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DIW Berlin
German Institute for Economic Research
Mohrenstr. 58
10117 Berlin

Tel. +49 (30) 897 89-0
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Nuclear Power, Democracy, Development, and Nuclear Warheads: Determinants for Introducing Nuclear Power

Lars Sorge[a,b], Anne Neumann[a,c], Christian von Hirschhausen[a,b], and Ben Wealer[a,b]

[a]*DIW Berlin,* [b]*Berlin University of Technology,* [c]*NTNU Trondheim*

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Abstract: This paper analyzes the nature of democratic development in a nation on the process of introducing nuclear power over the period 1960 - 2017 for an unbalanced panel of 171 countries. Given the involved political process of introducing nuclear power and its political importance, as well as the current tendency of about 30 countries to "go nuclear", this question is both of historic and current interest. We apply a multinomial logistic regression approach that relates the likelihood of a country to introduce nuclear power to its level of democratic quality and nuclear warhead possession. The model results suggest that countries with lower levels of democratic development are more likely to introduce nuclear power. Our results moreover indicate that countries which possess at least one nuclear warhead are more likely to continue to use nuclear power instead of not using nuclear power at all. We discuss these results in the context of the public policy debate on nuclear power, yet beyond energy and environmental issues addressing international relations, conflict, and security issues connected to nuclear energy.

JEL codes: P48, Q34, Q01, C35

Keywords: Nuclear power, nuclear warhead, democracy, multinomial logit, panel data

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1 Introduction

Nuclear power was one of the most important developments of the 20th century, and it continues to dominate discussions about energy security, climate change, and geopolitics well into the 21st century. Nuclear power emerged from the combination of "basic science and warfare" (Lévêque, 2014) in the 1940s, and decisions in this sector have always been based on political bargaining and state financing, rather than on pure economic rationality (Stirling and Johnstone 2018; Hirschhausen 2017; Wealer et al. 2018). Understanding the drivers of national decisions to "go nuclear", i.e. to bring nuclear power plants online in a country, is therefore crucial not only for interpreting the history, but also the future perspectives of nuclear technology: Currently, about thirty countries are considering, planning or starting nuclear power (World Nuclear Association, 2019), and the International Atomic Energy Agency (IAEA) still considers a high global potential for nuclear power up to the year 2050 (International Atomic Energy Agency, 2017).

The political nature of decisions on nuclear power raise interesting questions, in particular with respect to the drivers of these decisions, the criteria for going nuclear, (or not going nuclear), and the decision-making and implementation process. In the absence of hard economic criteria, the institutional and political framework of the participating actors plays an important role. The technical complexity of nuclear power and the need for strong vertical and horizontal coordination within the sector suggests centralized decision-making, in addition to political, cultural, and social characteristics of a country that influence the process (Gralla et al. 2017). In that context, the nature of the political system, e.g. the degree of democratic and competitive decision-making, can be expected to be an important variable.

This paper analyzes how a countries' choice to successfully introduce nuclear power - defined as the connection of a countries' first nuclear power plant to the grid - interacts with the level of democratic development while controlling for nuclear weapons, national development, energy transitions, and environmental indicators identified in the related literature. Our initial hypothesis, based on the existing literature and anecdotal evidence, is that due to the complex, and often controversial, political decisions required to develop nuclear power, less democratically governed countries are more likely to enter the sector and introduce nuclear power than countries with higher levels of democracy. We analyze the impact of democratic development on the successful introduction of nuclear power over the period 1960 - 2017 for an unbalanced panel of 171 countries. The model is based on a multinomial logistic regression approach that relates the likelihood of a country to introduce nuclear power to its level of democratic development. The model results robustly suggest that countries with lower levels of democratic development are more likely to introduce nuclear power.

The remainder of this paper is organized as follows. Section 2 outlines the theoretical underpinnings and reviews the related literature which empirically investigates the nexus between nuclear power and democracy. Section 3 presents the data and explains our empirical approach. Section 4 reports the empirical results and Section 5 concludes.

2 Background and related literature

This section draws on both theoretical and empirical literature to present an overview of which factors out of the political realm in particular are considered to be relevant for nuclear power development. Section 2.1 thus presents the theoretical underpinnings of our empirical analysis and section 2.2 reviews related empirical applications. In general, the early literature on nuclear power uses detailed case studies to analyze how nuclear power developed in different political contexts. A different strand, partly empirically, analyzes aggregate indicators which might facilitate the development of nuclear power development within a cross-country set up (Jewell and Ates, 2015). However, both, empirical analyses investigating the relationship between nuclear power deployment and democracy in particular, and contributions concerning more generally socioeconomic factors of nuclear power deployment are surprisingly scarce.

2.1 Theoretical underpinnings

Capital-intensive centralized large-scale energy infrastructure such as nuclear power is characterized by a technical lifetime which usually spans over decades. Nuclear power thus is subject to and interacts with different socio-economic institutional settings and various stakeholders during development, construction, and operation. In this regard, large scale energy technologies are considered not as a determinant of political regimes but rather as co-evolving with socio-economic institutions, actors, and social norms (Goldthau, 2014).

Theoretically, the relationship between democracy, political power, and energy infrastructures can be analyzed using the framework of concentrated energy-politics vs. distributed energy-politics: the spatial distribution of energy infrastructures differently impacts democratic development and the degree of democratic development differently impacts the spatial distribution of energy infrastructures. According to Burke and Stephens (2018), due to their inherent flexibility decentralized energy technologies are considered to more readily organize and enable distributed political and economic power, and vice versa. This relationship is characterized as strongly democratic and described as distributed energy-politics. On the contrary, energy technologies based on concentrated energy sources are considered to organize and enable more concentrated forms of power and centralized or authoritarian political relationships, and vice versa. This relationship thus is characterized as weakly democratic and refers to concentrated energy-politics. Thus, to what extent political power is concentrated and democracy is developed impacts the deployment of certain energy infrastructures, but the deployed energy system similarly can influence the level of democratic development.

Historically, certain environments and conditions encouraged the development of nuclear power. Sovacool and Valentine (2010) and Valentine and Sovacool (2010) develop a theoretical framework consisting of six influential factors supporting the development of nuclear power: i) strong state involvement in guiding economic development, ii) centralization of national energy planning, iii) campaigns to link technological progress to a national revitalization, iv) influence of technocratic ideology on policy decisions, v) subordination of challenges to political authority, and vi) low levels of civic activism.[1] Strong centrally led economic planning and state involvement either directly through government action or indirectly through state-owned utilities is considered necessary due to the inflexibility and complexity of nuclear power and a high degree of supply chain coordination to realize such energy mega-projects. Similarly, centralization of energy planning facilitates the necessary control and enables to overcome disagreements internally which lowers transaction costs during resolution processes encouraging the expansion of nuclear power. Since nuclear power historically is associated with technological progress and modernity, governmental strategies committed to link technological developments to a national renaissance encourages a national culture which is more likely to tolerate the risks associated with nuclear power. When technocratic ideology strongly influences public policy, the necessary ideological support for nuclear power development is provided. Conditions under which political and public debate are minimized more easily enable the implementation of governmental programs which run contrary to public interest. Lastly, environments which eliminate civic activism detrimentally impact public opposition which could oppose the development of nuclear power programmes. According to Sovacool and Valentine (2010) and Valentine and Sovacool (2010) these six catalysts are simultaneously political, social, and economic. However, only the political environment can influence and overpower both the social and economic dimension at least in authoritarian regimes more easily.

Influential factors such as centralization of national energy planning, subordination of challenges to political authority, and low levels of civic activism concern the realms of democracy. Kitschelt (1986) compare anti-nuclear protest movements in France, Sweden, the United States, and West Germany. Based on the analysis of these four western democracies, he argues that a countries' political and institutional dimension in which social movements operate shapes the level and pattern of anti-nuclear protests. Mobilization strategies and impacts of social movements can be explained partly by the general characteristics of political opportunity structures. Thus, chances of broad

[1] Sovacool and Valentine (2010) moreover identified the abatement of greenhouse gas emissions as a potential seventh factor emerging in the environmental policy realm.

mobilization increase if anti-nuclear movements for instance more easily can collect information about the issue against which they protest, and can disseminate ideas and information publically which in turn can influence policies concerning nuclear power development and expansion. Already in 1976, the importance of public perception towards nuclear power has been recognized by Weinberg (1976): "The public perception and acceptance of nuclear energy [...] has emerged as the most critical question concerning the future of nuclear energy". O'neil (1999) argues - based on analyzing the development of nuclear energy in transformation states - that citizens' willingness for anti-nuclear protest might be influenced by the level of nuclear energy dependence. He hypothesizes that anti-nuclear movements are less likely to occur in countries with a relatively large dependence on nuclear energy due to the public's fear of higher electricity bills or fear of negative growth effects, contrary to countries with lesser dependence on nuclear power. Similarly, different levels of fear about nuclear energy among societies might also determine the opposition. Lastly, O'neil (1999) concludes that support or opposition towards nuclear "[...] are not a function of democracy but rather of complex relationships between state, society, and the institutions they create".

Jewell and Ates (2015) emphasize the importance of political stability for both internal (program constancy and reliability) and external (investor confidence) factors to successfully develop nuclear power programs. Jewell (2011) observes that countries characterized as politically unstable (such as China, India, Korea, and Pakistan according to data on partial or total state failure from the Political Instability Task Force (PITF) database), the introduction of nuclear power for civil purposes was only possible in conjunction with developing nuclear weapons through mobilizing extraordinary political will and resources. Historically, nuclear power emerged as the "child of science and warfare" (Lévêque, 2014), in the victory countries of the war, i.e. the USA, the USSR, the UK, and France, later on also in China; since then, nuclear power has been developed at the intersection of military use and electricity generation. The development of atomic energy for civil purposes and the development of atomic energy for military use are in much of their course interchangeable and interdependent (Acheson-Lilienthal Report 1946). Similarly, Hirschhausen (2017) argues that nuclear power has to be analyzed under the topic of joint production (so called "economies of scope") as nuclear co-production includes military goods (e.g. plutonium, tritium) and services, as well as civilian goods and services (e.g. electricity, medical services).

2.2 Related empirical work

Fuhrmann (2012) utilizes a probit model for panel time series data on 129 countries over the period 1965 to 2000 to empirically identify factors which encourage countries to build nuclear power plants. Based on information from the International Atomic Energy Agency's Power Reactor Information System (PRIS) database, the dependent variable is dichotomous and coded as 1 if a country begins building a reactor in year t + 1 and 0 otherwise. As predictor variables, Fuhrmann (2012) includes GDP as a proxy for economic capacity, energy dependence, an indicator for nuclear weapons exploration, a dummy variable which indicates if a state shares a defense pact with a major supplier of nuclear power plants, Nuclear Non-Proliferation Treaty (NPT) membership dummies, nuclear accidents dummies which interact with the composite indicator from the Polity IV Project measuring a country's regime type. The empirical results indicate that higher levels of economic development are associated with a higher probability for construction. Countries which become less dependent on energy imports are less likely to build nuclear reactors. The indicator for nuclear weapons exploration, the supplier alliance dummy, and the NPT indicator are not statistically significant. Lastly, Fuhrmann (2012) shows that nuclear accidents differently impact construction depending on the regime type: highly authoritarian states tend to be less affected by the Chernobyl disaster for instance than countries with high levels of democratic development.

Yamamura (2012) empirically analyzes how the effect of free media impacts the view on nuclear energy after the 2011 Fukushima Daiichi nuclear disaster in Japan. He uses survey data on the views regarding the security of nuclear energy from a cross-sectional panel of 37 countries which was collected approximately 2 weeks after the incident. From the survey, Yamamura (2012) then obtains the rate of agreement that nuclear power plants are properly secured against accidents which he uses as the dependent variable. He controls for the presence of nuclear plants, the degree of freedom of media, the total number of natural disasters since 1970, GDP per capita, government expenditures, and includes dummies for East Asian countries. Yamamura (2012) finds that freedom of expression and media significantly influences views on the security of nuclear power plants. Citizens tend not to agree that nuclear power plants are properly secured against accidents in environments with high levels of freedom of expression and a free media. Moreover, his results show that freedom of expression and media is positively associated with the presence of nuclear plants.

Gralla et al. (2017) follow the assessment from the World Nuclear Association (WNA) and group countries in accordance with their nuclear energy strategies (no nuclear production, phase-out, planning to produce, produce nuclear energy) to then analyze which socioeconomic, technological, and environmental factors are characteristic for the respective group. Their descriptive analysis - based on the statistical mean for the respective group over the period 1960 to 2013 on 20 indicators - mainly shows that per capita energy use, carbon dioxide emissions, as well as household final consumption expenditure are higher in the nuclear countries group compared to countries planning to use nuclear energy and countries without nuclear energy use. They also utilize a generalized linear mixed model (GLMM) with the nuclear status of all nations that used nuclear energy between 1960 and 2013 as a dependent variable to identify which socioeconomic, technological, and environmental indicators correlate with the starting year of nuclear energy production. Their results show that out of the 96 world development indicators, 28 significantly correlate with the start of nuclear energy production. Gralla et al. (2017) however do not control for the level of democratic or institutional development.

3 Data and Methodology

Section 3.1 describes how we identify the three categories which define a countries' nuclear energy strategy chosen over time and presents a descriptive analysis of the utilized panel dataset. Section 3.2 specifies our methodological approach used to predict the probability of category membership in order to analyze if democracies tend not to start constructing nuclear power plans compared to democratically less developed countries.

3.1 Data

Our analysis covers the period from 1960 to 2017 and we construct an unbalanced panel time series data set covering 171 countries. We empirically analyze how the level of democratic development impacts a countries' choice to successfully introduce nuclear power while controlling for nuclear warhead ownership, national development and both energy transitions as well as environmental indicators.

Based on observable characteristics from the Power Reactor Information System (PRIS) database (PRIS, 2019), we first specify three categories which distinctively define a countries' nuclear energy strategy chosen over time. Thus, at each point in time we evaluate if countries currently use, have used at any point in time, or start to construct a nuclear power plant. Any given country which has no nuclear power plant under construction or operational at time t is categorized as "non-nuclear". Next, we define the period of the construction start of the first nuclear reactor until the first grid connection of any nuclear power plant as the observable outcome to "go nuclear", which then represents the successful introduction of nuclear power. Finally, at any point in time countries are categorized as "nuclear" if they have at least one nuclear power reactor fully operationally at time t. The three distinct different outcomes observable for a countries' nuclear energy strategy then are operationalized as our dependent variable which is categorical and of unordered nature.[2] Our key predictor of interest, the level of democratic development, comes from the Polity IV Project. The index from the Polity IV Project is a combination of the institutionalized democracy and autocracy indicator. The Polity score is computed by

[2] Concerning our definition of a countries' nuclear energy status, we follow the literature, e.g. Jewell and Ates (2015). We note that Italy started with the construction of the first nuclear reactor on 01 November 1958 which was connected to the grid on 12 May 1963. The last reactor in Italy was shut down on 01 July 1990. Kazakhstan started the construction of the first nuclear reactor on 01 October 1964 which was connected to the grid on 16 July 1973. The reactor was shut down on 22 April 1999. Lithuania started with the construction of the first nuclear reactor on 01 May 1977 which was connected to the grid on 31 December 1983. The last reactor in Lithuania however was shut down on 31 December 2009.

subtracting the autocracy from the democracy score which results in an unified polity scale ranging from +10 (strongly democratic) to -10 (strongly autocratic). We use the Polity2 score which is a modified version of the Polity index to facilitate the use in time-series analyses (Marshall et al., 2017). Following Haber and Menaldo (2011), we first normalize the Polity2 index to run from 0 to 100 to obtain a continuous democracy variable $D1$. To obtain a categorical measure for the democracy levels, we classify countries with a score of $D1 > 66$ as democratically free F, $33 < D1 < 66$ as democratically partly free PF, and $D1 < 33$ as democratically not free NF.[3]

The decision of a country to introduce nuclear power might partly be driven by the aim to develop nuclear weapon programmes. Nuclear reactors fueled by uranium used for generating civilian electric power accumulate plutonium. Nuclear power producing countries over time acquire enough quantities of plutonium usable for nuclear weapons (Deutch, 1992). It is therefore only a question of political will and willingness to develop nuclear weapons or not for nuclear power producing countries (Mez, 2012). We construct an indicator W which takes on the value one if a country possesses at least one nuclear warhead in a given year and zero otherwise. Moreover, we control for national development (GDP per capita, urbanization) and both energy transitions and environmental indicators (electric power consumption, fossil fuel rents, energy imports, CO_2 emissions per capita) from the World Development Indicators (WDI) database from The World Bank which all significantly correlate with nuclear energy production (Gralla et al., 2017).

GDP per capita GDP is measured in constant 2010 USD and is our main indicator for a countries' financial capacity. A high degree of national financial capacity for nuclear

[3]We choose the democracy indicator from the Polity IV Project over data from Freedom House which is another commonly used indicator for democratic quality. The indicator from Freedom House is available only from 1972 onward and moreover for the transitional year 1989 data is missing. Second, if we utilize data from 1972 onward, we have to exclude countries such as Argentina, Armenia, Belgium, Brazil, Bulgaria, Canada, Finland, Germany, India, Italy, Japan, Kazakhstan, Korea, Rep., Netherlands, Pakistan, Slovak Republic, Spain, Sweden, Switzerland, and Ukraine which all started constructing their first reactor before 1972. Put differently, if we use the indicator Freedom House, we effectively loose information on 20 out of 38 (53%) countries which ever have build a nuclear power plant. We nevertheless transform the measure from Freedom House following Helliwell (1994) to obtain a continuous democracy variable $D2$ with scores from 0 (no political rights and civil liberties) to 1 (complete set of political rights and civil liberties) to check the correlation with the indicator from the Polity IV Project. Table 4 in the appendix shows that both indicators are highly correlated. A detailed description of the underlying methodology from the Polity IV Project is available at `https://www.systemicpeace.org/`

power development is necessary to allocate initial investments for creating the regulatory, legislative and basic physical infrastructure before construction, but similarly required to finance actual construction of the first nuclear power plant (Jewell, 2011). Urbanization U is measured as the share of the population living in urban areas and reflects the transition from rural to urban areas. Urbanization intensifies the demand for urban infrastructure and transportation, and stimulates the concentration of consumption and production which is associated with increasing energy demand (Sadorsky, 2014). To control for a countries' electricity demand, we use electric power consumption E measured in kWh per capita as an additional predictor variable. Energy security considerations can translate into motivations for pursuing nuclear energy in order to increase energy independence. In countries such as Japan, UK, France, and Finland, independence of energy imports are main arguments for supporting nuclear power (Jewell, 2011; Gralla et al., 2017). We use energy imports EI (% of primary energy use) to measure energy security and independence. In countries which are richly endowed with fossil fuels, the presence of cheap and abundant domestic fuels is expected to similarly affect a countries' energy mix and thus the likelihood for nuclear power deployment. We thus construct an indicator for fossil fuel rents FFR which are the sum of oil rents, natural gas rents, coal rents measured in percentage of GDP. CO_2 emissions per capita CO_2 are measured in metric tons per capita and included since nuclear power is considered by some as a low carbon generation source although characterized by high lifecycle emissions (Sovacool, 2008).[4]

Table 1 shows how the three different nuclear energy statuses descriptively relate to the three previously defined levels of democratic quality.

Non-nuclear statuses dominate the sample. Within the given period, the majority of the total observations in our sample has been evaluated as democratically free according to the Polity IV Project indicator. Within the non-nuclear group, more than 40% of the observations are either democratically free or not free. Democratically less free

[4]For an assessment of nuclear power regarding various sustainability development criteria see Verbruggen et al. (2014) for instance.

Table 1: Frequency table for the nuclear energy statuses at each level of democratic quality

	Polity IV Project			
	F	*PF*	*NF*	Total
Non-nuclear	2,833	1,047	2,966	6,846
	(41.38)	(15.29)	(43.32)	(100)
Construction	50	28	96	174
	(28.74)	(16.09)	(55.17)	(100)
Nuclear	1,111	26	109	1,246
	(89.17)	(2.09)	(8.75)	(100.00)
Total	3,994	1,101	3,171	8,266
	(48.32)	(13.32)	(38.36)	(100)

Notes: F, PF, and NF corresponds to democratically free, partly free, and not free for the measure of democratic quality $D1$ from Polity IV Project, respectively. Row percentages are is in parentheses.

countries however clearly dominate the construction periods whereas "nuclear" statuses are characterized by higher percentages of democratically free countries.

Table 2: Summary statistics for the three different nuclear energy statuses

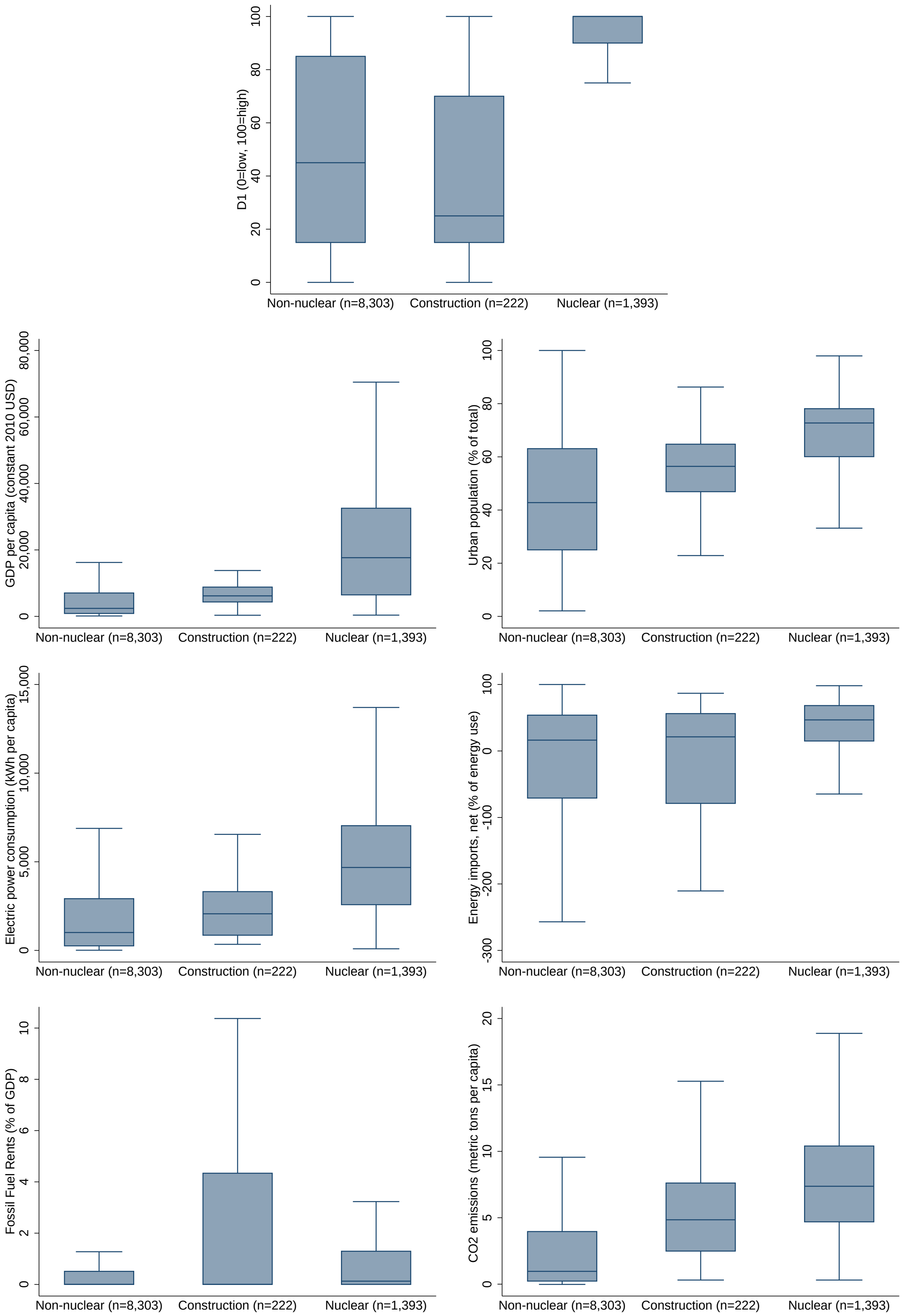
	$D1$	GDP	U	E	EI	FFR	CO_2
Non-nuclear	49.75	8,909.44	45.38	2,575.17	-114.78	3.70	3.86
	(36.04)	(18,013.23)	(24.65)	(4,496.27)	(651.24)	(10.38)	(8.14)
Construction	42.24	8,329.60	54.62	2,372.46	-29.06	4.86	5.48
	(34.71)	(8,670.71)	(16.63)	2,003.72	166.84	(9.12)	3.90
Nuclear	87.19	20,902.98	67.61	5,451.87	37.52	1.15	2.66
	(24.02)	(16,974.32)	(16.91)	(4,056.77)	(37.68)	(7.84)	(4.76)

Notes: Arithmetic mean is displayed and the standard deviation is in parentheses. D1 is the normalized democracy measure from Polity2 index running from 0 to 100 with greater values representing higher levels of democratic development (Haber and Menaldo, 2011). Data obtained from the World Development Indicators (WDI) database from The World Bank (last updated 24 April 2019).

Table 2 displays the mean value and standard deviation for all variables in their respective nuclear status. Figure 1 shows the boxplots for the variables for the three different nuclear energy statuses. The normalized democracy measure from the Polity2 index $D1$ is on average twice as high for the nuclear statuses compared to the construction statuses. $D1$ moreover is 1.75 times higher for the nuclear statuses compared to the non-nuclear statuses. For the non-nuclear statuses, $D1$ is 1.18 times higher compared to the construction statuses. Average GDP per capita is the greatest for the nuclear statuses and the lowest for the construction statuses. Similarly, the range of GDP per capita ist the greatest for the nuclear statuses. Urbanization levels are highest in nuclear statuses and construction statuses are characterized by higher urbanization levels than the non-nuclear statuses. The greatest variability for urbanization levels exists for the non-nuclear statuses compared to construction and nuclear statuses.

Average electric power consumption per capita is the highest for the nuclear statuses and the nuclear statuses show the greatest variability for electric power consumption. For the non-nuclear statuses, electric power consumption per capita is on average 0.92 times higher compared to the construction statuses. Nuclear statuses are characterized by positive values for the net energy imports indicator whereas both non-nuclear and construction statuses are associated with negative values. Thus, surprisingly, countries in a nuclear status on average tend to import energy whereas in particular non-nuclear and construction statuses are characterized by net energy exports. Construction statuses are characterized by the highest value for fossil fuel rents and also show the greatest variability for fossil fuel rents. Non-nuclear statuses have moreover higher fossil fuel rents on average compared to nuclear statuses. Average CO_2 emissions per capita for the nuclear statuses are 1.43 (2.03) times higher compared to the construction (non-nuclear) statuses, whereas the average CO_2 emissions per capita for the construction statuses are 1.42 times higher than for the non-nuclear statuses.

Figure 1: Boxplots for the three different nuclear energy statuses



Notes: Figures indicate the median for the respective variables for the three different nuclear energy status.

3.2 Empirical Specification

Due to the unordered nature of our outcome variable, we utilize a multinomial logistic regression approach to analyze if a countries' choice to "go nuclear" is significantly influenced by the level of democratic development. The multinomial logit model directly builds on the binary logit model and thus is applicable when the response variable has more than two categories. The categories of the outcome variable are restricted to be unordered and based on the assumption of the independence of irrelevant alternatives (IIA) stating that the inclusion or exclusion of categories does not affect the relative risks associated with the remaining categories (Hausman and McFadden, 1984). In the multinomial logit model, the log-odds ratio that country i will fall in response category j relative to the reference category J is assumed to follow a linear model:

$$\eta_{ij} = \log\left(\frac{\pi_i^{(\mathrm{j})}}{\pi_i^{(\mathrm{J})}}\right) = \alpha^{(j)} + \beta_1^{(j)} X_{1i} + ... + \beta_k^{(j)} X_{ki}, \tag{1}$$

where π_i is the probability for outcome j in the $i = 1, ..., n$ countries, $\alpha^{(j)}$ is a constant, and $\beta_1^{(j)}, ..., \beta_k^{(j)}$ are the k regression coefficients, for the $j = 1, ..., J-1$ outcomes. $X_{1i}, ..., X_{ki}$ are the k explanatory variables.

We model a countries' nuclear energy strategy in which economies face the following j choices in the defined categorical dependent variable N: not using nuclear at all ($j = 0$, "non-nuclear"), constructing a nuclear power plant ($j = 1$, "construction"), and having at least one nuclear power plant fully operational ($j = 2$, "nuclear"). Since we specify "non-nuclear" as our reference category, we obtain a model for the log odds of choosing "construction" over "non-nuclear"

$$\begin{aligned}\eta_{i1} = \log\left(\frac{\pi_i^{(1)}}{\pi_i^{(0)}}\right) = \alpha^{(1)} + \beta_1^{(1)} F_i + \beta_2^{(1)} PF_i + \beta_3^{(1)} NF_i + \beta_4^{(1)} W_i + \beta_5^{(1)} GDP_i \\ + \beta_6^{(1)} U_i + \beta_7^{(1)} E_i + \beta_8^{(1)} EI_i + \beta_9^{(1)} FFR_i + \beta_{10}^{(1)} CO_{2i},\end{aligned} \tag{2}$$

and a second model for the log odds of choosing "nuclear" over "non-nuclear":

$$\begin{aligned}\eta_{i2} = \log\left(\frac{\pi_i^{(1)}}{\pi_i^{(0)}}\right) = \alpha^{(2)} + \beta_1^{(2)} F_i + \beta_2^{(2)} PF_i + \beta_3^{(2)} NF_i + \beta_4^{(2)} W_i + \beta_5^{(1)} GDP_i \\ + \beta_6^{(2)} U_i + \beta_7^{(2)} E_i + \beta_8^{(2)} EI_i + \beta_9^{(2)} FFR_i + \beta_{10}^{(1)} CO_{2i},\end{aligned} \quad (3)$$

where the factor variables F_i, PF_i, and NF_i correspond to the transformed normalized Polity2 index $D1$. Moreover, we include the dummy variable indicator for nuclear warheads W, GDP per capita GDP, the share of urban population U, electric power consumption (kWh per capita) E, net energy imports (% of energy use) EI, fossil fuel rents (% of GDP) FFR, and CO_2 emissions (metric tons per capita) CO_2.

4 Empirical Results

We start conducting model specification tests and test for the the assumption of independence of irrelevant alternatives (IIA) of the multinomial logit model (Long and Freese, 2006).[5]

We first test if combining our dependent categories would increase the efficiency of our estimates. We thus test if a pair of outcomes is indistinguishable using both a Likelihood Ratio (LR) and Wald test. For both the LR and Wald test and for every pair of outcomes we can reject the null hypothesis that alternatives can be collapsed. This indicates our models are efficiently defined in terms of the dependent categories. Next, we use both a LR and Wald test to assess if the effect of an independent variable equals zero across all equations. Again, for both the LR and Wald test, we can reject the null hypothesis that all coefficients for each regressor are equal to zero. Third, we use the Hausman test of IIA

[5]The results of all tests are available upon request. We inspect the correlations among variables to evaluate if multicollinearity affects our analyses. The results are in Table 4 in the appendix and indicate overall relatively low correlation among the variables. However, the correlation between GDP and U, GDP and E, GDP and CO_2, U and E, U and CO_2, and E and CO_2 exceeds 0.5.

(Hausman and McFadden, 1984). The test statistics for all three categories are negative which suggests that the IIA has not been violated.[6]

We interpret the estimated parameters in Table 3 from the the multinomial logistic regression approach relative to the reference group "non-nuclear". The results show the exponentiated estimates for the log odds ratios associated with equations (2) and (3), respectively, which are interpreted in terms of the relative risk ratios (RRR). The RRR indicate how the probability of choosing alternative j relative to the reference group changes if the corresponding variable increases by one unit, ceteris paribus. We thus interpret the respective category of interest (partly free or not free) relative to the base category (free). Next to our baseline estimations, we test if the results are driven by countries such as the United States and Russia which possessed nuclear weapons and nuclear power plants already since the beginning of our sample period.

All estimated parameters are statistically significant at least the 10% level, except for the parameters on PF, GDP, and CO_2 in estimation (1), (2), and (3) for $j = 1$. The parameters on FFR are only statistically significant for $j = 1$ in estimation (1), (2), and (3). We begin interpreting the baseline estimation (1) and the RRR for $j = 1$. The RRR for NF is above unity. Thus, for democratically not free countries compared to democratically free countries the relative risk of being in the construction group relative to the non-nuclear group would be expected to increase, ceteris paribus. Given all other variables are held constant and compared to democratically free countries, the probability that democratically not free countries are in the construction group instead of in the non-nuclear group increases by 153% ($(2.526 - 1) \times 100$). On the contrary, the RRR for the statistically not significant parameter on PF is below unity which indicates that democratically partly free countries compared to democratically free countries the relative

[6] The Hausman test of IIA in general unfortunately provides rather inconsistent results thus providing little guidance whether the the IIA assumption is violated or not: based on simulations, Cheng and Long (2007) show that the size properties of IIA tests commonly used depend on the data structure for the predictor variables. As a results, it is not uncommon that the IIA tests often reject the assumption when the alternatives seem distinct and often fail to reject IIA when the alternatives can reasonably be viewed as close substitutes even in well-specified models (Cheng and Long, 2007). They conclude that "[...] tests of the IIA assumption that are based on the estimation of a restricted choice set are unsatisfactory for applied work."

risk of being in the construction group relative to the non-nuclear group would be expected to decrease, ceteris paribus. On the contrary,

The RRR for $j = 2$ for both PF and NF are below unity. Thus, for both democratically partly free and not free countries compared to democratically free countries the relative risk of being in the nuclear group relative to the non-nuclear group would be expected to decrease, ceteris paribus. Given all other variables are held constant and compared to democratically free countries, the probability that democratically partly free countries are in the nuclear group instead of in the non-nuclear group decreases by 88% $((1-0.117)\times 100)$. Similarly, given all other variables are held constant and compared to democratically free countries, the probability that democratically not free countries are in the nuclear group instead of in the non-nuclear group decreases by 73% $((1-0.275)\times 100)$.

Table 3: Estimations (1) to (3) with categorized democratic quality from Polity IV Project

	(1) Baseline		(2) Baseline no USA		(3) Baseline no Russia	
	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)
PF	0.842	0.117^a	0.841	0.118^a	0.865	0.0859^a
NF	2.526^a	0.275^a	2.523^a	0.280^a	2.521^a	0.291^a
W	4.424^a	20.56^a	4.333^a	18.22^a	4.452^a	16.68^a
GDP	1.000	1.000^a	1.000	1.000^a	1.000	1.000^a
U	1.028^a	1.023^a	1.028^a	1.023^a	1.029^a	1.022^a
E	1.000^b	1.000^a	1.000^b	1.000^a	1.000^c	1.000^a
EI	1.002^a	1.008^a	1.002^a	1.008^a	1.002^a	1.008^a
FFR	1.029^a	0.983	1.029^a	0.985	1.029^a	0.974
CO_2	1.045	0.963^a	1.045	0.959^a	1.045	0.962^a
$cons$	0.00450^a	0.0544^a	0.00451^a	0.0547^a	0.00445^a	0.0571^a
N	4844		4789		4821	
Pseudo R^2	0.279		0.259		0.274	

Notes: The Relative Risk Ratio is displayed. Superscripts a, b, and c represent significance at 1%, 5%, and 10%, respectively. Democratically free F is the base category for the transformed categorical democracy indicator from the Polity IV Project. The reference group is non-nuclear (j=0).

The RRR for W are above unity in both $j = 1$ and $j = 2$ yet differing substantially in magnitude. Thus for countries which posses at least one nuclear warhead compared to countries without a nuclear warhead, the relative risk of being in the construction group and nuclear group, respectively, relative to the non-nuclear group would be expected to increase, ceteris paribus. Given all other variables are held constant and compared to countries without a nuclear warhead, the probability that countries which possess at least one nuclear warhead are in the construction group instead of in the non-nuclear increases by 342% ($(4.424 - 1) \times 100$). Similarly, given all other variables are held constant and compared to countries without a nuclear warhead, the probability that countries which possess at least one nuclear warhead are in the nuclear group instead of in the non-nuclear increases by 1,956% ($(20.56 - 1) \times 100$).

The RRR for U and EI are above unity for $j = 1$ as well as for $j = 2$. Thus, a one unit increase in U or EI increases the probability that to "go nuclear" (to be nuclear) is chosen instead of non-nuclear (non-nuclear). Countries which become rather energy importers are more likely to both construct and continue to use nuclear power. The RRR for FFR is above unity for $j = 1$. Thus, a one unit increase in FFR increases the probability that to "go nuclear" is chosen instead of non-nuclear. Increases in fossil fuel rents, which effectively function as an asset like any other stock of capital, increases the probability for entering the construction phase. The RRR for CO_2 is below unity for $j = 2$. Thus, a one unit increase in CO_2 decreases the probability that to to be nuclear is chosen instead of non-nuclear. Considering the national development and both energy transitions and environmental indicators only, the impact of a one unit increase on the probability that to "go nuclear" and to be nuclear is chosen instead of non-nuclear is the greatest in magnitude for U. If two countries are identical except for their urbanization levels, the country with higher urbanization is more likely to choose to "go nuclear" and to be nuclear than a country with lower urbanization. The RRR for both GDP and E are equal to one for $j = 1$ as well as for $j = 2$ which indicates a rather unsubstantial impact of both variables on defining a countries' nuclear energy strategy chosen over time.

Considering the magnitude of all the estimated parameters, both democracy effects and possession of a nuclear warhead tend to have the greatest impact on a countries' nuclear energy strategy chosen over time. Overall, the results do not vary substantially if we exclude the United States in estimation (2) or Russia in estimation (3).

4.1 Robustness

We conduct several robustness checks. We first create a dummy for the transitional years covering the period 1989 to 1992 to capture year effects which affect all countries between the fall of the Berlin Wall and and the collapse of the Soviet Union. We moreover utilize another specification with year effects to capture the influence of aggregate time-series trends. Second, we gradually increase a parsimonious specification which only includes the democracy control factor variable with the other relevant predictors until we arrive at the baseline specification given in equation (2) and (3), respectively. Third, we redo the entire analysis but use the democracy measure from the normalized Polity2 index in continuous modes.

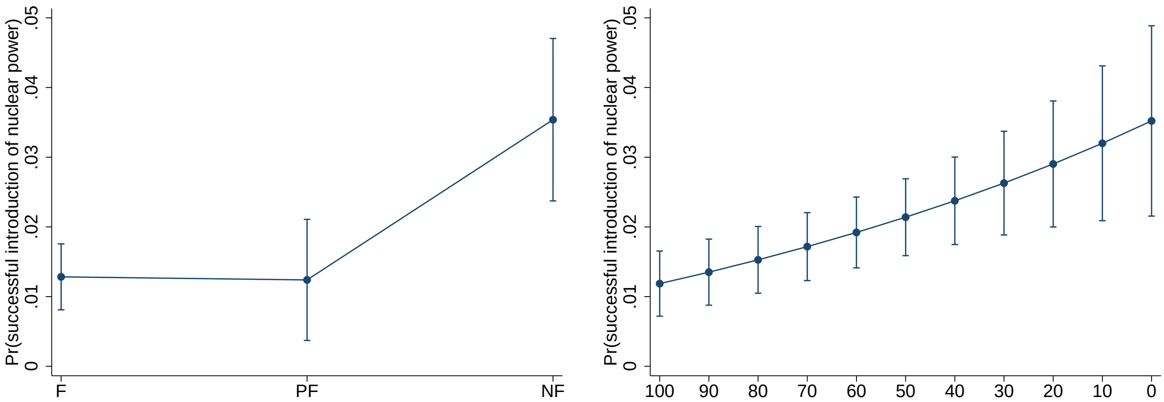
Table 5 in the appendix presents the results of estimation (4) with an additional dummy covering the period 1989 to 1992 and the outcome with year effects included. The results remain identical to estimation (1) in terms of both significance and magnitude for all the estimated parameters in both $j = 1$ and $j = 2$. The time dummy for the period 1989 to 1992 is statistically not significant for either $j = 1$ or $j = 2$ which indicates that effects of the transitional period into the post cold war era do not significantly impact a countries' nuclear energy strategy chosen over time. If we capture the influence of aggregate time-series trends with year effects in estimation (5), both significance and magnitude does not change. We can reject the null hypothesis that the coefficients for all years are jointly equal to zero at the 10% level significance level. The main implications remain the same. For not free countries compared to democratically free countries the relative risk of being in the construction group relative to the non-nuclear group would be expected to increase, ceteris paribus. Similarly, countries which posses at least one nuclear warhead compared to countries without a nuclear warhead, are more likely to be in the construction group and nuclear group, respectively, relative to the non-nuclear group.

Table 6 in the appendix show the results of our second robustness check in estimations (6) to (12) which do not alter the main implications: When we gradually increase a parsimonious specification which only includes the democracy control factor variable with the other relevant predictors, the results still suggest that i) in particular for democratically not free countries compared to democratically free countries the relative risk of being in the construction group relative to the non-nuclear group would be expected to increase and ii) that for both democratically partly free and not free countries compared to democratically free countries the relative risk of being in the nuclear group relative to the non-nuclear group would be expected to decrease. Moreover, similar to estimations (1) to (3), the RRR for W for both $j = 1$ and $j = 2$ is always above unity which indicates that countries which possess at least one nuclear warhead compared to countries without, the relative risk of being in the construction and nuclear group, respectively, relative to the non-nuclear group would be expected to increase. Our last robustness check is presented in Tables 7 to 9 in the appendix for the estimations (13) to (24). If we redo the entire analysis but use the democracy measures from the Polity IV Project in continuous modes, the results indicate that if a country increases its democracy level, we would expect this country to be more likely to choose non-nuclear over to go nuclear which supports our main findings.

4.2 Discussion

Based on our empirical analysis, the results altogether indicate the following: Robustly for estimations (1) to (12), we find i) that in particular for democratically not free countries compared to democratically free countries the relative risk of being in the construction (nuclear) group relative to the non-nuclear group would be expected to increase (decrease) and robustly for all estimations ii) that countries which possess at least one nuclear warhead compared to countries without are more likely to choose to construct a nuclear power plant and to use nuclear power, respectively, instead of not using nuclear power at all. Overall, the estimated probability for being a democratically not free country in the construction instead of in the non-nuclear group ranges from 83% in estimation (7) to 200% in estimation (11). The estimated probabilities for construction and to continue to use nuclear for possessing at least one nuclear warhead compared to not having a nuclear warhead ranges from 228% in estimation (19) to 384% in estimation (22) in case of construction and from 1568% in estimation (3) to 2635% in estimation (19) in case of to continue to use nuclear. Possession of a nuclear warhead tends in particular to encourage the strategy to continue to use nuclear. Our results regarding the democratic realm are broadly supported by Yamamura (2012) for freedom of expression and free media which significantly influences views on the security of nuclear power plants: Citizens tend not to agree that nuclear power plants are properly secured against accidents in environments with high levels of freedom of expression and a free media. In terms of nuclear weapons, our results contrast Fuhrmann (2012) who finds the impact of nuclear weapons exploration on the likelihood for construction to be statistically not significant.

Figure 2: Adjusted predictions with 95% confidence interval for group membership of successful introduction of nuclear power by levels of democratic quality



Notes: Left (right) plot indicates categorized (continuous) levels of the Polity IV Project democracy measure. F, PF, and NF corresponds to democratically free, partly free, and not free. The continuous levels of democratic quality on the horizontal axis in the right plot corresponds to $D1$ as defined above with greater values representing higher levels of democratic development (Haber and Menaldo, 2011).

Figure 2 shows the predicted probabilities for democratic quality while holding all other variables at their means. The left plot illustrates the predicted probabilities for the successful introduction of nuclear power at each level of democratic freedom - free F, partly free PF, not free NF - while holding all other variables at their means. The predicted probability for successfully introducing nuclear power increases with decreasing levels of democratic freedom. While the predicted probability for the successful introduction of nuclear power is slightly higher for democratically free countries than for democratically partly free countries considering the point estimates, in particular the upper bound of the confidence interval for democratically partly free countries is considerably greater in magnitude compared to democratically free countries. The right plot indicates the predicted probabilities for continuous levels of democratic quality while holding all other variables at their means. Greater values represent higher levels of democratic development. The predicted probability for successfully introducing nuclear power increases with decreasing levels of democratic freedom. Generally, democracy effects and the possession of a nuclear warhead tend to dominate a countries' nuclear energy strategy chosen over time instead of national development and both energy transitions and environmental indicators with the exception for urbanization levels.

5 Conclusion

This paper empirically analyzes how a countries' choice to successfully introduce nuclear power is influenced by the level of democratic development. We use an unbalanced panel time series data set on 171 countries covering the period 1960 to 2017. Our review reveals a gap particularly in the empirical literature analyzing the nexus between nuclear power and democracy but similarly nuclear weapon possession (Gralla et al., 2017). We follow the scarce related literature and define the period of the construction start until connection of any nuclear power plant as the observable outcome to "go nuclear" corresponding to the successful introduction of nuclear power. The characterization of a countries' nuclear energy strategy thus is based on unbiased information from the Power Reactor Information System (PRIS) database. Due to the polytomous nature of our dependent variable we apply a multinomial logistic regression approach. As the decision to introduce nuclear power might partly be driven by the aim to develop nuclear weapon programmes, we use an indicator for nuclear weapon possession. We moreover control for national development indicators (GDP per capita, urbanization) and energy transitions and environmental indicators (electric power consumption, energy imports, fossil fuel rents CO_2 emissions per capita) which significantly correlate with nuclear energy production (Gralla et al., 2017).

To assess the robustness of our results, we exclude countries such as the United States and Russia, we include a dummy for the transitional years covering the period 1989 to 1992 as well as year effects, gradually increase a parsimonious specification which only includes the democracy control factor variables with the other relevant predictors, and redid the entire analysis with the democracy measure from the Polity2 in continuous modes resulting in 24 estimations in total. The main implications from our analysis are robust for any specification. Our empirical results show that historically, democratically not free countries compared to democratically free countries are more likely to successfully introduce nuclear power instead of not using nuclear power at all. Our results moreover suggest that countries which possess at least one nuclear warhead compared to countries without a nuclear warhead are more likely to choose to use nuclear power instead of not using nuclear power at all. Both, democracy effects and possession of a nuclear warhead tend to dominantly impact a countries' nuclear energy strategy chosen over time. Urbanization levels moreover significantly affect the likelihood to choose "to go nuclear" and to continue to use nuclear the greatest in magnitude considering the national development and both energy transitions and environmental indicators.

Our analyses show how different stages of a countries' nuclear energy strategy - not using nuclear power at all, construction, and continued use of nuclear power - relates to different levels of democratic development. The successful introduction of nuclear energy thus tends to be more likely under conditions where political and public debate are minimized which more easily enables the implementation of governmental programs which might run contrary to public interest. The political setting moreover tends to dominate and overpower both the social and economic dimension at least in less democratic environments when it comes to nuclear energy deployment. Certainly, nuclear power requires a specific type of governance due to the very specific safety requirements of nuclear power plants and their impact on society. The very specific conditions in large-scale energy infrastructure projects such as institutional exceptions then tend to have an impact on the practices and institutions which define the governance of a project (Hellström et al., 2013). We thus provide empirical evidence on how certain political environments favor the implementation of large-scale energy infrastructures with lifespans over decades. It becomes more difficult for countries to move towards decentralized energy technologies that are considered to more readily organize and enable distributed political and economic power which effectively can create a technological lock-in, if the nuclear electricity industry moreover is both highly concentrated and connected with related policy decisions. (Fouquet, 2016).

Due to the dual-use dilemma nuclear energy is facing, our analyses moreover have implications beyond energy and environmental policy addressing international relations, conflict, and security issues. Nuclear weapon aspirations or possession might be accompanied by the pursuit of nuclear power, and vice versa. The ownership of nuclear weapons then can eventually impede a nuclear phase out globally. But similarly, the desire for nuclear warheads can motivate countries to construct nuclear power plants. In countries such as China, India, and Pakistan, the introduction of nuclear power for civil purposes was only possible in conjunction with developing nuclear weapons through mobilizing extraordinary political will and resources (Jewell, 2011). The synergies between military use of nuclear power and electricity generation in countries such as Iran for instance could result in a multi-nuclear Middle East with both Saudi Arabia and Egypt most likely being candidates choosing to "go nuclear" very soon in a response to a potential Iranian warhead (Dassa Kaye and Wehrey, 2007).

Future research could more prominently emphasize further geopolitical and military related aspects of nuclear power deployment. Are countries which are within proximity of hostile nuclear intercontinental ballistic missile are more likely to construct nuclear power plants? How does membership of defense alliances impact nuclear power deployment? Breaking down the democracy levels much more closely grained than free or not free is expected to provide further insights of nuclear power development. In this regard, research should consider the potential effects of specific democratic elements such as civil liberties, political rights, or corruption to evaluate which democratic characteristics are the most important for the successful introduction of nuclear power.

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A Appendix

Table 4: Correlation matrix

Variables	N	$D1$	$D2$	W	GDP	U	E	EI	FFR	CO_2
N	1.000									
$D1$	0.351^a	1.000								
$D2$	0.355^a	0.881^a	1.000							
W	0.365^a	0.124^a	0.115^a	1.000						
GDP	0.234^a	0.314^a	0.392^a	0.112^a	1.000					
U	0.314^a	0.352^a	0.392^a	0.137^a	0.599^a	1.000				
E	0.251^a	0.280^a	0.386^a	0.097^a	0.754^a	0.561^a	1.000			
EI	0.107^a	0.213^a	0.191^a	0.044^a	-0.076^a	-0.026^c	0.014	1.000		
FFR	-0.087^a	-0.246^a	-0.269^a	-0.027^a	0.083^a	0.191^a	0.049^a	-0.452^a	1.000	
CO_2	0.178^a	0.093^a	0.168^a	0.108^a	0.721^a	0.540^a	0.538^a	-0.238^a	0.336^a	1.000

Notes: Superscripts a, b, and c represent significance at 1%, 5%, and 10%, respectively.

Table 5: Estimations (4) and (5) with categorized democratic quality from Polity IV Project with transitional period dummy and year effects

	(4) Dummy		(5) Year Effects	
	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)
PF	0.843	0.117^a	1.076	0.113^a
NF	2.526^a	0.275^a	1.979^b	0.253^a
W	4.438^a	20.59^a	4.299^a	21.59^a
GDP	1.000	1.000^a	1.000^b	1.000^a
U	1.029^a	1.023^a	1.031^a	1.024^a
E	1.000^b	1.000^a	1.000	1.000^a
EI	1.002^a	1.008^a	1.003^a	1.008^a
FFR	1.030^a	0.983	1.073^a	0.995
CO_2	1.045	0.963^a	0.979	0.952^a
Dummy 1989 - 1992	1.148	1.051	-	-
Year Effects	no	no	yes	yes
$cons$	0.00443^a	0.0541^a	0.0950^a	0.0318^a
N	4844		4844	
Pseudo R^2	0.279		0.302	

Notes: The Relative Risk Ratio is displayed. Superscripts a, b, and c represent significance at 1%, 5%, and 10%, respectively. Democratically free F is the base category for the transformed categorical democracy indicator from the Polity IV Project. The reference group is non-nuclear (j=0).

Table 6: Estimations (6) to (12) with categorized democratic quality from Polity IV Project

	(6)		(7)		(8)		(9)		(10)		(11)		(12)	
	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)
PF	1.515^c	0.0633^a	1.539^c	0.0719^a	1.359	0.101^a	1.502	0.113^a	0.942	0.110^a	0.994	0.120^a	0.874	0.122^a
NF	1.834^a	0.0937^a	1.833^a	0.0933^a	2.102^a	0.126^a	2.557^a	0.172^a	2.603^a	0.154^a	3.008^a	0.258^a	2.615^a	0.269^a
W			3.372^a	23.42^a	3.660^a	21.80^a	4.187^a	22.48^a	4.583^a	20.80^a	4.370^a	19.01^a	4.512^a	19.44^a
GDP					1.000	1.000^a	1.000^a	1.000	1.000	1.000^a	1.000	1.000^a	1.000	1.000^a
U							1.031^a	1.033^a	1.030^a	1.025^a	1.030^a	1.021^a	1.029^a	1.021^a
E									1.000	1.000^a	1.000	1.000^a	1.000	1.000^a
EI											1.001	1.008^a	1.002^a	1.007^a
FFR													1.032^a	0.973^c
$cons$	0.0176^a	0.392^a	0.0172^a	0.312^a	0.0142^a	0.228^a	0.00340^a	0.0400^a	0.00431^a	0.0663^a	0.00410^a	0.0565^a	0.00430^a	0.0587^a
N	8266		8266		7055		7045		4866		4860		4860	
Pseudo R^2	0.128		0.192		0.203		0.238		0.234		0.274		0.276	

Notes: The Relative Risk Ratio is displayed. Superscripts a, b, and c represent significance at 1%, 5%, and 10%, respectively. Democratically free F is the base category for the transformed categorical democracy indicator from the Polity IV Project. The reference group is non-nuclear (j=0).

Table 7: Estimations (13) to (15) with continuous democratic quality from Polity IV Project

	(13) Baseline		(14) Baseline no USA		(15) Baseline no Russia	
	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)
$D1$	0.991^a	1.024^a	0.991^a	1.023^a	0.991^a	1.023^a
W	4.614^a	21.89^a	4.525^a	19.57^a	4.756^a	19.07^a
GDP	1.000	1.000^a	1.000	1.000^a	1.000	1.000^a
U	1.027^a	1.021^a	1.027^a	1.021^a	1.027^a	1.021^a
E	1.000^c	1.000^a	1.000^c	1.000^a	1.000^c	1.000^a
EI	1.002^a	1.007^a	1.002^a	1.008^a	1.002^a	1.007^a
FFR	1.030^a	0.995	1.030^a	0.997	1.030^a	0.987
CO_2	1.044	0.962^a	1.045	0.959^a	1.044	0.962^a
$cons$	0.0118^a	0.00727^a	0.0118^a	0.00748^a	0.0116^a	0.00780^a
N	4844		4789		4821	
Pseudo R^2	0.279		0.259		0.273	

Notes: The Relative Risk Ratio is displayed. Superscripts a, b, and c represent significance at 1%, 5%, and 10%, respectively. $D1$ is the normalized democracy measure from Polity2 index running from 0 to 100 with greater values representing higher levels of democratic development (Haber and Menaldo, 2011). The reference group is non-nuclear (j=0).

Table 8: Estimations (16) and (17) with continuous democratic quality from Polity IV Project with transitional period dummy and year effects

	(16) Dummy		(17) Year Effects	
	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)
$D1$	0.991^a	1.024^a	0.995^c	1.024^a
W	4.627^a	21.92^a	4.490^a	22.99^a
GDP	1.000	1.000^a	1.000^b	1.000^a
U	1.027^a	1.021^a	1.030^a	1.022^a
E	1.000^c	1.000^a	1.000	1.000^a
EI	1.002^a	1.008^a	1.003^a	1.008^a
FFR	1.030^a	0.995	1.076^a	1.006
CO_2	1.044	0.962^a	0.977	0.952^a
Dummy 1989 - 1992	1.160	1.060	-	-
Year Effects	no	no	yes	yes
$cons$	0.0116^a	0.00722^a	0.179^a	0.00375^a
N	4844		4844	
Pseudo R^2	0.280		0.304	

Notes: The Relative Risk Ratio is displayed. Superscripts a, b, and c represent significance at 1%, 5%, and 10%, respectively.$D1$ is the normalized democracy measure from Polity2 index running from 0 to 100 with greater values representing higher levels of democratic development (Haber and Menaldo, 2011). The reference group is non-nuclear (j=0).

Table 9: Estimations (18) to (24) with continuous democratic quality from Polity IV Project

	(18)		(19)		(20)		(21)		(22)		(23)		(24)	
	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)	Construction (j=1)	Nuclear (j=2)
$D1$	0.994^a	1.041^a	0.994^a	1.041^a	0.993^a	1.036^a	0.990^a	1.030^a	0.990^a	1.029^a	0.988^a	1.024^a	0.990^a	1.024^a
W			3.281^a	27.35^a	3.688^a	25.44^a	4.334^a	24.68^a	4.835^a	22.30^a	4.601^a	20.50^a	4.702^a	20.78^a
GDP					1.000	1.000^a	1.000^a	1.000	1.000	1.000^a	1.000	1.000^a	1.000	1.000^a
U							1.030^a	1.031^a	1.029^a	1.024^a	1.029^a	1.019^a	1.027^a	1.019^a
E									1.000	1.000^a	1.000	1.000^a	1.000	1.000^a
EI											1.001	1.007^a	1.002^a	1.007^a
FFR													1.032^a	0.984
$cons$	0.0332^a	0.0103^a	0.0323^a	0.00811^a	0.0301^a	0.0101^a	0.00935^a	0.00317^a	0.0118^a	0.00506^a	0.0132^a	0.00737^a	0.0117^a	0.00777^a
N	8266		8266		7055		7045		4866		4860		4860	
Pseudo R^2	0.151		0.216		0.218		0.247		0.241		0.275		0.277	

Notes: The Relative Risk Ratio is displayed. Superscripts *a*, *b*, and *c* represent significance at 1%, 5%, and 10%, respectively. $D1$ is the normalized democracy measure from Polity2 index running from 0 to 100 with greater values representing higher levels of democratic development (Haber and Menaldo, 2011). The reference group is non-nuclear (j=0).