Nitrate water pollution, drinking water supply costs, and farming practices – An empirical assessment for Germany

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Water Pollution is a Global Topic

- Most serious problem in high income countries: nutrient water pollution (Craswell et al., 2021; European Commission, 2021)
- Wide ranging impacts on human health (Lundberg et al., 2004), biodiversity (Canfield et al., 2010), and climate (Galloway et al., 2003)
- Evidence of external costs remains very fragmented, incomplete, and mostly descriptive (Evans et al., 2019)

→ Dearth of economic research (Keiser and Shapiro, 2019)

Economic Consequences of Nitrate Groundwater Pollution

- Drinking Water Directive: restricts nitrate content to 50 mg/l (EU, 1998)
- Production processes vary in their functioning and effectiveness, resource and disposal requirements, as well as capital and operating costs (UBA, 2017)
- Measures to lower nitrate concentration (e.g. water blending) give rise to additional cost

Figure: Sonja Och / Greenpeace

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RQ: Does groundwater nitrate increase the cost of water supply?

Paper in a Nutshell

Research Question

Does groundwater nitrate increase the cost of water supply? Does organic farming lower nitrate groundwater pollution?

Data

Large panel data sets on German water companies and groundwater sampling stations (2008 to 2016)

Estimation Method

Empirical evidence is based on two-way fixed effects regressions.

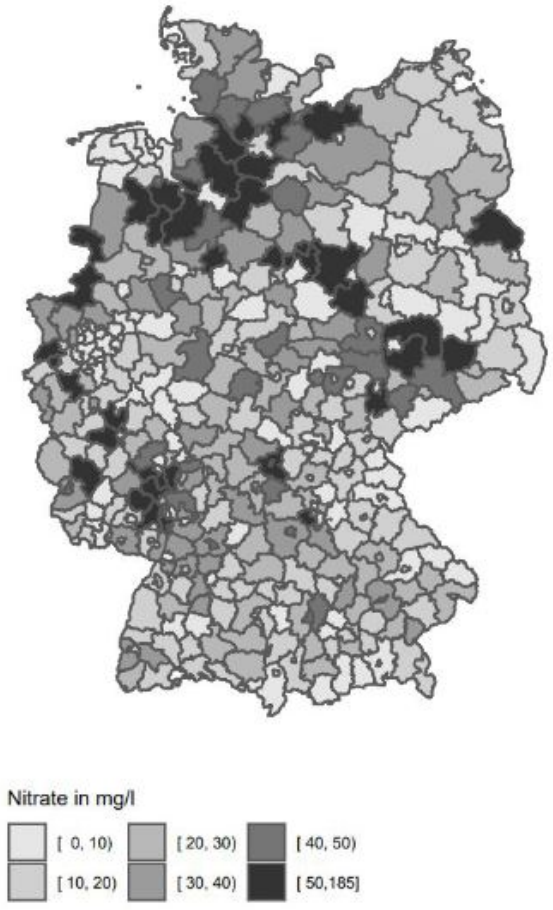
Results

- Water supply firms incur substantial cost through groundwater nitrate
- Increases in both treatment and total cost
- Organic farming is associated with significantly lower nitrate levels

Data

Data on groundwater nitrate levels (UBA)

- Monthly/annual values
- 1,350 groundwater sampling sites
- 2008-2016



Data on drinking water companies (Research Data Center)

Public water supply survey; 2007, 2010, 2013, 2016; and
AFiD-panel of energy and water supply companies; 2008-2016

- Company-level data on total costs and water treatment cost, as measured by expenditures for raw materials and supplies
- Physical labor input (number of hours worked)
- Expenses for labor, interest payments, and depreciation
- Physical components of their production processes, e.g. amount of distributed drinking water
- Plant-level volumes and sources of water extracted

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$\rightarrow$ We estimated nitrate levels at the plant's location using inverse distance weighting

Inverse distance weighted nitrate averages and hydrogeologically restricted values

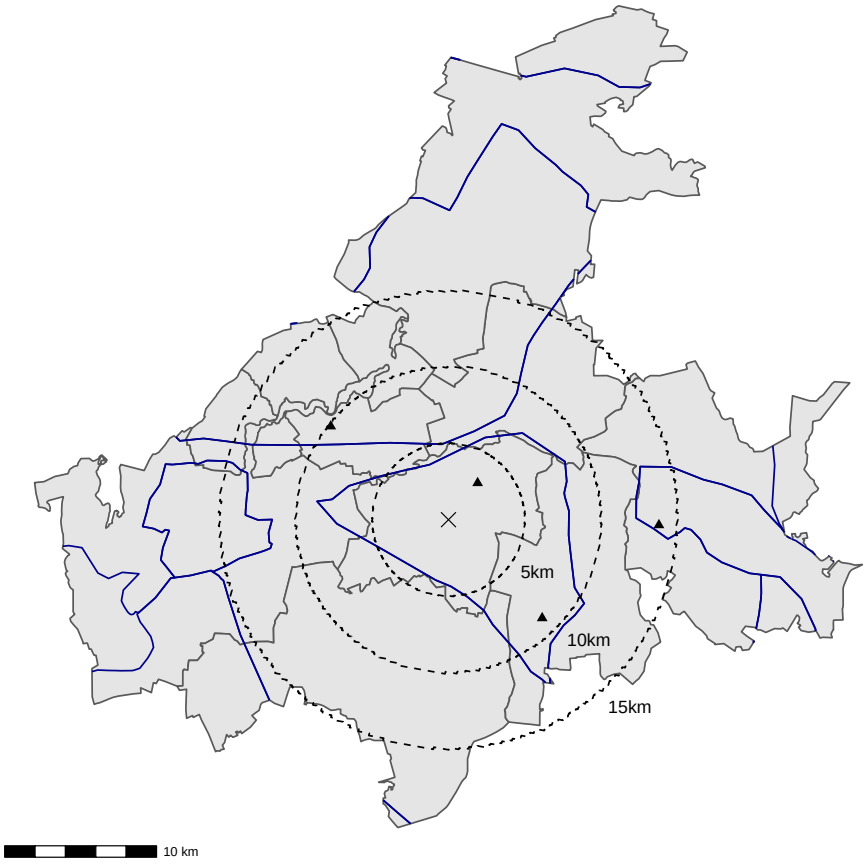

Figure: Visualization of approach to approximate nitrate concentrations at water abstraction plants

Data on weather (German Weather Agency)

- Weather measurements from 612 monitors (precipitation and temperature), 2008-2016

Data on settlement structure (Regional Statistics, Federal Agency of Cartography & Geodesy)

- Population size and administrative shapefiles on German municipalities

Empirical Strategy Ia

Effect of nitrate groundwater pollution on treatment costs

$$ln(C_{it}) = \alpha\ ln(N_{it}) + \beta\ ln(Q_{it}) + \delta\ ln(G_{it}) + \gamma' ln(W_{it}) + \mu_i + \theta_t + \epsilon_{it} \qquad (1)$$

- C_{it} = annual water treatment cost (in €)
- N_{it} = annual nitrate levels (averaged across all abstraction sites, in mg/l)
- Q_{it} = total volume of water abstracted (in m^3)
- G_{it} = share of groundwater abstraction (in %)
- W_{it} = weather variables
- μ_i / θ_t = station/year fixed effects

We estimate the two-way fixed effects model via OLS with standard errors clustered at the firm level.

Table: Regression results for treatment costs

DV: ln(Treatment cost)	(1)	(2)	(3)	(4)	(5)	(6)
ln(Nitrate)	0.046**	0.043**	0.043**	0.044**	0.044**	0.042**
	(0.019)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
ln(Water abstracted)		0.838*	0.807	0.732	0.716	0.777
		(0.488)	(0.496)	(0.482)	(0.483)	(0.500)
ln(Share groundwater)			0.150	0.152	0.154	0.144
			(0.096)	(0.096)	(0.095)	(0.098)
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Weather controls	No	No	No	Linear	Quadratic	Quintiles
Nobs	2754	2754	2754	2754	2754	2754
N	512	512	512	512	512	512
Adj.R2	0.890	0.891	0.891	0.891	0.891	0.891

Notes: This table depicts OLS estimates on the impact of groundwater nitrate on treatment costs of water suppliers. Nitrate is measured as a volume-weighted average of nitrate measurements within a four kilometer radius around the plant location. Standard errors are clustered at the firm level. Significance levels denoted by $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. *Source:* Research Data Center (RDC) and Research Data Center (RDC), own calculations.

Empirical Strategy Part Ib

Effect of nitrate groundwater pollution on firms' total cost

$$c(w, q) = \min \left[w'x : (q, x) \in T \right] \tag{2}$$

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$$ln(TC_{it}) = \beta_0 + \underbrace{\sum_{k=1}^{2} \beta_k ln(w_{kit})}_{\text{Input prices}} + \underbrace{\sum_{m=1}^{2} \phi_m ln(q_{mit})}_{\text{Outputs}} + \underbrace{\delta_1 ln(n_{it})}_{\text{Nitrate}} + \underbrace{\sum_{r=1}^{3} \delta_r ln(z_{rit})}_{\text{Control variables}} + \mu_i + \theta_t + \epsilon_{it}$$

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$$ln\frac{TC_{it}}{w_{1it}} = \beta_0 + \beta_k ln\frac{w_{2it}}{w_{1it}} + \sum_{m=1}^{2} \phi_m ln(q_{mit}) + \delta_1 ln(n_{it}) + \sum_{r=1}^{3} \delta_r ln(z_{rit}) + \mu_i + \theta_t + \epsilon_{it}$$

Estimation via OLS with standard errors clustered at the firm level.

Table: Regression results for total costs

DV: ln(Total cost)	(1)	(2)
ln(Nitrate)	0.019*	0.018*
	(0.010)	(0.010)
ln(Labor price)	0.733***	0.733***
	(0.143)	(0.143)
ln(Water delivered)	0.884***	0.840***
	(0.159)	(0.163)
ln(Population served)	0.187	0.236
	(0.147)	(0.157)
ln(Share groundwater)		0.040
		(0.061)
ln(Share residential)		−0.024
		(0.098)
ln(Population density)		−0.058
		(0.086)
Firm FEs	Yes	Yes
Year FEs	Yes	Yes
Nobs	1846	1846
N	342	342
Adj.R2	0.986	0.986

- 0.02 percent cost increase for each additional percent of groundwater nitrate (in mg/l)
- Average Firm (50.000 customers) → annual increase of 335.000 Euros

Conclusion

- Reducing nitrate water pollution pressing and high on the political agenda, Surprisingly little literature especially in comparison to air pollution
- This study provides sound empirical evidence on the costs and causes of nitrate water pollution
- Water supply firms incur additional costs due to groundwater nitrate pollution; potentially passed-through to consumers
- Findings imply that expanding organic farming activities could contribute to improving water quality

End

Thank you for your attention!

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