Effects of the USDA Rural Development Water and Waste Disposal Loan and Grant Program on Rural Water Quality and Local Businesses

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1. Introduction

The formulation of environmental policies by the U.S. government has been instrumental in improving environmental quality in the country over the last few decades. Early environmental regulations and standards established by the U.S. government include the Clean Air Act of 1963 and the Clean Water Act of 1972. Since then, many other environmental laws and regulations have been enacted at the federal and state levels to protect air and water further, and this effort continues to the present day.

Several studies provide evidence that environmental policies can positively impact environmental quality. These studies generally find that mandatory regulations, regular inspections, strong enforcement mechanisms, and other incentive programs have significantly improved environmental quality. For example, Greenstone and Hanna (2014) suggest that strict monitoring and enforcement of regulations effectively reduce environmental pollution. Shapiro and Walker (2018) suggest that environmental regulations significantly reduced pollution from manufacturing industries between 1990 and 2008. Hu et al. (2022) show that the effects of policies on pollution reduction vary among cities and are affected by regional economic development. Liu et al. (2022) provide quantitative estimates of the influence of the Environmental Quality Incentives Program (EQIP), a voluntary conservation program on working agricultural land in the United States that provides cost-sharing contracts to improve environmental quality on agricultural lands. They find evidence that EQIP payments have improved some aspects of water quality, such as reduced biochemical oxygen demand and nitrogen, but have also increased total suspended solids, fecal coliform, and phosphorus.

We add to this strand of literature by studying the effectiveness of USDA Rural Utilities Service Water and Environmental Programs (WEP). Ours is the first paper to assess the effectiveness of the WEP program in reducing water pollution. We also improve the existing literature on environmental improvement by introducing the effect on business activity in welfare analysis. We use unique 12-digit hydrological unit code level data from 12 U.S. states of the Mississippi River Basin. We focus on nitrogen and phosphorus levels in surface water as our primary pollution outcome variables of interest. Our preliminary results show that increases in water pollution negatively affect establishment job creation and entry.

The remainder of this paper proceeds as follows. In the next section, we describe the water quality data. Section 3 describes the business outcome data and linking process. Section 4 introduces the rural development and environmental policy to support rural water treatment investment, the USDA Water and Environmental Program (WEP). Section 5 explains our empirical approach, section 6 presents preliminary results for the effect of water quality on business outcomes, and section 7 concludes.

2. Watershed Pollution Data

The primary data used for the paper include nitrogen, phosphorus, dissolved oxygen and fecal sediment water pollution level readings collected by monitoring stations within HUC12 watershed areas for the twelve states of the Mississippi watershed basin.[2] We use these data to explore water trends over time, and the effect of water quality on local business activity.

Water quality outcome data are sourced from the Water Quality Portal (WQP) of the National Water Quality Monitoring Council, a cooperative service that consolidates data from the US Geological Survey (USGS) National Water Information System (NWIS), Environmental Protection Agency (EPA) STOrage and RETrieval (STORET) Data Warehouse, USDA Research Service Sustaining The Earth's Watersheds-Agricultural Research Database System (STEWARDS), and hundreds of federal, state, local and tribal agencies and monitoring organizations. WQP

[2] The twelve states are Louisiana, Mississippi, Arkansas, Tennessee, Missouri, Illinois, Iowa, Wisconsin, Minnesota, Kentucky, Indiana, and Ohio.

monitoring station latitude and longitude location data were geocoded to HUC12 watersheds using ArcGIS software and USGS watershed shape files.

The data on nitrogen pollution levels are standardized and harmonized by Krasovich et al. (2022) into the Standardized Nitrogen and Phosphorus Dataset (SNAPD), where measurements (in mg/L) can be compared across time and space for the Mississippi/Atchafalaya River Basin. The SNAPD project solved issues of the comparability of water quality data from nonpoint source (NPS) water pollution monitoring, particularly challenging due to decentralized agricultural production across expansive land regions, the diffuse transport of contaminants into waterways, and the numerous authorities and institutions performing the monitoring. The data standardize the units of measurement (e.g., mg/L or ppm), the chemical form of the nutrient (e.g., nitrate or nitrogen), and sample fraction (e.g., filtered or unfiltered) variations in sample reporting.[3] Where standardization was not possible because the necessary information was not recoverable, observations were excluded from SNAPD such that the data are a subset of the available water quality data in the WQP.

Figure 1 shows the average nitrogen concentration levels for all watersheds in the 12 Mississippi River Water Basin states from 2001 to 2018. Nitrogen concentration varies by up to 30 percent in any given year, around the mean of 1.07 mg/L. The first decade of this millennial saw sustained water quality improvement for both nitrogen and phosphorus concentration through 2010. Nitrogen water quality had a couple of bad years, with a 2004 peak driven by watershed degradation in primarily Iowa and Illinois, and a 2007 peak driven by Illinois (McIsaac et al., 2016). After 2010, phosphorus concentrations were volatile, yet settling down after 2015. Nitrogen concentrations were reasonably steady from 2010 to 2015, at which point water quality began to degrade through 2018.

[3] See Krasovich et al. (2022) for details: https://www.nature.com/articles/s41597-022-01650-6

There are 10,196 HUC12 watersheds in our data covering the 12 states of the Mississippi River Water Basin. We explore water pollution outcomes before and after WEP investment for treated watersheds.

3. Job creation, job destruction and business establishment entry and exit

Much attention in the literature has focused on housing values and population benefits of water quality. In his paper we explore both the direct effects of pollution abatement policies on rural water quality, as well as the potential effects over time of water quality on business activity. Few prior studies focus on commercial activity. Ihlanfeldt and Taylor (2004) investigate the effect of hazardous waste sites on the market value of nearby commercial and industrial properties. Yu and Zhang (2023) explore the effects of the China Black-and-Smelly Water Program (BSWP) on business growth. Their paper differs from this one in two important dimensions. We focus on business outcomes in rural areas where their focus is for businesses in neighborhoods near treated waterways in the largest urban cities in China (e.g., Beijing, Shanghai). Second, the BSWP government program funded waterway, embankment and area revitalization improvement investments (recreation parks, etc.) where the estimated program effects are unable to disentangle these various mechanisms due to the available data.

Our business outcomes are measured using Dunn & Bradstreet (D&B) data as captured in the National Establishment Time-Series (NETS) dataset. These data include establishment level measures of employment, date the establishment opened, producing industry (North American Industry Classification System NAICS), and location. Latitude and longitude location data were geocoded to HUC12 watersheds using ArcGIS software and USGS watershed shape files.

The establishment entry rate is the count of establishments born within the watershed during the last year divided by the average of total establishments at t and t-1. The exit rate is defined similarly for exiting establishments. NETS data are near universe in coverage because most businesses are incented to register with D&B to receive a DUNS number in order to establish a business credit record and register a company profile in the D&B Business Directory. DUNS numbers are used by lenders, grant funders and potential business partners to determine the reliability and financial stability of companies. For example, U.S. federal contractors were required to supply a DUNS number when bidding or applying to do business with the federal government. In 2022 the U.S. General Services Administration (GSA) changed this, and DUNS numbers are no longer required in the U.S. government System for Award Management (SAM) and the Contractor Performance Assessment Reporting System (CPARS). However they are still required by many state and local governments, as well as the European Union. Most companies will register with D&B and request a DUNS number as part of establishing their business. As such, the NETS data capture entry quite comprehensively. D&B uses the data for it's business information products, and makes substantial investments into maintaining the accuracy and timeliness of the data. Many businesses also maintain a business profile with D&B, though not all, where we anticipate some measurement error exists in the employment dynamics metrics constructed for job creation and destruction used in this paper.

We define job creation as the difference in employment for growing establishments as a share in relation to the average establishment employment in the current and prior period (Davis, Haltiwanger and Schuh 1996). Averaging employment to calculate rates (Tornquist, Vartia and Vartia 1985) is particularly useful for measures of establishment entry and exit.

$$JC_{jt} = \sum_{i \in j,\ \Delta E > 0} E_{it} - E_{it-1}$$

For establishment *i* in location *j* and time *t*. Similarly, job destruction is

$$JD_{jt} = \sum_{i \in j,\ \Delta E < 0} E_{it-1} - E_{it}$$

The job creation rate for a location is job creation relative to location employment as calculated by the sum of average establishment employment over a consecutive two-year period[4]

[4] This approach is more flexible than simply using the average of location total employment across the two periods. These measures can accommodate changes in classification, for example establishments that move, or when using characteristic classes such as young vs. old where an establishment can cross a threshold from young to old over a two-year period.

$$JCR_{jt} = \frac{100\, JC_{jt}}{\sum_{i \in j} 0.5(E_{it} + E_{it-1})}$$

The measure is in percentage terms and ranges from zero to 200. The job destruction rate is

$$JDR_{jt} = \frac{100\, JD_{jt}}{\sum_{i \in j} 0.5(E_{it} + E_{it-1})}$$

We expect municipalities in recreation and retirement destination counties as defined by the USDA ERS County Typology Codes to benefit from local wastewater treatment investments and water quality improvements through increases in retail and service establishment sales, employment and new business entrants over time. Improved water treatment facilities may also improve the attraction of locations to potential business entrants in manufacturing and farming support, a relationship we will also explore.

4. USDA Rural Development Water and Environmental Programs (WEP)

The 1972 U.S. Clean Water Act (CWA) financed $650 billion in grants to municipal wastewater treatment plants, transitioning to a revolving loan program in 1987 with the Water Quality Act (WQA) and in 2014 the Water Infrastructure Finance and Innovation Act (WIFIA) provided broader eligibility criteria for water infrastructure credit programs. The CWA was one of the first modern U.S. environmental laws administered by the Environmental Protection Agency (EPA) and has been widely influential. Keiser and Shapiro (2019) investigate the effect of CWA grants to urban municipal wastewater treatment plants on water pollution concentrations and find each grant decreases the probability that downriver areas violate standards for being fishable by half a percentage point.

Less known than CWA and the focus of this paper are Water and Environmental Program (WEP) grants and loans administered by the USDA Rural Development (RD) agency’s Rural Utility Service (RUS). In a typical fiscal year, the USDA Rural Development (RD) agency provides about $1.5 billion in loans and grants for water and waste infrastructure projects to rural communities

(RD 2023). The paper explores the effect of the USDA Water and Waste Disposal Loan and Grant Program on water quality improvement as measured by using the dissolved oxygen content in water bodies and how water quality improvement impacts local rural business entry and employment growth. Between 2009 and 2016 RUS funded $13.9 billion for 5,825 projects for the construction of water and waste facilities in rural communities (RD 2017). Through WEP, rural communities with populations 10,000 or less obtain technical assistance and financing to develop drinking water and waste disposal systems. Our data include 15,425 funded WEP project investment locations across all fifty U.S. states from 2005 to 2019. Of these projects, 53% are for water treatment facilities, 35% for sewer system facilities, 5% a combination of water and sewer, 1% solid waste facilities, 0.5 percent storm drainage systems, and 5% other. We focus in this paper on the 5,344 sewer treatment projects and employ a triple-difference research design that compares water pollution before versus after WEP investments occurred, upstream versus downstream of recipient sewer treatment project, and against a comparison group of rural municipal water treatment facilities that do not receive WEP loans or grants.

Data for funded loans and grants are provided by the USDA Rural Development, and include information on the project, facility, loan obligation, grant obligation, other funding, total project cost, location, date construction began, and date construction completed. The data are linked to upstream and downstream water quality monitoring data sourced from the Water Quality Portal (WQP) of the National Water Quality Monitoring Council, a cooperative service that consolidates data from the US Geological Survey (USGS) National Water Information System (NWIS), Environmental Protection Agency (EPA) STOrage and RETrieval (STORET) Data Warehouse, USDA Research Service Sustaining The Earth's Watersheds-Agricultural Research Database System (STEWARDS), and hundreds of federal, state, local and tribal agencies and monitoring organizations.

We explore the impact of USDA WEP investments on wastewater treatment and quantify the magnitudes of water quality improvement as captured by WQP water monitoring station data. We will further link Dunn and Bradstreet National Establishment Time-Series (NETS) data on business establishment employment, sales and entry and exit dynamics to rural communities with WEP wastewater treatment improvement grants and loans to investigate the extent to which water infrastructure investments impact rural businesses.

Our plan is to geocode WEP investments to HUC12 watershed areas for analysis. We expect a HUC12 watershed to be a reasonably good geographic unit of analysis, however will experiment with this. WEP grants and loans are awarded for projects to rural areas with populations of 10,000 or less. As an example, USDA issued a press release in 2021 announcing "The village of Baldwin, Wis., is receiving a $14.5 million loan and a $3.6 million grant to replace its wastewater treatment plant, improving service for nearly 4,000 people."[5] As shown in Figure 2, Baldwin is the only municipality in the HUC12 watershed, however the rural geography of the watershed is larger than the village. As a side note, counties or HUC8 watersheds would be far too large a geographic unit for the analysis of this paper.

For this example watershed, there are twelve monitoring stations as shown in the figure on the right (two are on top of each other on the Rush River in the middle of the figure). We have precise latitude and longitudinal coordinates for water monitoring locations, WEP project locations, and NETS establishments. For many cases we can follow Kaiser and Shapiro (2018) to estimate upstream and downstream differences in water quality before and after project completion. However, for many rural areas sufficient monitoring does not always exist to support this empirical approach. As an alternative we will experiment with using rural place geographies as the unit of analysis, as well as generating spatial measures for incrementally increasing distances from treated waterways to analyze dissipation of effects on businesses.

5. Empirical Strategy

[5] https://www.usda.gov/media/press-releases/2021/10/14/biden-harris-administration-invests-272-million-improve-rural-water

We use a difference-in-differences model in a panel data setting to estimate the average treatment effect on the treated (ATET) of a binary WEP funded wastewater improvement project treatment on a continuous water pollution outcome. The linear model is given by

$$y_{ht} = \gamma_h + \gamma_t + X_{ht}\beta + D_{ht}\delta + \varepsilon_{ht} \quad (1)$$

where h denotes the HUC12 watershed and t is the year. y_{ht} is the outcome measured as nitrogen or phosphorus levels in mg/L. X_{ht} include watershed and economic covariates and controls. Monitoring stations are located within watersheds, and the WEP treatment occurs at a specific discharge point within the HUC12 watershed as captured by the indicator D_{ht}, where $D_{ht} = 1$ for all observations that are subject to the WEP treatment in watershed h at time t. We include HUC12 watershed fixed effects γ_h and year time effects γ_t. The HUC12 fixed effects accommodate unique time invariant features of the watershed location, in addition to differences in the mix of local farms and industrial activity in the immediate area.

Identification will come from the implementation of improvements to wastewater treatment facilities as a result of investment grants and loans to rural communities through the WEP program. These improvements result in a discrete change in the point sources of municipal wastewater discharges after the completion of construction, and are measured in readings from monitoring stations over time.

We further estimate the effect of water quality improvements on local business activity within the HUC12 watershed area as follows

$$y_{ht} = \gamma_h + \gamma_t + X_{ht}\beta + \varepsilon_{ht} \quad (2)$$

where as above h denotes the HUC12 watershed and t is the year. y_{ht} is the outcome measured as establishment entry, establishment exit, job creation, or job destruction. X_{ht} includes time varying watershed and economic conditions such as population, income and employment. X_{ht} also includes interaction terms for pre- and post-treatment years with water quality and other controls.

We are in the process of fully linking the WEP data to upstream and downstream water monitoring data, as well as experimenting with different control groups for comparison. We will perform parallel trend tests for pre-treatment periods, and granger causality tests to investigate the possibility of changes due to anticipation of treatment.

6. Results

The following results are presented for the relationship of business dynamism and water quality. These are suggestive correlations without yet including other location controls or the identification strategy as discussed above. We are currently working on these enhancements for the paper.[6] As discussed above, we geocoded both water monitoring locations and business establishment locations into HUC12 watershed geographies. The four tables that follow estimate equation (2) for all HUC12 watersheds in the 12 states of the Mississippi River Basin. Future versions of the paper will focus on WEP treated watersheds to better identify the effects of water treatment investments on water quality and local business responses.

We find declining water quality has a negative and significant effect on local entrepreneurship. In the OLS specification in column (1) of Table 1, a ten percent increase in nitrogen concentration is associated with a decrease in establishment entry of seven tenths of a percent. Column (3) includes watershed fixed effects to control for time invariant local features of the area and economy. The response remains negative and significant, though the magnitude as captured by year-to-year changes is smaller. Nevertheless, given the substantial fluctuations in water quality as discussed above, the business response can be meaningful. Like the results for nitrogen, in column (4) with watershed fixed effects a ten percent increase in phosphorus pollutants is correlated with a tenth of a percent decline in new establishment entry.

In Table 2, OLS results in column (1) show an increase in nitrogen concentrations reduces establishment exit. Note however that the response is approximately a half of that for entry.

[6] We were using an older version of the WEP program data with incomplete location data that made GIS geocoding of project locations into HUC12 watersheds difficult. The USDA Rural Development agency has kindly agreed to provide a new data file for the project which we will receive shortly.

Some degree of natural churn in business establishments is expected in the economy, sometimes associated with a process of creative destruction. Thus, on net though fewer establishments appear to exit, a greater number of potential entrants choose not to establish their business. Introducing fixed effects in column (3) for nitrogen and (4) for phosphorus, we see a positive relationship where year-to-year increases in pollution are associated with increased establishment exit. These specifications do not as yet control for other potential drivers of and shocks to entrepreneurship yet are suggestive of a connection between water quality and business activity.

OLS results for job creation in Table 3 column (1) for nitrogen pollutants and column (2) for phosphorus show expected negative correlations of water pollution and employment. The magnitudes are modest however, and the coefficients in the fixed effects specifications in columns (3) and (4) are insignificant.

In Table 4, paralleling the discussion above for entry and exit, the OLS results appear to show increases in water pollution dampen job loss, however the coefficients are smaller than for job gains where on net increased water pollution is correlated with softening employment. The coefficient for phosphorus pollutants in column (4) shows a small positive relationship for increased job destruction with declining water quality, though significant at only the 10% level.

7. Conclusions

This paper presented evidence of the effect of water quality on local business activity. Preliminary results indicated that increases in water pollution negatively affect job creation within businesses and entry of business in the local watershed area. These early results suggest that good water quality is consistent with rural development and job growth. We are unable to know if this relationship is causal without implementing our identification strategy. Though the fixed effects results control for differences in the time-invariant differences across locations, without including time-varying local controls, it is impossible to test the robustness of the results.

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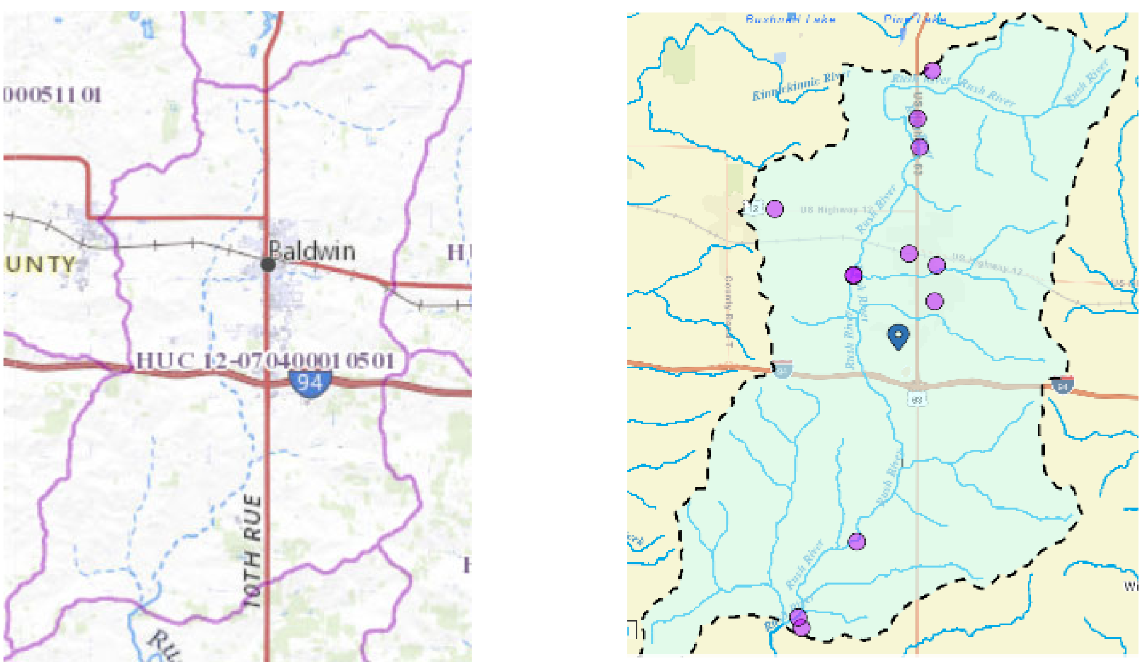
Figure 1: Nitrogen and phosphorus concentration by year

Figure 2: HUC12 Watershed 070400010501, including Baldwin, WI



Source: Left graph USGS National Map (https://apps.nationalmap.gov/viewer/)
Right graph EPA How's My Waterway (https://mywaterway.epa.gov/)

Table 1: Establishment Entry

Dependent variable: ln(establishment entry rate)	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Nitrogen concentration ln(mg/L)	-.0731*** (.0024)		-.0103** (.0034)	
Phosphorus concentration ln(mg/L)		-.0493*** (.0026)		-.0113** (.0038)
constant	2.08*** (.01)	1.96*** (.01)	2.07*** (.01)	2.05*** (.01)
watershed fixed effects	No	No	Yes	Yes
year effects	Yes	Yes	Yes	Yes
adjusted R2	.417	.406	.405	.404
N	45,963	40,558	45,963	40,558

Table 2: Establishment Exit

Dependent variable: ln(establishment exit rate)	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Nitrogen concentration ln(mg/L)	-.0295*** (.0025)		.0103** (.0038)	
Phosphorus concentration ln(mg/L)		-.0186*** (.0027)		.0178*** (.0042)
Constant	1.59*** (.012)	1.57*** (.015)	1.63*** (.01)	1.66*** (.02)
watershed fixed effects	No	No	Yes	Yes
year effects	Yes	Yes	Yes	Yes
adjusted R2	.539	.534	.484	.485
N	42,925	38,099	42,925	38,099

Table 3: Job Creation

Dependent variable: ln(job creation rate)	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Nitrogen concentration ln(mg/L)	-.0120***		-.00620	
	(.0021)		(.00330)	
Phosphorus concentration ln(mg/L)		-.0243***		-.00693
		(.0023)		(.00370)
Constant	4.65***	4.60***	4.66***	4.66***
	(.01)	(.01)	(.01)	(.01)
watershed fixed effects	No	No	Yes	Yes
year effects	Yes	Yes	Yes	Yes
adjusted R2	.111	.119	-.0821	-.0610
N	47,951	42,619	47,951	42,619

Table 4: Job Destruction

Dependent variable: ln(job destruction rate)	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Nitrogen concentration ln(mg/L)	-.00439*		-.000723	
	(.00222)		(.003529)	
Phosphorus concentration ln(mg/L)		-.00961***		.00913*
		(.00237)		(.00390)
constant	4.46***	4.44***	4.48***	4.51***
	(.01)	(.01)	(.01)	(.01)
watershed fixed effects	No	No	Yes	Yes
year effects	Yes	Yes	Yes	Yes
adjusted R2	.185	.191	-.00576	.00966
N	46,470	41,308	46,470	41,308