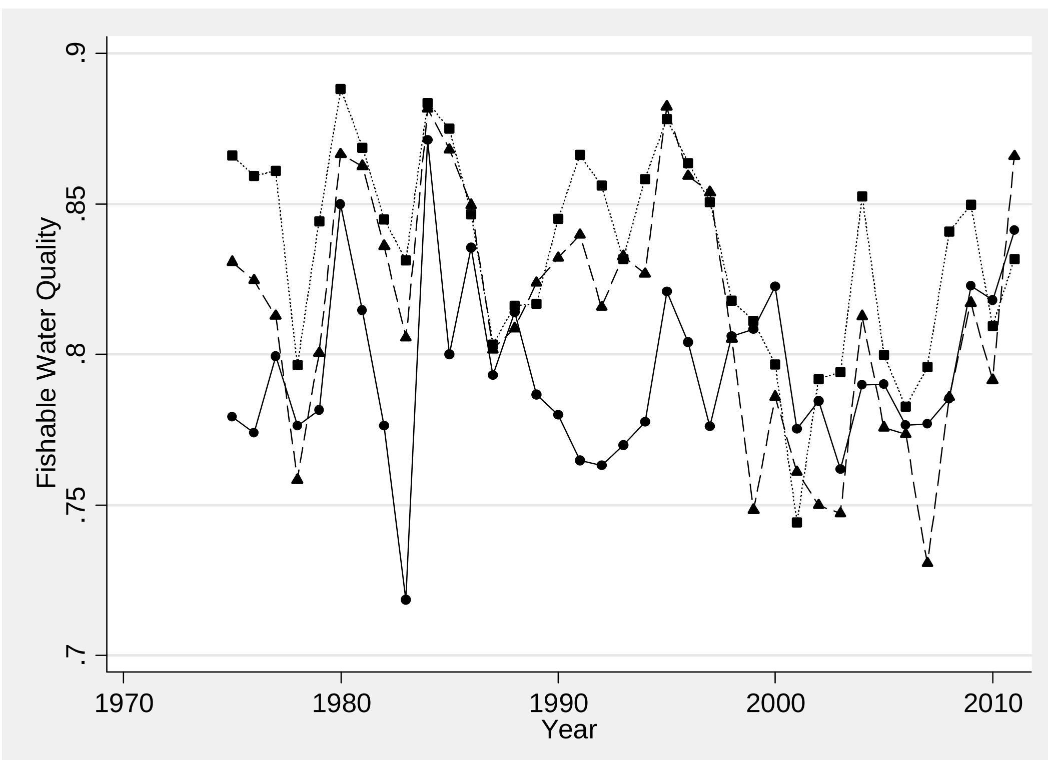
Independent Variables	Swimmable Index State Average	Fishable Index State Average	Fishable Index Recreation Weighted Average	
	(1)	(2)	(3)	(4)
Real GDP/Capita	1.387	2.584	18.485	29.322
	(0.11)	(0.29)	(1.70)	(2.72)
$(\text{Real GDP/Capita})^2$	-75.214	-77.193	-314.715	-460.764
	(-0.42)	(-0.59)	(-1.97)	(-2.94)
Unemployment Rate	-	-	-	0.010
				(2.68)
Constant	0.775	0.838	0.563	0.303
	(3.85)	(5.74)	(3.16)	(1.59)
R^2	.305	.299	.300	.425
No. of Obs.	37	37	37	37

[a] The numbers in parentheses are t-statistics for the null hypothesis of no association.

Figure 1

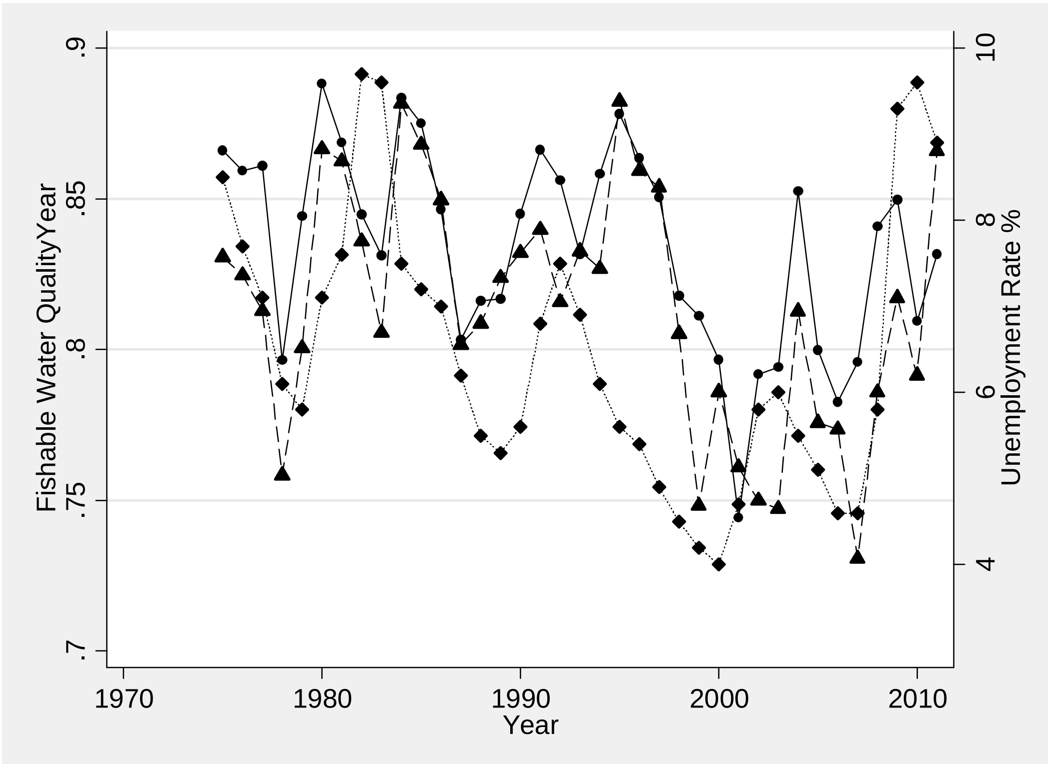


(a) Swimmable Water Quality: 1975-2011

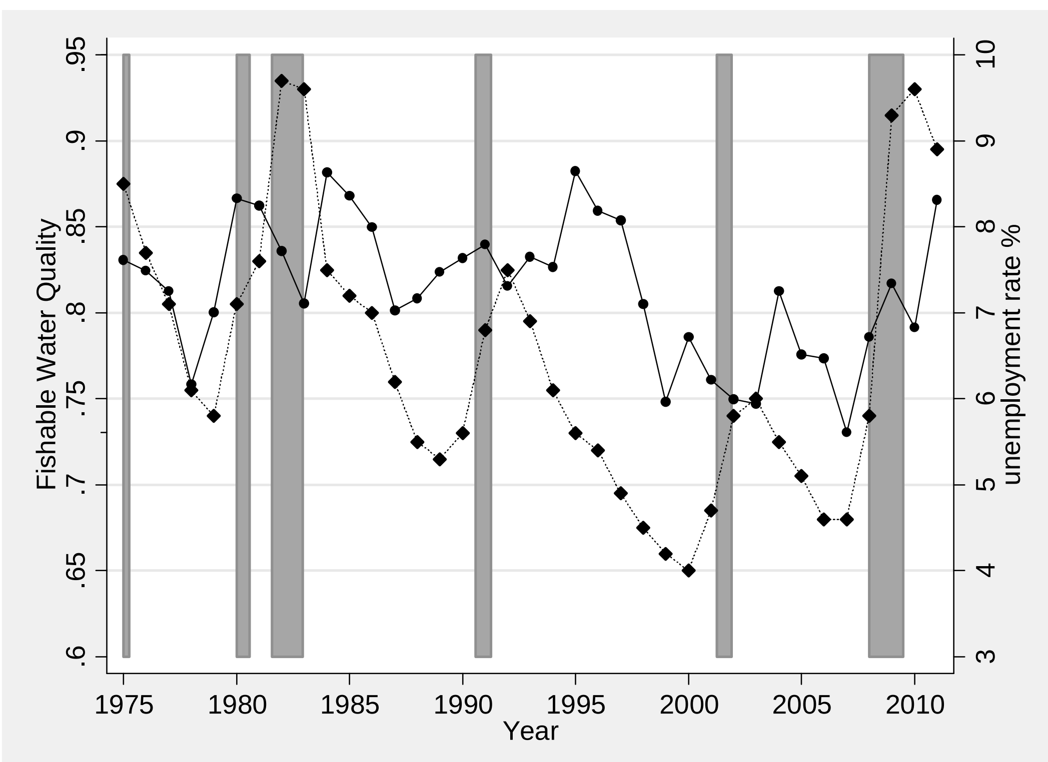


(b) Fishable Water Quality: 1975-2011

Figure 2



(a) Average Across States, Recreation Weighted WQ Index, and the Unemployment Rate



(b) Recreation Weighted WQ Index with Unemployment and NBER Recessions