AGRICULTURAL LAND USE, LOCAL POLITICAL POWER, AND GROUNDWATER NITRATE CONTAMINATION IN GERMANY

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Abstract

In this article, we analyze whether agricultural land use increases groundwater nitrate contamination in Germany and whether local political power could reinforce this relationship. The theory motivating our analysis is based on farmers' disbelief in the effectiveness of formal rules, limited law enforcement in fertilizer application, and local political power. Taken together, these three aspects facilitate the formation of an informal code of conduct in the application of fertilizer that permits nitrate contamination. By using the average nitrate values for the period of 2012 to 2014 from 1213 groundwater measuring stations, we find that land used for agriculture has indeed a statistically significant and positive correlation with the measured nitrate values (mg/l). However, the analysis of these average values shows no conclusive evidence that nitrate contamination is reinforced by local political power. Our theory needs to be scrutinized by additional qualitative assessments and farm level data on nitrate surplus.

Keywords

Groundwater nitrate contamination, local political power, Germany

1 Introduction

The goal set by the EU-Water Framework Directive (2000/60/EC) to achieve a good qualitative and quantitative status of all water bodies within the EU in 2015 has failed. In Germany, the EU-Commission is currently threatening the country with a daily penalty of 858,000 Euro if the groundwater nitrate contamination is not reduced considerably (FRANKFURTER ALLGEMEINE ZEITUNG 2019; BUNDESMINISTERIUM FÜR ERNÄHRUNG UND LANDWIRTSCHAFT 2019). The European Union spends roughly €70 billion to €320 billion annually for the consequences of nitrogen pollution (SUTTON ET AL. 2011). Indeed, the results for the average nitrate values for the period of 2012 to 2014 show that roughly 18% of the measuring stations within Germany have nitrate concentrations above the threshold value of 50 mg/l; the highest nitrate levels are linked to agricultural land use (UMWELTBUNDESAMT 2017, P. 17).

To manage the use of fertilizer more sustainably through setting the right institutions has been a constant debate in the European Union and the United States alike (CENTNER 2004). A reaction to the recent nitrate scandal in Germany was the amendment of the Fertilizer Ordinance in 2017 to encourage farmers to employ good agricultural practices and to use manure more providently to protect the environment (BUNDESMINISTERIUM FÜR ERNÄHRUNG UND LANDWIRTSCHAFT 2019). However, a judgment of the European Court of Justice (ECJ) in 2018 states that Germany violated the Nitrates Directive because the country did not take any additional measures or increased existing measures to protect water from agricultural nitrates pollution. This has also led to an open debate about the topic between farmers and civil society; farmers claim less regulation and civil society demands more regulation in the application of organic and non-organic fertilizer.

The scope and regulation of agricultural nitrate pollution has also been a topic of constant debate in the socioeconomic literature. Already three decades ago, the term "economics of nitrate pollution" was coined (HANLEY 1990). While KANTER ET AL. (2019) suggest broader considerations of agricultural value chains beyond the farm to tackle nitrate pollution more

efficiently, MCGUIRE ET AL. (2013) focus on farmers' identities for better comprehension. ALMASRI (2007) suggest improved management frameworks to tackle nitrate contamination by applying multi-criteria decision analysis. TODERI ET AL. (2007) propose participatory approaches that go beyond the mere biophysical modelling to better understand the groundwater pollution issue and to provide local solutions. GASTEYER (2008) also finds that actor networks and coalitions determine water concerns. Beyond the socioeconomic literature, the issue of nitrogen flows is also a major topic in ecological modelling (see for example the articles published in the Special Issue from the 17th International Nitrogen Workshop in 2014).[1]

However, to the best of our knowledge, there are no comparable studies that have analyzed local informal institutions in the application of fertilizer. This article is a first attempt to close this research gap. We seek to better understand the relationships of groundwater nitrate contamination with agricultural land use and local political power. The theory motivating our analysis is linked to a sociopsychological mechanism that facilitates the formation of an informal code of conduct in the application of fertilizer that permits nitrate contamination. We focus on Germany because of the puzzle that the country has a modern and technologically advanced agricultural sector —which would normally allow efficient nitrogen fertilizer application—, but at the same time faces strong water pollution of its groundwater and surface water bodies. The data used for our study are the average nitrate values for the period of 2012 to 2014 from 1213 nitrate measuring stations provided by the Federal Ministry of the Environment (Umweltbundesamt) that are matched with the local policy variables.

The rest of the paper is organized as follows: Section 2 describes our theoretical considerations and hypotheses, section 3 the methodology and data, and section 4 discusses the major empirical findings. Finally, in section 5, we draw conclusions.

2 Theoretical considerations and hypotheses

For the following theoretical considerations, it is important to stress once more that nitrate pollution of ground and surface water is a huge problem in Germany, but that the impact of agriculture on groundwater and surface water contamination is still under debate given the different views of civil society and farmers.

We argue that farmers do not believe in the effectiveness of the formal rules of the nitrate and water directives to protect the environment in Germany; this is, for example, shown by mass protests of German farmers in January 2020 against the amendment of the fertilizer regulation.[2] This disbelief in the effectiveness of formal institutions that govern nitrate and water contamination could then lead to the formation of informal institutions at local level. A comprehensive definition of informal institutions is the one suggested by HELMKE AND LEVITSKY (2004, P. 727) who define informal institutions as "socially shared rules, usually unwritten, that are created, communicated, and enforced outside of officially sanctioned channels".

As informal institutions in the context of farmers disbelieving in the measures regulated by the nitrate and water directives, we understand an informal code of conduct in the application of organic and non-organic fertilizer. This code of conduct is linked to farmers' economic goals to maximize profits and to reduce manure storage costs; this prompts an unsustainable application of organic and non-organic fertilizer. Alongside the issue of disbelief, we further argue that there is a lack of enforcement of formal rules that can trigger noncompliant behaviors (see also HELMKE AND LEVITSKY 2004). In the case of nitrate water contamination, it is simply not possible to directly control the timing and frequency of fertilizer application of each individual farmer or contracted workers through formal institutions. Because of the disbelief in

[1] Special Issue from the 17th International Nitrogen Workshop, The Journal of Agricultural Science, Volume 152, Supplement S1, published in December 2014 by Cambridge University Press.

[2] https://www.faz.net/aktuell/politik/inland/wir-haben-es-satt-bauernproteste-in-berlin-16588502.html

the effectiveness of the nitrate and water directives combined with the enforcement problem, we further argue that farmers possibly tolerate excessive use of fertilizer, which then could become one behavioral element of their informal code of conduct and building block of their identity, which can be defined as low-conservationist (see STETS (2006) for an overview of identity theory and MCGUIRE ET AL. (2013) for a case-study of the shift from low-conservationist to conservationist identities among US Cornbelt farmers).

Even though farmers set up their informal institutions in the application of fertilizer, their noncompliance with official rules requires tolerance from civil society. The German nitrate scandal has generated resistance from civil society, such as the "Wir haben es satt" or in English "we are fed up" protests[3], and a movement from conventional to organic food consumption. The informal institutions of farmers' fertilizer application are, thus, highly scrutinized by civil society in Germany; however, we argue that in communities where local political power is exercised by farmers or by political parties who support low-conservationist ideologies, the informal institutions linked to the noncompliance with formal rules could be widely tolerated, thereby leading to increased contamination of ground and surface waters in the respective communities. Our first hypothesis follows from these considerations:

H1: The nitrate groundwater contamination is higher in communities governed by a mayor who is a conventional farmer than in communities without such a mayor.

The second hypothesis is linked to the power of local political parties. SCHAUB (2019) finds that there is an ideological division of political parties with respect to agricultural pollutants in Germany by analysing election manifestos published between 1998 and 2018. Specifically, he finds that officially the Greens and the Left parties largely support a shift to organic agricultural production to decrease contamination, while the Christian Democratic Union (CDU), the Free Liberal Party (FDP), and the Alternative for Germany (AfD) advocate a liberal agricultural sector without much regulation. This leads to the second hypothesis to be tested:

H2: The nitrate groundwater contamination is higher in communities governed by the CDU, the FDP, or the AfD, than in communities governed by the Greens or the Left.

3 Methodology and data

To test our hypotheses, we combine data on the average groundwater nitrate contamination (mg/l) with data on land use and political power. The methodology used is an ordinary least squares regression analysis. As follows, we describe first the empirical methodology and then the dataset as well as provide descriptive statistics.

3.1 Methodology

In the base model, we first analyze the effect of land use on the nitrate concentration in Germany's groundwater; then we gradually include the variables for measuring political power. The base model is specified as follows:

$$nitrate_i = \alpha + \beta_1 land\_use_i + \gamma_1 \mathbf{x}_i + \varepsilon_i \quad (1)$$

where $nitrate$ is a continuous variable that refers to the average nitrate concentration levels, measured in mg/l, of the 1213 measuring stations in Germany for the period from 2012 to 2014. The most crucial independent variable is $land\_use$; it includes eight land use categories: arable land, forest, residential area, grassland, wine growing area, horticulture and special crops, mixed land use, and other land use (base category). $\mathbf{x}$ is the vector of variables that control for regional characteristics, including federal states controls. ε_i is the disturbance.

To analyze the impact of political power in groundwater nitrate concentration, we include a dummy variable, $mayor\_farmer$, indicating if the profession of the mayor of the respective

[3] https://www.wir-haben-es-satt.de/

community, where the groundwater measuring station is located, is linked to agricultural activities or not:

$$nitrate_i = \alpha + \beta_1 land\_use_i + \rho_1 mayor\_farmer_i + \gamma_1 \mathbf{x}_i + \varepsilon_i \quad (2)$$

If ρ_1 is significantly different from zero and positive, *H1* cannot be rejected on statistical grounds. Additionally, we extend the model with a categorical variable of the party represented by the mayor, $party$, to test the hypothesis *H2*:

$$nitrate_i = \alpha + \beta_1 land\_use_i + \rho_1 mayor\_farmer_i + \rho_2 party_i + \gamma_1 \mathbf{x}_i + \varepsilon_i \ , \quad (3)$$

where ρ_2 is expected to be positive if it is either the CDU, the FDP, or the AfD or negative if it is either the Greens or the Left following the results from SCHAUB (2019).

3.2 Data

Dependent variable

We use the average groundwater nitrate values (mg/l) for the measuring period of 2012 to 2014 provided by the Federal Ministry of the Environment (Umweltbundesamt). In Germany, it is up to the federal states to monitor the groundwater status using their own measuring networks. For the regular reporting to the European Environment Agency (EUA) on the state of the groundwater, representative measuring points were selected by the federal states and combined into an EUA groundwater network. This measuring network comprises 1213 measuring stations through which all essential land uses are recorded.

Table 1 provides the descriptive statistics considering the 1213 groundwater measuring stations in Germany. The descriptive statistics show that the average nitrate value of the 1213 measuring stations is 28.8 mg/l with a standard deviation of 41.5. While the average value of 28.8 mg/l is within the permissible range of nitrate contamination, at roughly 18% of the measuring stations the nitrate values are above the permissible level of 50 mg/l leading to substantial groundwater contamination issues (Figure 1).

Explanatory variables

The categorical variable of land use consists of eight categories: 44.3% of the measuring stations are surrounded by arable land, 27.4% by forests, 7.4% by residential area, 10.8% by grassland, 0.3% by wine growing area, 0.7% by horticulture and special crops, 7.8% by mixed use, and 1.3% by other use (base category) (Table 1).

The variable of the mayor and the political parties were linked to the measuring stations through the coordinates of the measuring stations. First, the community was identified through its coordinates. Second, the mayor of the community and his/her profession as well as the party represented by the mayor were linked through an online search. A mayor with a profession associated with agricultural activities is considered as a "farmer" and a mayor with a profession linked to non-agricultural activities is considered as a "non-farmer". As not all mayors and political parties could be identified through the online search, the dataset is reduced to 891 and 1101 observations, respectively.

Altogether 4.2% of the measuring stations are located in a community where the mayor is a farmer. By applying a *ttest*, we do not find a statistically significant difference in the means of the nitrate values (mg/l) between communities where a farmer is a mayor or not. However, Figure 2a, which shows the difference in the distribution of nitrate values (mg/l), considering if the mayor is a farmer or not, shows extreme values of nitrate contamination higher than 250 mg/l in two communities where the mayor's profession is linked to agricultural activities.

The political parties represented in our sample are the Christian Democratic Union (CDU) and the Christian Social Union (CSU) with a combined portion of 60.3%, the Social Democratic Party (SPD) with a portion of 16.4%, the Alliance 90/The Greens (Greens) (base category) with a portion of 0.4%, the Free Democratic Party (FDP) with a portion of 0.2%, the Left with a

portion of 1.5%, and voter communities & others with a combined portion of 21.2%. There is no information on the Alternative for Germany (AfD) party; possibly because it was established only in 2013. Figure 2b shows the differences in the distribution of nitrate values (mg/l) considering the political parties. It is visible that in communities led by the Greens and the Left, there are much less nitrate values above the threshold of 50 mg/l, while all others overpass the threshold of 50 mg/l much more frequently.

We also include dummy variables of the federal states in the analysis to control for regional specific effects (Table 1). Other important determinants linked to nitrate contamination like livestock density, soil conditions and the distribution of biogas plants are not included in the analysis because of scaling issues.

4 Results and discussion

Table 2 shows the OLS results for four different model specifications. We find that agricultural land use is linked to higher levels of groundwater nitrate contamination in Germany. The findings are in line with the descriptive findings of the Federal Ministry of the Environment (Umweltbundesamt). To quantify the land use effect, different magnitudes are observed. The base category for land use is other land use; it implies that the land use effects are always compared to the base category in the following interpretations. If the measuring station is located on arable land, the nitrate value increases by approximately 31 to 38 mg/l depending on the model considered (columns 1 to 4). If the measuring station is located in a wine growing area, the nitrate value increases by approximately 35 to 40 mg/l. If the measuring station is located in an area of horticulture or where specialized crops are grown, the nitrate value even increases by approximately 64 to 72 mg/l. The areas without extensive agricultural activities, except for mixed land use, have almost no statistically significant relationship with nitrate groundwater contamination. This provides evidence that agricultural practices are linked to groundwater nitrate contamination in Germany. However, caution should be exercised in the interpretation of the results due to the ecological complexity of the water cycle. Effects on the nitrate concentrations in groundwater can be greatly delayed because the flow time from the soil surface through the water-unsaturated cover layers to the groundwater can often be years or even decades (UMWELTBUNDESAMT 2017).

To better understand local political power, we include a dummy variable indicating whether the mayor is a farmer or not into the regression (Table 2, column 2) and a categorical variable for the parties (the Greens are the base category) (Table 2, column 3) and also consider the combined effect of both variables (Table 2, column 4). In contrast to our theoretical expectations, the average effects are all statistically insignificant; therefore, we cannot provide conclusive evidence of the effect of local political power and cannot confirm our two hypotheses. However, as reported in the data section, the distribution of the nitrate levels shows that the extreme case with a nitrate value of 308 mg/l is in a community where the mayor is a farmer (Figure 2a) and the party represented by the mayor is the CDU/CSU; moreover, this measuring station is surrounded by arable land. To further support our argument, in communities led by the Greens the nitrate values are all below the official threshold of 50 mg/l providing some evidence (though statistically insignificant) of our theoretical considerations. While the average findings are statistically insignificant, the extreme cases could indicate a strong positive relationship between nitrate values and local political power. Our theory needs to be further scrutinized by additional qualitative assessments and farm level data on nitrate surplus.

5 Conclusions

We use data on average groundwater nitrate contamination (mg/l) for the measuring period of 2012 to 2014 provided by the Federal Ministry of the Environment (Umweltbundesamt) and

link them with an online search to the information of the mayors and their professions as well as the political parties. Our findings indeed show strong statistically significant and positive correlations between agricultural land use (compared to other land use) and groundwater nitrate contamination: for arable land an increase of roughly 31 mg/l, for wine growing areas an increase of roughly 36 mg/l, and for horticulture or where specialized crops are grown an increase of roughly 64 mg/l. However, on average we cannot find statistically significant evidence that nitrate contamination is reinforced by local political power in the communities considered. Nevertheless, the extreme value of nitrate contamination is in an area with arable land and where the mayors' profession is linked to agriculture and the party represented by the mayor is the CDU/CSU. Our findings, thus, provide some evidence that the effects of agricultural land use possibly reflect indirectly the underlying agricultural practices linked to farmers' disbelief in the effectiveness of formal rules and low-conservationist identities as well as limited law enforcement in fertilizer application. However, our theory needs to be scrutinized by additional qualitative assessments and farm level data on nitrate surplus given the limitations of the dataset used.

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Tables

Table 1: Descriptive Statistics

Variables in English	Variables in German	Definition	mean/sd
DEPENDENT VARIABLE			
Nitrate value (mg/l) 2012/2014	Nitratwert (mg/l)	Nitrate values (mg/l) measured by the Federal Environmental Agency (Umweltbundesamt) in Germany for the period of 2012-2014	28.772 (41.45)
Nitrate value (mg/l) 2008/2011	Nitratwert (mg/l)	Nitrate values (mg/l) measured by the Federal Environmental Agency (Umweltbundesamt) in Germany for the period of 2008-2011	29.325 (41.51)
EXPLANATORY VARIABLES			
Land use			
Arable land	Ackerland	1 if the measuring station is surrounded by arable land, 0 otherwise	0.443 (0.50)
Forest	Wald	1 if the measuring station is surrounded by forest, 0 otherwise	0.274 (0.45)
Residential area	Siedlung	1 if the measuring station is surrounded by residential area, 0 otherwise	0.074 (0.26)
Grassland	Grünland	1 if the measuring station is surrounded by grassland (including permanent and temporary grassland and meadows), 0 otherwise	0.108 (0.31)
Wine growing area	Weinanbau	1 if the measuring station is surrounded by wine growing area, 0 otherwise	0.003 (0.06)
Horticulture & special crops	Gartenbau & Sonderkulturen	1 if the measuring station is surrounded by horticulture and special crops production area, 0 otherwise	0.007 (0.08)
Mixed use	Gemischte Nutzung	1 if the measuring station is surrounded by mixed land use area, 0 otherwise	0.078 (0.27)
Other	Andere Nutzung	1 if the measuring station is surrounded by other land use, 0 otherwise	0.013 (0.11)
Political power			
Mayor farmer*	Bürgermeister Landwirt	1 if the measuring station is located in a community where the mayor is a farmer, 0 otherwise	0.042 (0.20)
Christian Democratic Union (CDU)** and the Christian Social Union (CSU)	Christlich Demokratische Union CDU und Christlich Soziale Union (CSU)	1 if the measuring station is located in a community where the CDU/CSU is the party represented by the mayor, 0 otherwise	0.603 (0.49)
Social Democratic Party (SPD)**	Sozialdemokratische Partei (SPD)	1 if the measuring station is located in a community where the SPD is the party represented by the mayor, 0 otherwise	0.164 (0.37)
Alliance 90/The Greens (Greens)**	Bündnis 90/Die Grünen (Grüne)	1 if the measuring station is located in a community where the SPD is the party represented by the mayor, 0 otherwise	0.004 (0.06)
Free Democratic Party (FDP)**	Freie Demokratische Partei (FDP)	1 if the measuring station is located in a community where the FDP is the party represented by the mayor, 0 otherwise	0.002 (0.04)
The Left**	Die Linke	1 if the measuring station is located in a community where the Left is the party represented by the mayor, 0 otherwise	0.015 (0.12)
Voter communities & others**	Wählergemeinschaft & andere	1 if the measuring station is located in a community where the FDP is the party represented by the mayor, 0 otherwise	0.212 (0.41)
Federal states			
Brandenburg	Brandenburg	1 if the measuring station is located in the federal state of Brandenburg, 0 otherwise	0.080 (0.27)
Berlin	Berlin	1 if the measuring station is located in the federal city state of Berlin, 0 otherwise	0.004 (0.06)
Baden-Württemberg	Baden-Württemberg	1 if the measuring station is located in the federal state of Baden-Württemberg, 0 otherwise	0.099 (0.30)
Bavaria	Bayern	1 if the measuring station is located in the federal state of Bavaria, 0 otherwise	0.195 (0.40)
Bremen	Bremen	1 if the measuring station is located in the federal city state of Bremen, 0 otherwise	0.002 (0.04)
Hesse	Hessen	1 if the measuring station is located in the federal state of Hesse, 0 otherwise	0.059 (0.23)
Hamburg	Hamburg	1 if the measuring station is located in the federal city state of Hamburg, 0 otherwise	0.002 (0.05)
Mecklenburg-Vorpommern	Mecklenburg-Vorpommern	1 if the measuring station is located in the federal state of Mecklenburg-Vorpommern, 0 otherwise	0.066 (0.25)
Lower Saxony	Niedersachsen	1 if the measuring station is located in the	0.137

		federal state of Lower Saxony, 0 otherwise	(0.34)
North Rhine-Westphalia	Nordrhein-Westfalen	1 if the measuring station is located in the federal state of North Rhine-Westphalia, 0 otherwise	0.095 (0.29)
Rhineland-Palatinate	Rheinland-Pfalz	1 if the measuring station is located in the federal state of Rhineland-Palatinate, 0 otherwise	0.056 (0.23)
Schleswig-Holstein	Schleswig-Holstein	1 if the measuring station is located in the federal state of Schleswig-Holstein, 0 otherwise	0.044 (0.20)
Saarland	Saarland	1 if the measuring station is located in the federal state of Saarland, 0 otherwise	0.007 (0.09)
Saxony	Sachsen	1 if the measuring station is located in the federal state of Saxony, 0 otherwise	0.052 (0.22)
Saxony-Anhalt	Sachsen-Anhalt	1 if the measuring station is located in the federal state of Saxony-Anhalt, 0 otherwise	0.058 (0.23)
Thuringia	Thüringen	1 if the measuring station is located in the federal state of Thuringia, 0 otherwise	0.045 (0.21)
N			1213

*The sample consists of 891 observations due to missing observations.

**The sample consists of 1101 observations due to missing observations.

Table 2. OLS regressions for nitrate groundwater contamination in Germany (2012-2014)

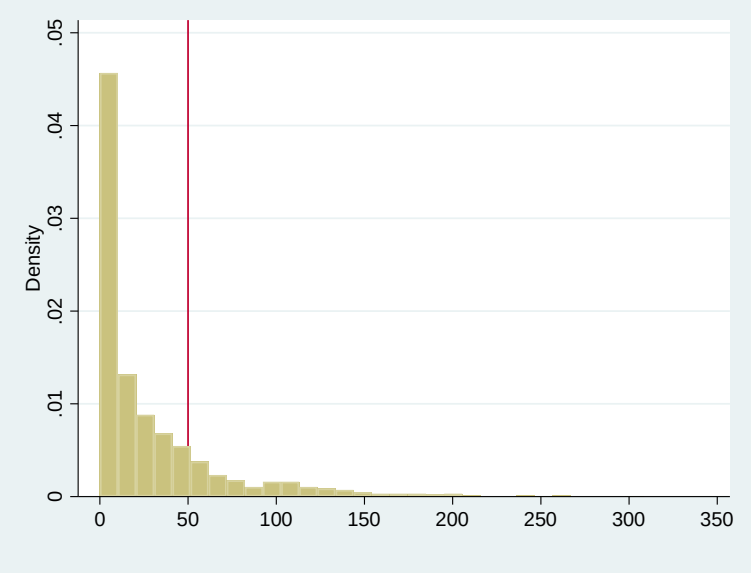
	Nitrate value (mg/l) (2012-2014)			
	(1) OLS	(2) OLS	(3) OLS	(4) OLS
Arable land	37.160***	35.901***	38.256***	31.325***
	(4.64)	(6.56)	(5.27)	(6.80)
Forest	2.678	1.956	3.260	-3.452
	(4.03)	(6.13)	(4.60)	(6.34)
Residential area	7.837*	6.534	9.377*	2.874
	(4.41)	(6.47)	(4.87)	(6.71)
Grassland	8.573*	8.725	8.782*	3.410
	(4.37)	(6.43)	(4.97)	(6.66)
Wine growing area	40.490***	38.492***	42.387***	35.868**
	(8.09)	(14.07)	(8.06)	(14.25)
Horticulture & special crops	64.740***	71.615***	63.777***	64.191***
	(18.02)	(23.33)	(18.02)	(23.60)
Mixed use	26.120***	30.374***	27.903***	26.362***
	(5.51)	(7.81)	(6.81)	(8.50)
Mayor farmer		-0.826		-0.678
		(10.02)		(10.30)
CDU/CSU			-3.111	-1.891
			(7.82)	(8.19)
SPD			-5.086	-1.010
			(8.12)	(8.53)
Greens			1.209	-2.245
			(12.18)	(14.30)
FDP			-4.059	-14.576
			(12.98)	(10.23)
Left			4.674	4.025
			(8.40)	(8.91)
Federal states	YES	YES	YES	YES
_cons	30.533	31.813	34.300	36.941
	(27.41)	(27.89)	(28.94)	(29.73)
N	1213	891	1101	828
R^2	0.189	0.205	0.201	0.213

Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.010. The reference category for land use is "other land use". The reference category for the political parties is The Greens. The federal state controls include 16 federal states; the reference category is Bremen.

Source: Authors' estimations.

Figures

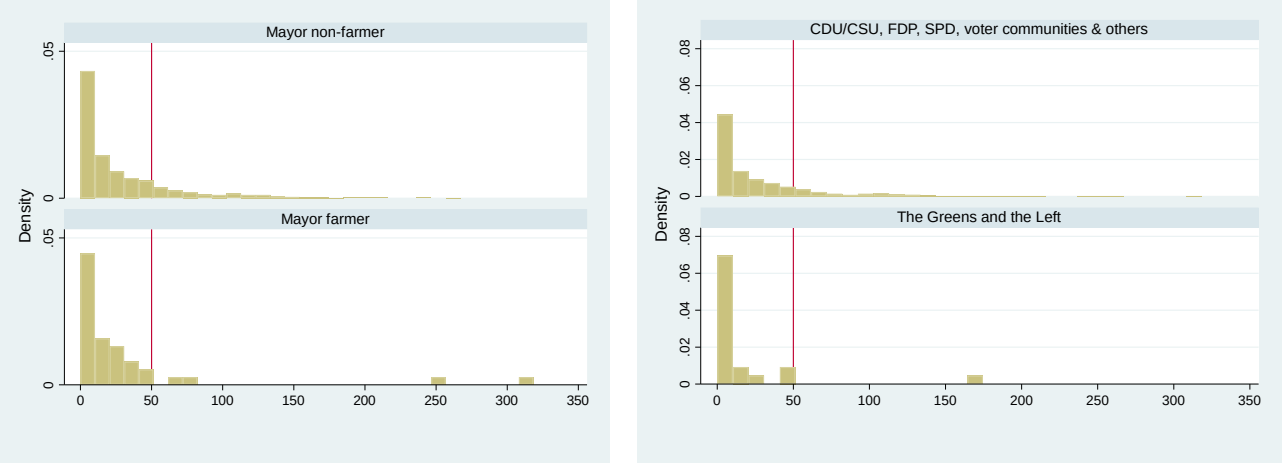
Figure 1: The distribution of average nitrate values (mg/l) for the period of 2012 to 2014



Note: The red line indicates the 50 mg/l legal threshold of nitrate concentration.

Source: Authors.

Figure 2: The distribution of average nitrate values (mg/l) for the period of 2012 to 2014 by profession and party



(a) (b)

Notes: The red line indicates the 50 mg/l legal threshold of nitrate concentration. CDU refers to the Christian Democratic Union (CDU), CSU to the Christian Social Union (CSU), SPD to the Social Democratic Party, and FDP to the Free Democratic Party.

Source: Authors.