The Impact of Demographics on Energy Consumption and Renewable Energy Adoption in the United States

Introduction

In developed democracies, ideally individual preferences influence energy policy making because people elect representatives that they feel best embodies and aligns with their beliefs and value systems. Therefore, the demographic composition in a geographic plays a crucial role in explaining disparities in energy systems (Chapman et al., 2021). In addition, certain determinants of consumers affects the level of awareness and acceptance regarding different energy sources (Sardianou and Genoudi, 2013; de Sena, Ferreira, and Braga, 2016). This implicitly determines energy policy because of the importance, or potential irreverence, surrounding this issue incites the level of pro-activeness that constituents wield on their elected officials who can enact new policies. Thus the cultural preferences within society can have important effects on the levels of renewable energy adoption or fossil fuel consumption. I attempt to investigate this phenomenon by examining demographic data from the United States in conjunction with data regarding energy source consumption by state. The policy implications arising from this analysis are crucial for the development of energy policies that are widely accepted and embraced across various population segments. Ensuring equitable and inclusive energy policy is paramount for meeting climate targets that benefit the majority of society.

This text is structured as follows. I begin by motivating my analysis by briefly examining the current literature concerning the effect of social demographics on energy policy adoption. Subsequently, I describe the data utilized for analysis. I follow that with exploratory analysis and discussion of the results. Finally, I conclude with policy implications and recommendations.

Literature Review

There are several causes differing levels of energy structures. There is a large area of literature that aims to explain this by determining consumers' levels of awareness and and willingness to adopt progressive energy structures that rely on renewable energy. Awareness is the first step to widespread adoption because it permeates into the norms and belief systems within society (Claudy et al., 2010; Nyrud, Roos, and Sande, 2008). The existent literature has cited that specifically variations in income, age, age squared, gender, education levels, employment, household size, and income among other factors influences differences in preferences and awareness about different energy sources (Ayodele et al., 2021; Claudy et al., 2010; Kowalska-Pyzalska, 2018; Liu, Wang, and Mol, 2013; Sardianou and Genoudi, 2013; de Sena, Ferreira, and Braga, 2016). Although these authors make significant contributions to the literature, it is important to note that most of these studies are concerned with variation in preferences on an individual level, failing to consider other factors such as population density or availability of specific energy sources (Alipour et al., 2020).

Data

The forthcoming analysis contains two forms of data: data collected from an HTML and a dataset. I collect the data on energy source consumption using web scraping techniques and download demographic data from the U.S. Census Bureau. I web scrape data available in HTML form from the United States Energy Information Administration (EIA). The EIA is a federal agency that is within the U.S. Department of Energy Specifically, I use data available within their State Energy Data System. I web scrape two data found on two separate HTMLs. The first HTML contains information on primary energy consumption estimates by source (in trillions of British thermal units) in 2021 while the second HTML displays total energy consumption estimates, real gross domestic product (GDP), and energy consumption estimates per real dollar of GDP respectively for 2021. This provides me data on state level consumption of coal, natural gas, petroleum, nuclear, and total renewable energy consumed (U.S. Energy Information Administration, 2021). The energy data is state based (including the District of Columbia), indicating rankings and corresponding consumption levels for each energy source.

I merge the energy source consumption data with demographic data from the American Community Survey (ACS) 1 Year Estimates: Selected Population Profiles survey table data. This data sheds light on broad social, economic, and housing profiles for different subgroups presented as population counts and percentages (U.S. Census Bureau, 2021). I use data available on gender, the unemployment rate, median age, percentage of civilian population employed in natural resources, construction, and maintenance occupations, median household income that is inflation adjusted to 2021 dollars, educational attainment at the high school level or higher, and average household size. Although the figures are estimates, they are based on a survey sample and the margins of error reported are relatively low.

Results

I initially plot maps to see which states are leaders in consumption with respect to each energy source. Figure 3 gives an indication of regional variations in energy source consumption in addition to states with highest and lowest Texas appears to be a leader in energy consumption of of all sources of energy. This is most likely attributed to the fact that it has the second highest GDP of any state. In fact these two measures are highly correlated because energy is an input in many production processes, however as GDP increases and technology improves there may be a decrease in energy consumed without a reduction in GDP (Soytas and Sari, 2003). It is particularly interesting that the consumption patterns for most states are similar for all energy sources. Additionally, these maps indicate that there is less of a decline in renewable consumption along the entirety of the ranking indicating there may be already a concerted effort from states to alter their consumption habits.

In order to analyse the relationship between demographic characteristics and consumption of varying energy types I run an Ordinary Least Squares regression to determine if there are significant relationships between the categorical variables and each energy type. I include controls for GDP and Energy Intensity which measures the energy in-

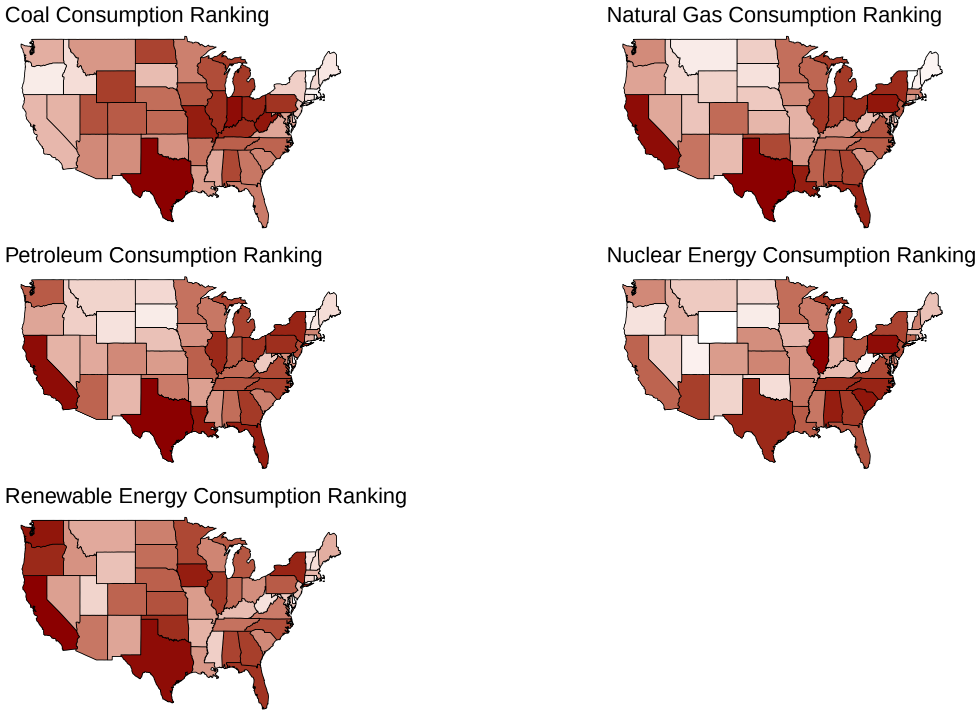

Figure 1: State Level Ranking of Energy Source Consumption within the United States

efficiency of an economy. It is important to note that no tests have been conducted to determine that the underlying OLS assumptions hold, thus these results cannot be interpreted as causal, rather suggestive of the associations between each independent variable and a specific energy type holding all else constant. Equation (1) shows the full model of explanatory variables chosen based off of the literature. I have do not include additional variables because of the limited number of observations in my data ($N = 51$). Thus, I choose the variables most commonly cited as determinants in variation of energy source consumption to avoid overfitting the model to noise in the data, which compromises the generalizability of the associations found (Babyak, 2004). Furthermore, I perform a log transformation on the dependent variables, adding a small constant to avoid issues with undefined values. This approach is particularly relevant as many of the variables exhibit right-tailed distributions, likely due to the fact that several states do not utilize specific types of energy.

$$
\begin{aligned}
\text{EnergyType} = \beta_0 + \beta_1 \times \text{Female} + \beta_2 \times \text{Unemployment} \\
+\beta_3 \times \text{Natural Resource} + \beta_4 \times \text{Age} \\
+\beta_5 \times \text{Age}^2 + \beta_6 \times \text{Household Income} \\
+\beta_7 \times \text{High School Degree} + \beta_8 \times \text{Log GDP} \\
+\beta_9 \times \text{Log Energy Consumption} + \varepsilon
\end{aligned} \tag{1}
$$

Table 2 shows the results of the linear model. The controls of GDP and energy intensity (energy inefficiency) are significant for all energy types with the exception of energy intensity for nuclear. This is most likely explained by the efficiency of nuclear energy (Brook et al., 2014). Beginning with coal, only median household income, and log energy intensity are significant at conventional levels. There is an inverse relationship between median household income and coal consumption, perhaps due to the fact that states with wealthier residents can afford to rely on more expensive technologies that rely on renewables. The only variable of significance for nuclear energy consumption is GDP. In terms of renewables, female is significant however this contradicts the literature that females have a higher affinity towards renewables (Ayodele et al., 2021). A higher share of workers in natural resource oriented occupations increase renewables. Again median household income seems to decrease renewable energy consumption which may be due to asset rich retirees (Islam and Meade, 2013), and is also found to have an adverse correlation with renewables by Alipour et al. (2020). Petroleum use is significantly correlated with average household size and the share of population working in natural resources, both of which are positive. Finally, natural gas is negatively correlated with the linear component of age however positively with the quadratic age term indicating that the initial decrease in consumption with increasing age starts to reverse. In addition, having educational attainment of a high school degree or more and average age both seem to have negative impacts on natural gas consumption.

	Coal	Nuclear	Renewable	Petroleum	Natural Gas
Intercept	-15.90	-201.23^{*}	-2.53	-9.96	78.58^{**}
	(56.05)	(110.52)	(20.49)	(6.37)	(30.89)
Female	-0.75	1.45	-0.32^{*}	0.03	-0.27
	(0.48)	(0.95)	(0.18)	(0.05)	(0.27)
Unemployment Rate	-0.42	-0.68	-0.18	0.05	-0.17
	(0.35)	(0.69)	(0.13)	(0.04)	(0.19)
NR, Construction, Maintenance Occupations	-0.42	-0.28	0.35^{***}	0.07^{**}	-0.09
	(0.30)	(0.59)	(0.11)	(0.03)	(0.17)
Median Age	1.59	4.51	0.99	0.06	-1.90^{*}
	(1.95)	(3.84)	(0.71)	(0.22)	(1.07)
Median Age^2	-0.02	-0.05	-0.01	0.00	0.02^{*}
	(0.03)	(0.05)	(0.01)	(0.00)	(0.01)
Median Household Income	-0.00^{***}	0.00	-0.00^{*}	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High School Degree or Higher	0.23	0.14	0.02	0.01	-0.25^{**}
	(0.19)	(0.37)	(0.07)	(0.02)	(0.10)
Average Household Size	2.96	3.42	-0.75	1.14^{***}	-3.78^{***}
	(1.98)	(3.90)	(0.72)	(0.22)	(1.09)
Log Real GDP	1.47^{***}	2.55^{***}	1.05^{***}	0.98^{***}	1.27^{***}
	(0.28)	(0.56)	(0.10)	(0.03)	(0.16)
Log Energy Consumption per GDP	2.36^{**}	2.84	-0.61^{*}	0.97^{***}	1.75^{***}
	(0.94)	(1.86)	(0.34)	(0.11)	(0.52)
R^2	0.74	0.58	0.83	0.98	0.78
Adj. R^2	0.67	0.47	0.78	0.97	0.73
Num. obs.	51	51	51	51	51

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 1: Regression Output for each Energy Type

It is important to note the limitations of this analysis. For example, race is not controlled for which has been previously determined as significant in influencing energy consumption and adoption (Goldstein, Reames, and Newell, 2022). Moreover, I use consumption as a proxy measure for adoption and awareness levels even though many individuals or households do not possess control over what energy type they rely on. A more robust analysis that assures OLS assumptions have been satisfied would yield causal estimates.

Discussion

Overall it seems that most of the findings are insignificant. More research needs to be done to determine if this insignificant relationship was caused by the underlying demographic characteristics or if the model specification suffers from a lack of robustness. Despite these findings, subgroups within the population are more likely to have an affinity towards policies that are inclusive and this aids the development of renewable energy use and diversified energy structures (Ratinen and Lund, 2015).

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