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Exploring Citizens' Support for Policy Tools at the Food, Energy, Water Nexus

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The food, energy, and water (FEW) nexus is attracting the attention of scholars throughout the fields of engineering, biological sciences, and public policy, among others. However, one important piece missing from the research is an understanding of the types of FEW-related policies citizens support and the factors that drive public support for those policies. As reported in this article, data from a nationally representative survey of the adult U.S. population show that the public's support for different policy tools varies. To understand more about the public's preferences, we use a series of analytic techniques including factor analysis and factor score regressions to test possible explanations for these preferences. We find that citizens' knowledge about FEW nexus issues increases their support of policies for managing food, energy, water resources; broad concern for the environment also increases support. The public's preferences are also influenced by political ideology, political party identification, and education. These results contribute to an understanding of the public's potential willingness to embrace the role government can play in addressing FEW nexus issues. © 2017 American Institute of Chemical Engineers Environ Prog, 37: 148–154, 2018

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INTRODUCTION

The nexus of food, energy, and water (FEW) has begun attracting the attention of scholars throughout the fields of engineering, biological sciences, and public policy, among others. Rather than considering food, energy, and water as separate resources, a nexus approach considers them as interconnected resources. Across these various disciplines, scholars have started to develop strategies for tackling issues related to the FEW nexus. Research in areas such as environmental sensors and remote sensing, cyber infrastructure, and mathematical modeling have produced promising approaches for managing FEW resources in a more integrative way [1]. However, one important piece missing from this multi-disciplinary agenda is the development of an understanding of how public policies can be crafted to provide more efficient and equitable allocation of the FEW nexus resources. To remedy this deficiency, an important first step in democratic societies is identifying the types of policies citizens support and the factors that drive public preferences for those policies. After all, in democratic systems of government, citizen support is a force that greatly influences the formulation and adoption of public policies. The analyses presented here reveal the public's preferences for managing nexus resources.

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THE FOOD-ENERGY-WATER NEXUS

Historically, research has focused on the individual nodes in the nexus: food or energy or water. The movement away from the more traditional "silo" approach to natural resource use practices has been encouraged by organizations such as the United Nations and the World Economic Forum [2]. "The nexus approach requires that interrelating factors be brought together, those that previously had been considered separated, indeed even isolated" [3]. These are complex relationships. For example, consider the interaction of water with food and energy. "The availability of water dictates the viability of food resources and supports food production…-water is intricately intertwined with the production, transportation, and use of most forms of energy…" [4]. Adjusting one node in the nexus affects the other nodes; explicit and implicit tradeoffs are involved. Addressing these relationships as a nexus rather than as separate silos increases the likelihood that public policies will lead to more efficient and equitable allocation of resources.

PUBLIC OPINION AND POLICY PREFERENCES

Public opinion expresses attitudes which themselves are based on individuals' values and beliefs [5]. With respect to governing, these opinions often take the form of policy preferences, that is, views about the substance and design of statutes and regulations. A general consensus exists in the literature that public opinion has an impact on the formulation of public policy in the U.S., and that policymakers are relatively responsive to shifts in public opinion [6,7]. A meta-analysis of 30 studies appearing in leading scholarly publications between 1990 and 2000 demonstrated that public opinion influenced U.S. public policy in three-quarters of the studies, and even when controlling for the role of interest groups, political parties, and elites, the impact remained substantial [8]. However, research into policy preferences has been somewhat inconclusive when attempting to identify definitive explanations for the public's favorability toward certain policies. A person's general political knowledge and level of interest appear to have a significant impact on policy preferences, as do highly specific facts about particular policy issues [9]. People tend to be supportive of policies that comport with their conceptualization of the world around them. Well-informed citizens generally understand their policy preferences but "ignorance of policy-specific information leads many Americans to hold political views different from those they would hold otherwise" [9].

One of the compelling questions facing policymakers in the U.S. is how to design policy tools that reflect and maximize political support. There has been limited research on how preferences for different policy options such as economic or social regulation, market incentives, and tax expenditures are constructed and even less research on whether these preferences are constant across different policy areas [10]. As a consequence, the level of public favorability toward various policy tools that could be adopted to address the FEW nexus is unclear. Studies have shown that most Americans favor reforming food policy [11], that they are willing to consider alternative energy policy options [12,13], and that they are concerned about policies affecting water quality [14]. However, to address food, energy, and water resources more effectively, it is imperative that research on public preferences and the explanations for those preferences be conducted from a nexus perspective.

DATA AND METHODS

In August 2015, a survey of U.S. public opinion on the FEW nexus was conducted by a market research firm, GfK Group. The questions on the survey were developed in an iterative process by social scientists from disciplines such as political science, public administration, and sociology. After pilot testing the survey, GfK recruited participants from its panel member database (approximately 55,000 members over 18 years of age), which had been constructed through probability-based home address sampling. GfK's panel sampling frame represents approximately 97 percent of U.S. households. Panel members selected to participate accessed the survey online. From the 3,363 panelists selected by GfK, a total of 1,979 surveys were completed; a response rate of 58.8 percent. The 1,979 figure includes an oversampling of respondents in the state of Texas and the city of Houston, which we removed from our analysis for a net N of 1,463 (43.5% response rate). A review of the survey participants' average characteristics and attitudes with U.S. Census Bureau data shows that they are broadly representative of the U.S. adult population.

In developing an understanding of the public's support for food-energy-water policy tools, we provide both a descriptive and multivariate analysis. For the descriptive analysis we examine the overall support for various policy tool items and show how this support varies across each of the nexus nodes.

Our multivariate analysis involves two types of analyses: factor analysis and an ordinary least-square factor score regression. Four sets of factor analyses are examined, one for each of the nexus nodes and one for the nexus construct. Furthermore we conduct four ordinary least-square factor score regressions, again, one for each of the nexus nodes and one for the nexus construct. In the models the predicted factor scores are used as our dependent variables and we estimate models with the same set of independent variables across nexus nodes. These independent variables and controls include: knowledge scale, concern about the environment, concern about the relevant nexus node (food availability for the food model, energy supply for the energy model, water quality for the water model, and all three for the nexus model), political ideology, political party identification, age, age squared, sex, education, household income, race and ethnicity, and state controls.

DESCRIPTIVE ANALYSIS

Table 1 displays the overall support for each of the policy tools, by nexus node, while Figure 1 displays this information graphically. In our survey, respondents were asked the following question: "A number of policy options have been proposed to manage (food/energy/water) resources. Please indicate your level of opposition or support for each of the

Table 1. Support for tools.

Tool Type	Food Policy Options	% Support
Spending 1	Provide free space gardens	61%
Spending 2	Build food composting facilities	59%
Spending 3	Free space local farmers' markets	60%
Spending 4	Establish seeds banks biodiversity	52%
Tax Incentives	Tax incentives farmers pesticides	59%
Tax Incentives	Tax incentives farmers & food	64%
Regulate 1	Require farmers soil conservation	56%
Regulate 2	Limit land crops biofuel not food	40%
Fees	Charge impact fees land loss	41%
Fees	Charge fees restaurants waste	44%
Promote	Campaigns buy local grown food	60%
Plan	Nat'l plan preserve agriculture land	58%
Tool Type	**Energy Policy Options**	**% Support**
Spending 1	Build power plants	37%
Spending 2	Build pipelines other regions	42%
Spending 3	Charging stations elec vehicles	46%
Spending 4	Fed funding research renewables	53%
Tax Incentives	Tax incentives develop solar	61%
Tax Incentives	Tax cuts oil & gas exploration US	35%
Regulate 1	Relax environmental standards	48%
Regulate 2	New construction high energy efficiency	65%
Fees	Charge higher rates high demand	25%
Fees	Charge higher rates high volume	45%
Promote	Campaigns voluntary energy cons	54%
Plan	Nat'l plan energy state borders	43%
Tool Type	**Water Policy Options**	**% Support**
Spending 1	Build dams & reservoirs	45%
Spending 2	Build pipelines other regions	35%
Spending 3	Build desalination plants	54%
Spending 4	Buy farmers' water for cities	19%
Tax Incentives	Tax incentives water saving equipment	64%
Tax Incentives	Tax incentives irrigate agri	62%
Regulate 1	Low water landscaping	51%
Regulate 2	Lawn water reclaim/reuse	55%
Fees	Charge higher rates hot summer	18%
Fees	Charge higher rates high volume	50%
Promote	Campaigns voluntary water conservation	51%
Plan	Nat'l plan water state borders	36%

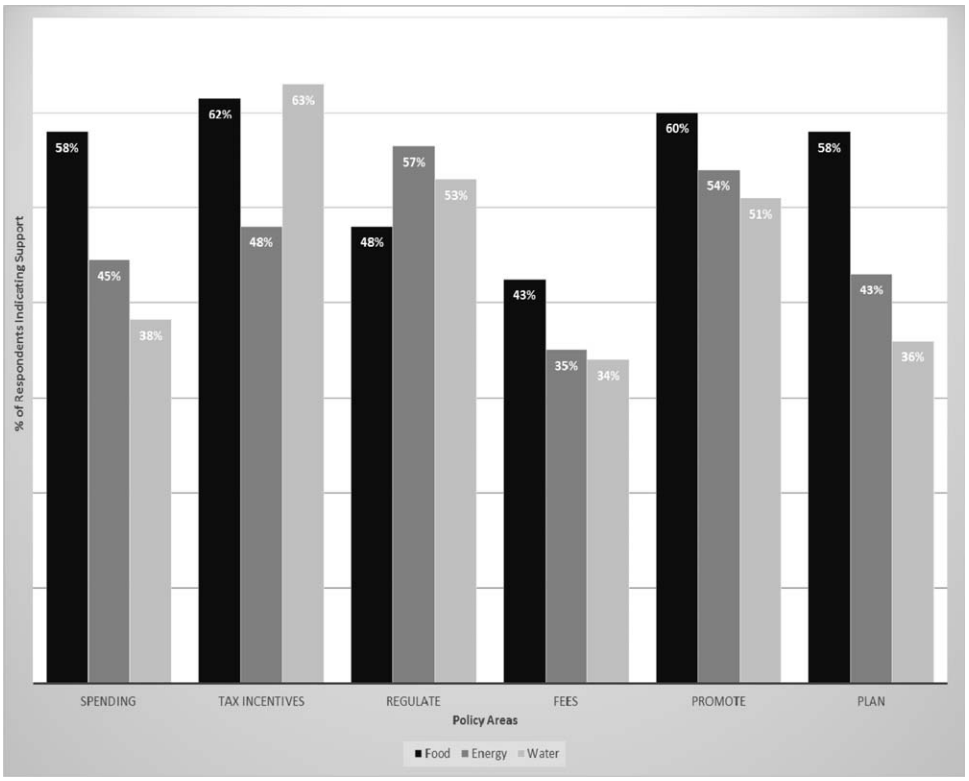

Figure 1. Support for policy tools.

following options." The levels of opposition or support included the following choices: (1) Strongly Oppose, (2) Oppose, (3) Neutral, (4) Support, and (5) Strongly Support. For this descriptive analysis of support, we combine the fourth (support) and fifth (strongly support) categories and calculate an overall level of support for each of 12 policy tools for each of the nexus nodes. To allow for comparisons within and across nexus nodes, we constructed similar questions that reflected different categories of tool types. For example, each node has four questions that relate to direct government spending, two questions about tax incentives, two questions about additional regulations, two questions about utilizing fees, one question on promoting issues associated with the nexus node, and one question about national plans for coordination. Although the policies themselves are specific to a given node, they represent the types of tools that are commonly available to governmental entities. Their use is not necessarily mutually exclusive; a government may choose to bundle an assortment of policy tools from several categories as it tries to design viable approaches.

Food policy tools receive the highest overall average level of support among the three issues areas at 55% support. The most highly supported food policy tool, at 64% support, is giving tax incentives for farmers to use more energy efficient methods of growing and transporting food. The least favored food policy tool is limiting the amount of land that can be used to grow crops for biofuels rather than food, with 40% support. The overall level of support for energy policy tools is less than that of food policy tools at 46% support. The most highly supported energy policy tool is requiring that new construction meets high energy efficiency standards (65% support). The least supported energy policy tools is charging higher energy rates during high demand times of day, which has 25% support. The overall level of support for water policy tools is similar to energy policy at 45% average support. The most highly favored water policy tool, with 64%, is giving tax incentives for the installation of water-saving equipment. The least supported water policy tool is charging higher water rates during the hottest part of the summer, at 18%; interestingly support for buying water from farmers to use in cities is similarly low with 19%. These two water policies garner the least support across all 36 policy tools.

These measures of public support are averaged across policy tool type and nexus nodes in Figure 1. This figure highlights the relatively higher support for food policy tools compared to energy and water. Across four of the six tool types the ordering of public support from greatest to least is food policies, followed by energy policies, followed by water policies. Figure 1 also highlights the differences in public opinion across the types of policy tool as well. For example, tax incentives have significantly higher public support across all three policy areas than the use of fees.

MULTIVARIATE ANALYSIS

Dependent Variables

Before constructing our dependent variables we conducted an exploratory factor analysis to determine how well related the items measuring the constructs of food, energy, water, and nexus policy tools are. In conducting factor analysis we use the principal-factor method to analyze the correlation matrix of items that constitute our factors.

Table 2 displays the results for the food policy items. In general this factor analysis lends strong support for the construction of a single food policy tools factor. The eigenvalue for the first factor is 5.82 with a large difference between the eigenvalue of factor 1 and factor 2. Additionally, the loadings of each of the food policy items are high, ranging from 0.45 to 0.77 and no items load significantly highly on other factors.

Table 2. Factor analysis for food policy factor.

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	5.81856	5.52585	1.0058	1.0058
Factor2	0.29272	0.11568	0.0506	1.0564
Variable		**Factor1**		**Uniqueness**
Item 1		0.7233		0.3847
Item 2		0.7361		0.4439
Item 3		0.7538		0.4227
Item 4		0.7308		0.4029
Item 5		0.7307		0.4392
Item 6		0.7196		0.4448
Item 7		0.4502		0.7337
Item 8		0.7761		0.3305
Item 9		0.7233		0.3707
Item 10		0.6935		0.4972
Item 11		0.6052		0.5651
Item 12		0.6513		0.5319

Table 3. Factor analysis for energy policy factor.

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.3925	1.7904	0.7296	0.7296
Factor2	1.60211	1.11733	0.3446	1.0742
Variable		**Factor1**		**Uniqueness**
Item 1		0.1263		0.68
Item 2		−0.0572		0.4734
Item 3		0.6352		0.563
Item 4		0.7135		0.4396
Item 5		0.6015		0.6018
Item 6		0.3340		0.5418
Item 7		0.7356		0.4274
Item 8		0.0226		0.5554
Item 9		0.6854		0.4981
Item 10		0.7540		0.4113
Item 11		0.3675		0.635
Item 12		0.5219		0.5507

Table 4. Factor analysis for water policy factor.

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.67044	3.12506	0.918	0.918
Factor2	0.54539	0.06243	0.1364	1.0544
Variable		**Factor1**		**Uniqueness**
Item 1		0.4098		0.6946
Item 2		0.4635		0.6196
Item 3		0.6383		0.5717
Item 4		0.7004		0.3941
Item 5		0.5721		0.5917
Item 6		0.6254		0.5314
Item 7		0.6460		0.5223
Item 8		0.6898		0.4088
Item 9		0.4963		0.6647
Item 10		0.2947		0.7981
Item 11		0.3607		0.6902
Item 12		0.5610		0.5503

The results of the energy policy tools factor analysis are shown in Table 3. In the case of energy policy tools the first factor has an eigenvalue of 3.39, slightly lower than the eigenvalue for food policy tools, but still a significant difference (1.79) exists between the eigenvalue of factor 1 and factor 2. The larger problem for this factor analysis is the relatively low loading of several items in the analysis. Despite these weak loadings, all of the items are retained for our initial construction of an energy policy tools factor to remain consistent across the nexus nodes on the number and types of policy tools. In Supporting Information Appendix A, we provide factor score regression results after removing the three items from the energy factor and the nexus factor that have low loadings.

The evidence for a water policy tool factor (Table 4) is similarly as strong as the food policy factor. The first factor has an eigenvalue of 3.67 with a difference between factor 1 and factor 2 of 3.13. The loadings of the items on factor 1 are quite high as well, averaging 0.538.

To determine whether an overall nexus policy tool factor could be created, we included all 36 policy tools in a factor analysis. The results provide strong evidence of the existence of an overall nexus policy tool factor (Table 5). The eigenvalue of factor 1 is 10.69 with a difference between factor 1 and factor 2 of 8.54. Interestingly, the average loading of factor 1 is 0.504 with only 5 of the 36 items loading at less than 0.3, with 3 of these 5 items being the same items that loaded weakly on the energy policy tool factor. Again, we retain all

Table 5. Factor Analysis for Nexus Policy Factor.

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	10.68527	8.54335	0.6296	0.6296
Factor2	2.14192	0.27828	0.1262	0.7559
Variable				**Factor1**
Item 1				0.2650
Item 2				0.3248
Item 3				0.5748
Item 4				0.6427
Item 5				0.5118
Item 6				0.5557
Item 7				0.5755
Item 8				0.6458
Item 9				0.3765
Item 10				0.1858
Item 11				0.2645
Item 12				0.4883
Item 13				0.0848
Item 14				−0.0278
Item 15				0.6170
Item 16				0.6675
Item 17				0.5648
Item 18				0.3120
Item 19				0.6830
Item 20				0.0176
Item 21				0.6110
Item 22				0.6534
Item 23				0.3092
Item 24				0.5156
Item 25				0.6315
Item 26				0.7069
Item 27				0.7076
Item 28				0.6703
Item 29				0.7129
Item 30				0.7105
Item 31				0.3627
Item 32				0.7428
Item 33				0.6357
Item 34				0.6537
Item 35				0.5465
Item 36				0.6390

Table 6. Descriptive statistics.

Variable	N	Mean	SD	Min	Max
Water Policy Factor	1383	−0.03	1.09	−4.78	3.16
Energy Policy Factor	1385	−0.03	1.1	−3.96	2.56
Food Policy Factor	1378	−0.02	1.05	−4.12	2.22
Nexus Policy Factor	1329	−0.03	1.03	−4.62	2.69
Knowledge Scale	1463	58.83	22.11	0	100
General Concern: The Environment	1446	6.56	2.78	0	10
General Concern: Water Quality	1448	6.77	2.82	0	10
General Concern: Energy Supply	1445	6.2	2.79	0	10
General Concern: Food Availability	1448	5.75	3.05	0	10
Political Ideology: Liberal	1410	3.78	1.54	1	7
Political Party Affiliation: Democrat	1454	4.22	2.06	1	7
Age	1463	46.98	17.55	18	93
Male	1463	0.48	0.5	0	1
Education (Highest Degree Received)	1463	10.08	2.17	1	14
Household Income	1463	11.94	4.55	1	19
White, Non-Hispanic	1463	0.65	0.48	0	1
Black, Non-Hispanic	1463	0.12	0.32	0	1
Other, Non-Hispanic	1463	0.06	0.25	0	1
Hispanic	1463	0.15	0.36	0	1
2+ Races, Non-Hispanic	1463	0.01	0.11	0	1

Note: Weights used.

of the items for a single nexus factor as the eigenvalue is quite high, the difference between factor 1 and factor 2 is large, and the average loading is sufficiently high, but, we also conduct a second factor analysis removing these low loading items and construct an additional factor score as a robustness check.

Independent Variables

In constructing our factor score regression models, five independent variables are of primary interest: a respondent's knowledge, concern for the environment, and specific concern for food, energy, and water. The knowledge scale measures the percentage of technical knowledge questions about nexus issues a respondent accurately answered in a true or false framework. The scale has six items which can be examined in Supporting Information Appendix B. The average score on the knowledge scale is 58.8% correct with a range of 0–100 and a standard deviation of 22.11 (Table 6).

We also include a general concern about the environment and a specific concern about relevant node for each model. For example, in our food policy tools model we include both a question about the respondent's general concern about the environment and a question about the respondent's level of concern about food availability, whereas the energy policy tools model contains the general concern item and a measure of the respondent's concern about energy supply.

The models also contain a host of variables relevant to research on public opinion including political ideology, political party affiliation, age, sex, education (measured in highest degree received), household income (measured in levels), race/ethnicity, and state dummy variables to control for state-specific characteristics.

FACTOR SCORE REGRESSION RESULTS

We estimate four models for our main results and display the results in Table 7.[1] Each model uses our set of independent variables to predict overall support for either a specific nexus node or the overall nexus factor. As discussed above, in each of these models our dependent variable is a factor score.

[1]For robustness, in Supporting Information Appendix C, we also include results in which we calculate the dependent variables as simple summative indices.

Food

In this model, both the knowledge scale and general concern about the environment variables are positive and significant at the $P < 0.01$ level. This suggests that individuals who have more technical knowledge about nexus issues are, in general, more supportive of public policy tools for addressing issues in the domain of food. Furthermore, respondents reporting more concern about the environment are also more likely to report greater support for food policy tools. Partisanship matters as well with Democrats more likely to support food policy tools ($P < 0.01$). Political ideology is marginally statistically significant at the $P < 0.10$ level, and suggests that the more liberal a person is, the more likely he or she is to be supportive. Additionally, higher levels of education are also related to higher levels of support for food policy tools.

Energy

For the energy policy tools model, we also find that the knowledge scale and general concern about the environment are positive and significant at the $P < 0.01$ level. Individuals who have more technical knowledge about nexus issues are, in general, more supportive of an array of public policy tools for addressing energy resource issues. Furthermore, individuals who report that they are more concerned about the environment are also more likely to report more support of energy policy tools. In this model, ideology and political party identification are both significant at the $P < 0.01$ level and suggest that the more liberal individuals are and the more they identify with the Democratic party, the more likely they are to support energy policy tools. The relationship with age and energy policy tools is marginally significant and nonlinear. Furthermore, being a male ($P < 0.01$), having more education ($P < 0.01$), having a larger household income ($P < 0.05$), and being white ($P < 0.10$) are all related to higher levels of support.

Table 7. Support for policy tools by nexus node, factor score.

	Food	Energy	Water	Nexus
	b/se	b/se	b/se	b/se
Knowledge Scale %	0.0038***	0.0043***	0.0031**	0.0039***
	(0.0014)	(0.0013)	(0.0013)	(0.0013)
General Concern: The Environment	0.14***	0.16***	0.095***	0.15***
	(0.016)	(0.017)	(0.021)	(0.016)
General Concern: Food Availability	−0.0045			−0.015
	(0.014)			(0.013)
General Concern: Energy Supply		−0.021		−0.023
		(0.015)		(0.016)
General Concern: Water Quality			0.038**	0.036**
			(0.019)	(0.017)
Liberal	0.043*	0.12***	0.067***	0.075***
	(0.026)	(0.024)	(0.026)	(0.023)
Democrat	0.055***	0.068***	0.037*	0.059***
	(0.019)	(0.017)	(0.020)	(0.016)
Age	−0.0074	−0.013	−0.018**	−0.014*
	(0.0091)	(0.0083)	(0.0090)	(0.0084)
Age*Age	0.00011	0.00018**	0.00024***	0.00019**
	(0.000089)	(0.000079)	(0.000089)	(0.000081)
Male	−0.023	0.19***	0.13**	0.076
	(0.058)	(0.053)	(0.060)	(0.054)
Education (Highest Degree Received)	0.039**	0.058***	0.076***	0.056***
	(0.018)	(0.015)	(0.016)	(0.016)
Household Income	−0.0042	0.014**	0.015*	0.0041
	(0.0073)	(0.0069)	(0.0075)	(0.0068)
White	0.11	0.27*	0.21	0.17
	(0.15)	(0.15)	(0.18)	(0.15)
Black	−0.017	−0.032	−0.032	−0.042
	(0.19)	(0.17)	(0.20)	(0.17)
Other	−0.0026	−0.0063	−0.19	−0.026
	(0.19)	(0.20)	(0.24)	(0.19)
Hispanic	−0.13	0.014	0.17	−0.019
	(0.18)	(0.17)	(0.20)	(0.17)
2+ Races	0	0	0	0
	(.)	(.)	(.)	(.)
Constant	−0.76	−1.80***	−2.33***	−1.55***
	(0.51)	(0.38)	(0.60)	(0.43)
R-squared	0.2547	0.3401	0.2407	0.3384
Number of Observations	1341	1352	1344	1291

Note: Significance Levels: *$P<0.10$ ** $P<0.05$ *** $P<0.01$, population weights used, controls for states.

Water

In the water policy tools model, the knowledge scale is positive and significant at the $P<0.05$ level and general concern about the environment is positive and significant at the $P<0.01$ level. These two findings mirror those from the preceding two models. In the water policy model, a respondent's concern with water quality is also positive and significant at the $P<0.01$ level. Political ideology is statistically significant at the $P<0.01$ level in the direction of more liberal leaning being related to more support for water policy tools. Party identification is marginally significant at the $P<0.10$ level. Age is significant at the $P<0.05$ level and nonlinear. Here again, being male ($P<0.05$), having higher levels of education ($P<0.01$), and higher levels of household income ($P<0.10$) are all associated with higher levels of support for water policy tools.

Nexus

For our Nexus policy tools model, both the knowledge scale and general concern for the environment are positive and significant at the $P<0.01$ level. Respondents who have more technical knowledge about nexus issues are, in general, more supportive of a range of public policy tools for addressing various nexus-related issues. Furthermore, individuals who report greater concern about the environment tend to report more support of policy tools for addressing nexus issues. The respondent's concern about water quality is also statistically significant at the $P<0.05$ level. Political ideology (more liberal) and political party identification (Democratic Party) are significantly related to more support for nexus policy tools. Age is marginally significant and nonlinear, and the level of education is positively related to nexus policy tools and significant at the $P<0.01$ level.

CONCLUSION

The food, energy, water (FEW) nexus has begun drawing more attention from a wide array of scholars. However, in a democratic society, one critical piece of managing these resources in a more efficient and equitable manner is an understanding of both the public's general support for nexus policy tools and the variables that drive that support. We

contribute to this understanding by examining the level of support for and predictors of citizens' support for 36 policy tools, 12 comparable tools for each of the nexus nodes.

Citizens express the highest levels of support for food policy and essentially indistinguishable overall preferences for water and energy policy tools, on average. Importantly, specific, technical knowledge about the FEW nexus and general concern about the environment are related to higher levels of support for policy tools in all of our models. These results suggest two specific takeaways: (1) There is broad support for a number of policy tools across these nodes that can aid in the more efficient and equitable management of food, energy, and water resources, and, (2) Policymakers and scientists can garner additional support for these policies by more effectively communicating relevant technical facts about the FEW nexus and by highlighting the far-reaching impact these issues have on the environment.

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