

“Nuclear Diplomacy” - State of the Art of Nuclear Power Plants Exports and some Econometric Analysis

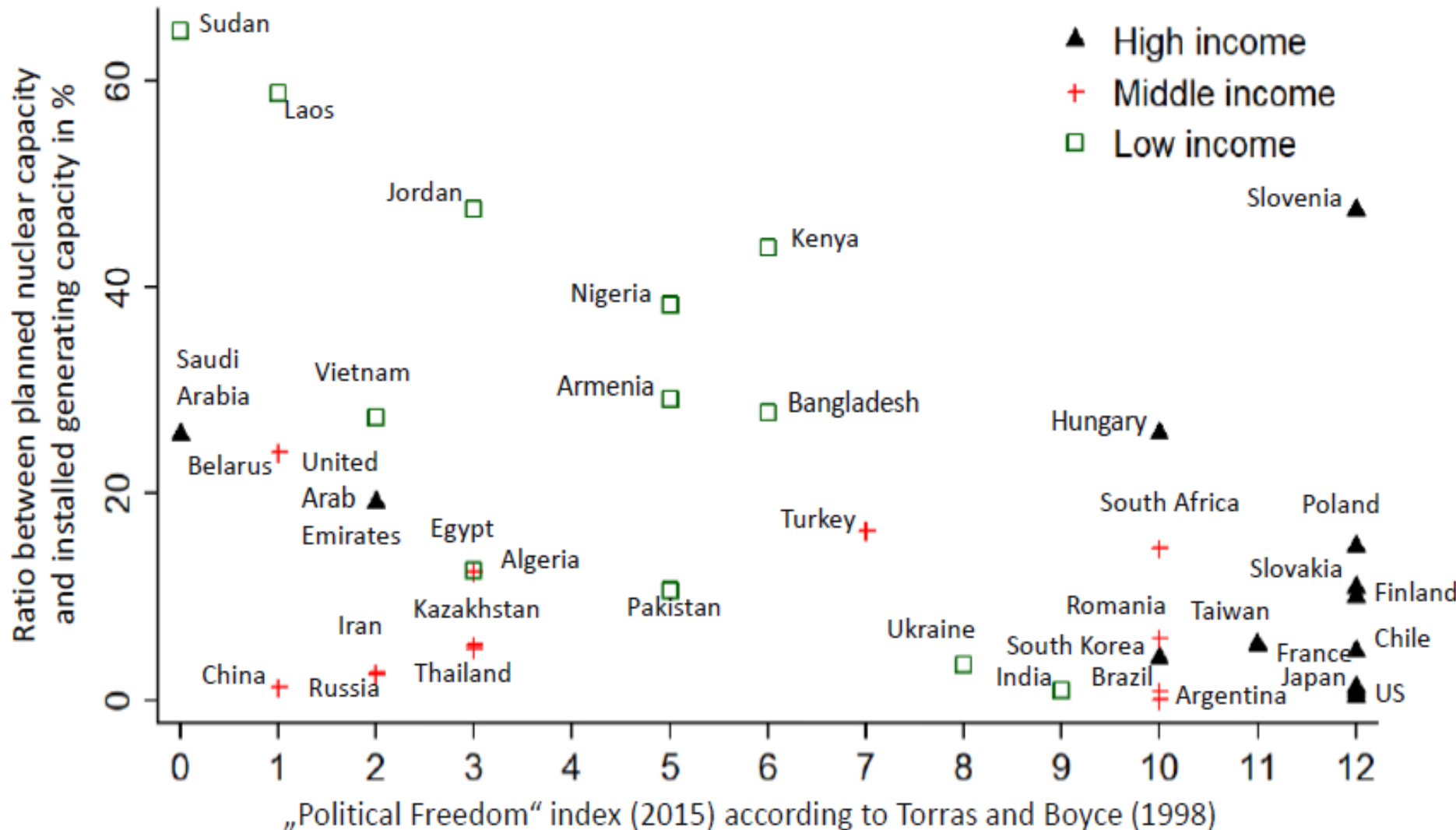


Christian von Hirschhausen, Ben Wealer, Anne Neumann, and Lars Sorge

Agenda

- 1) Motivation and research question**
- 2) Related literature**
- 3) Country groupings, data, and variable selection**
- 4) Methodology**
- 5) Empirical results**
- 6) Conclusion**

Link between nuclear newbies and “political freedom“



Motivation and research question

State-owned nuclear companies in Russia and China provide nuclear power plants to emerging countries at very favorable conditions including finance and fuel services (World Nuclear Association, 2018a; Schneider et al., 2018).

Research question: How is a countries' choice to go nuclear influenced by the level of democratic development?

Hypothesis: Democracies tend not to invest in future nuclear power development in contrast to totalitarian countries.

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Related literature

- Low levels of civic activism are influential factors in supporting development of nuclear power (Sovacool and Valentine, 2010)
- Driving forces and barriers for nuclear energy for both newcomer and established nuclear countries (Jewell, 2011)
 - Technical requirement: sufficiently large and reliable grid.
 - Financial capacity: entails allocating an initial investment usually from public funds.
 - Institutional capacity: influences the ability to establish private investment.
- Socio-economic, environmental and technological factors characterizing a countries' nuclear energy strategy (Gralla et al., 2017)
 - Nuclear countries including phase-out countries used more energy per capita and showed higher levels of carbon emissions.
 - Adoption of nuclear energy does not appear to reduce fossil fuel use or enable energy independence.
 - Focus on the political dimension of nuclear power highly relevant to complement the global view on nuclear energy.

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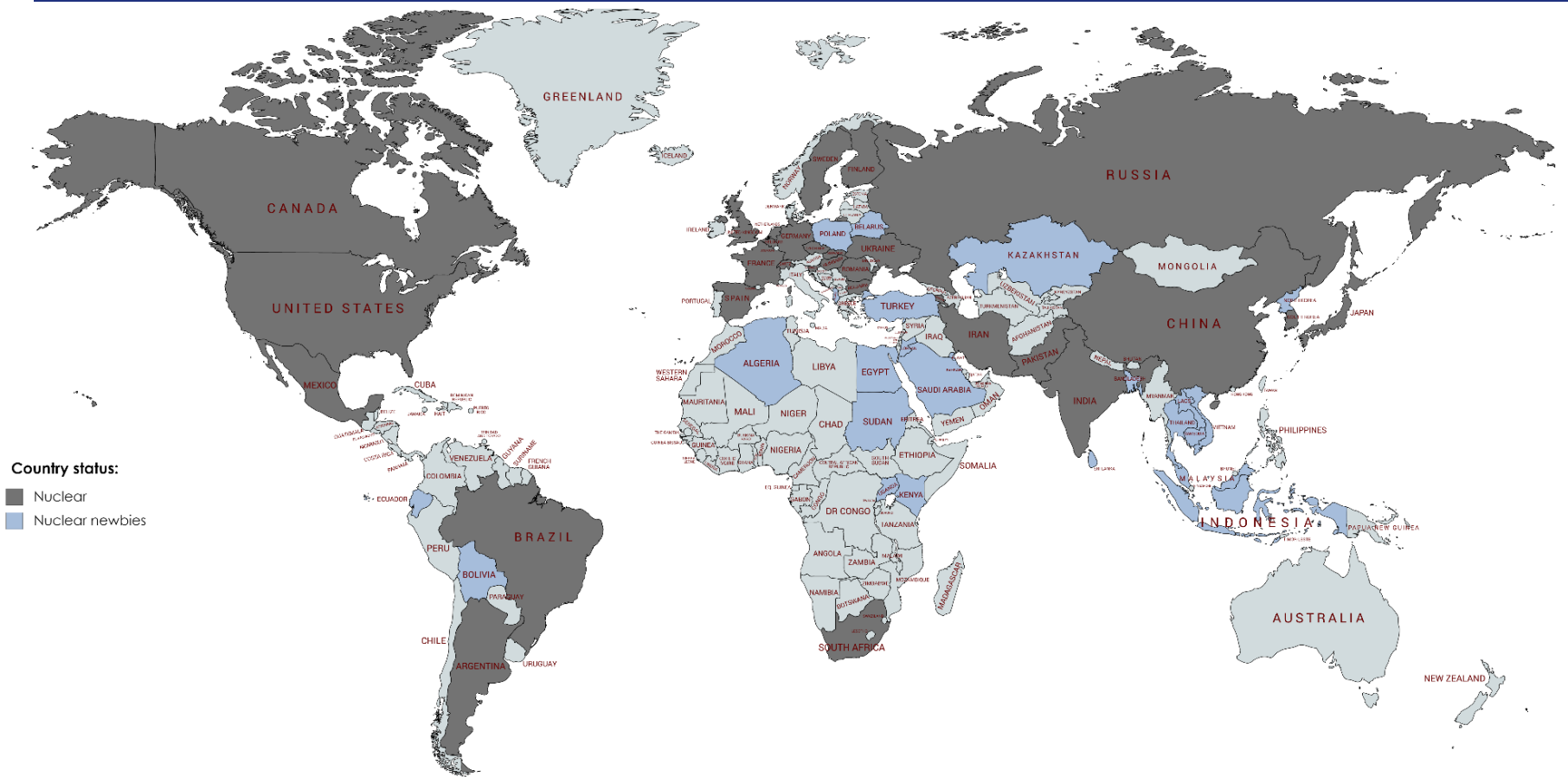
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Global perspective



Notes: Countries not colored are considered as non-nuclear. **Nuclear group:** Argentina, Armenia, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, India, Iran, Japan, Korea, Rep., Mexico, Netherlands, Pakistan, Romania, Russian Federation, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and United States. **Nuclear newbies group:** Albania, Algeria, Bangladesh, Belarus, Bolivia, Cambodia, Ecuador, Egypt, Indonesia, Jordan, Kazakhstan, Kenya, Dem. People's Republic Of Korea, Kuwait, Lao PDR, Malaysia, Poland, Saudi Arabia, Sri Lanka, Sudan, Thailand, Turkey, Uganda, and Vietnam.

Sources: Wealer et al. (2018), World Nuclear Association (2018a), World Nuclear Association (2018b), and PRIS (2018).

Measures of democratic development

Freedom House

- Basic democratic rights considering political rights (PR) and civil liberties (CL)
- PR and CL measured on a one-to-seven scale
- Aggregated country average:
- Free (1.0 to 2.5)
- Partly Free (3.0 to 5.0)
- Not Free (5.5 to 7.0)

Polity IV Project

- Political regime characteristics (democratic vs. autocratic)
- Normalized Polity2 index from 0 to 100 (Haber and Menaldo, 2011)
- Aggregated country average:
- Polity2 > 66 → Free
- 33 < Polity 2 < 66 → Partly Free
- Polity2 < 33 → Not Free

Freedom House description

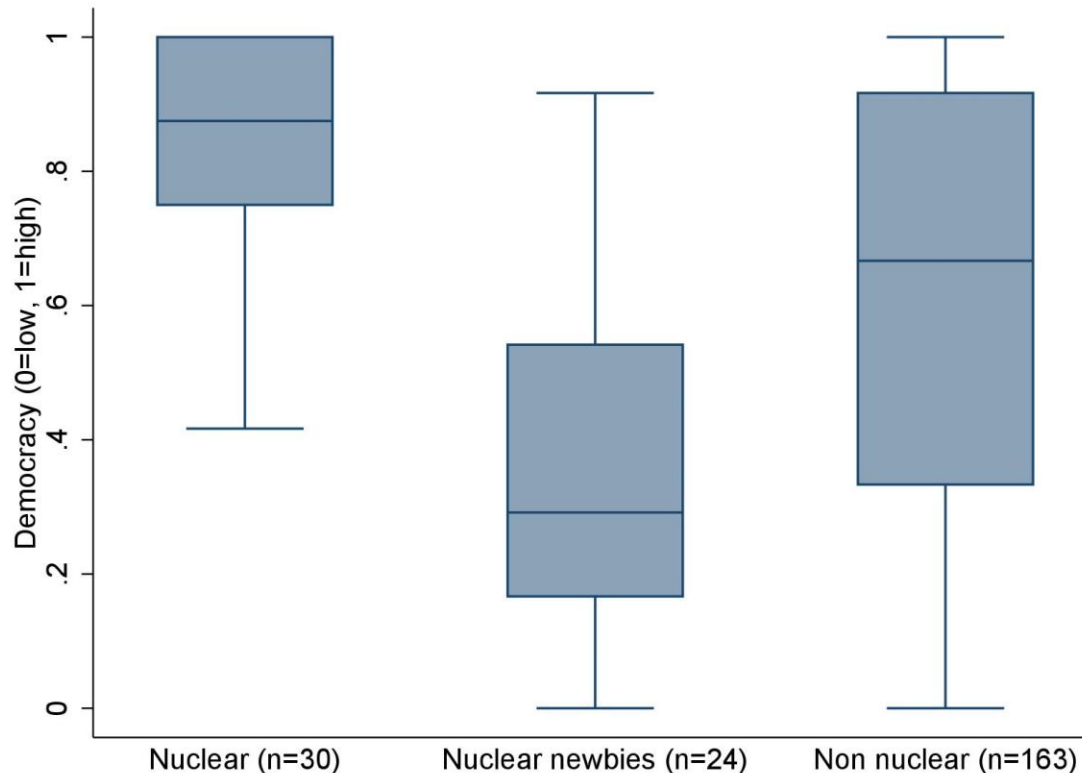
Political rights:

Countries and territories with a rating of 1 (highest level of political) enjoy a wide range of political rights, including **free and fair elections**. Candidates who are elected actually rule, **political parties are competitive**, the **opposition** plays an **important role** and **enjoys real power**, and the interests of **minority groups** are well **represented** in politics and government.

Civil liberties:

Countries and territories with a rating of 1 (highest level of civil liberties) enjoy a wide range of civil liberties, including **freedoms of expression, assembly, association, education, and religion**. They have an established and generally **fair legal system** that **ensures the rule of law** (including an independent judiciary), allow **free economic activity**, and tend to strive for **equality of opportunity for everyone, including women and minority groups**.

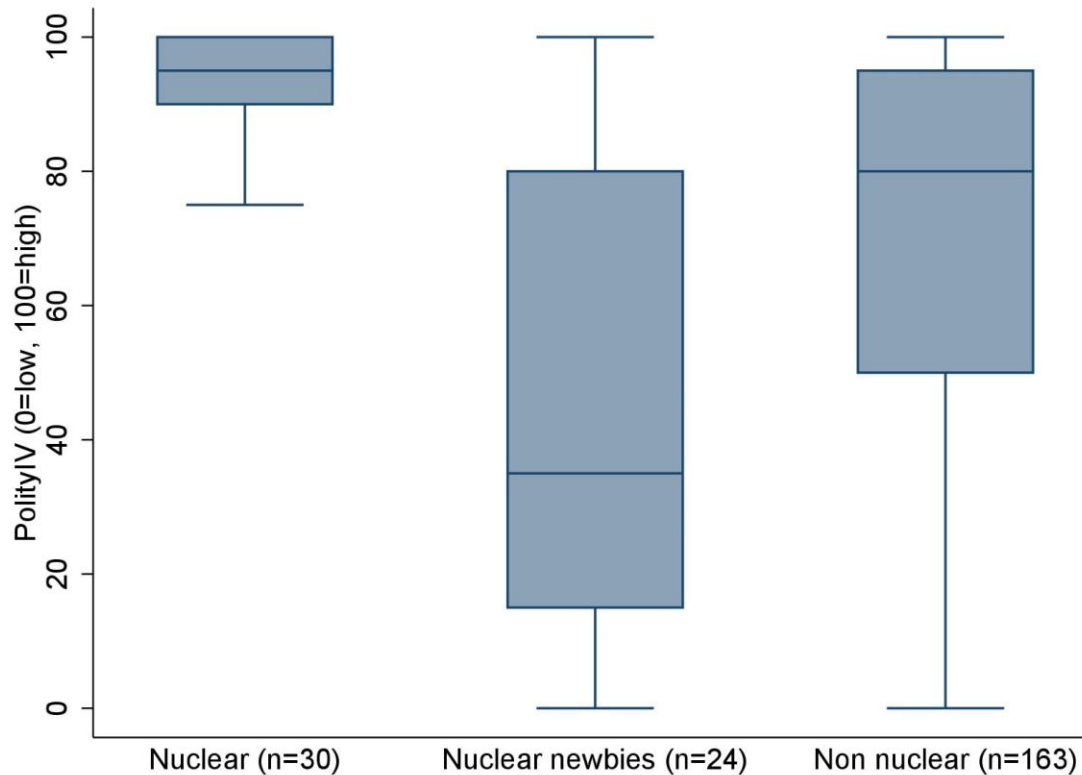
Freedom House (continuous)



- Low levels of civic activism are influential factors in supporting development of nuclear power (Sovacool and Valentine, 2010).
- Helliwell (1994): democracy measure graded with scores from 0 (no political rights and civil liberties) to 1 (complete set of political rights and civil liberties).
- Democracy measure I: $(14 - (PR + CL)) / 12$

➤ Emerging nuclear countries have the lowest democracy score in 2017.

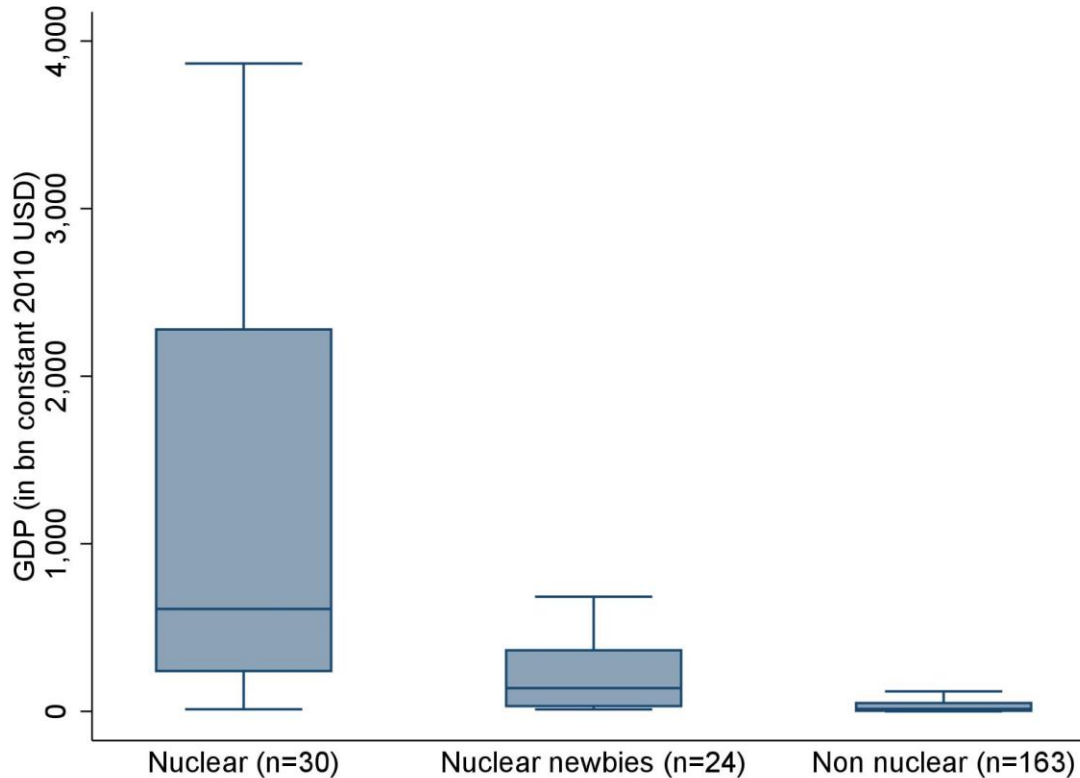
Polity IV Project (continuous)



- Low levels of civic activism are influential factors in supporting development of nuclear power (Sovacool and Valentine, 2010).
- Normalized Polity2 index from 0 (strongly autocratic) to 100 (strongly democratic) (Haber and Menaldo, 2011).
- Democracy measure II: $(Polity+10)*5$

➤ Emerging nuclear countries have the lowest democracy score in 2017.

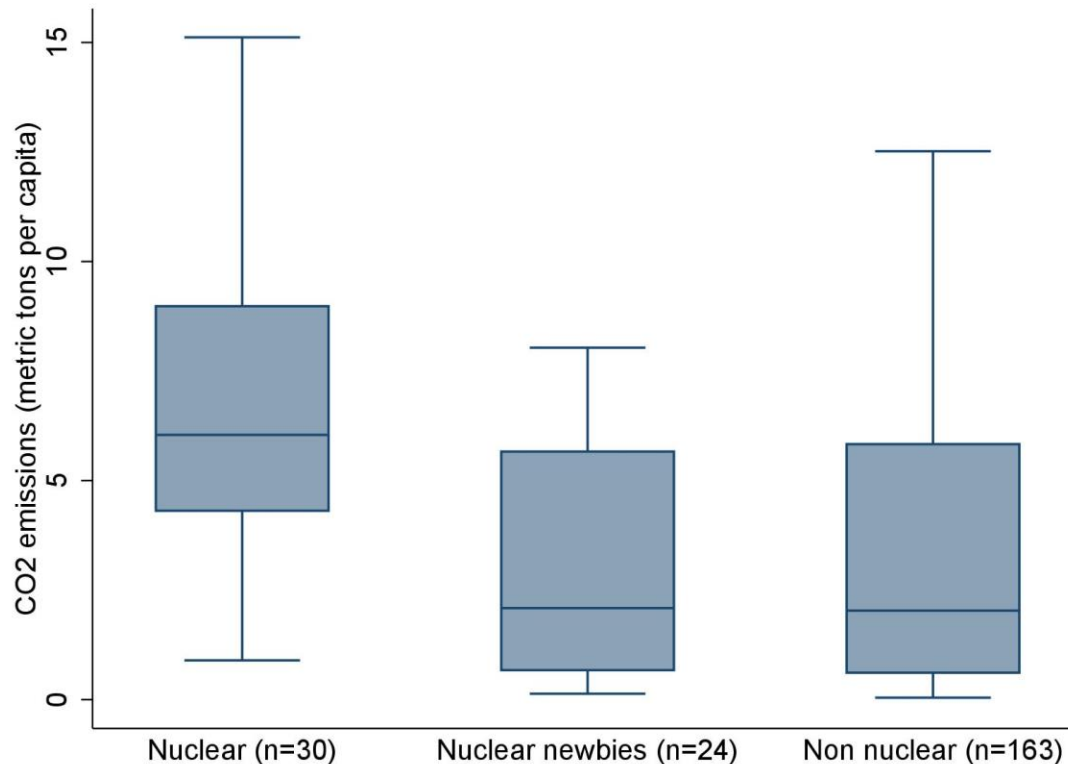
GDP



- Main indicators of financial capacity are the country's GDP or its GDP per capita (Jewell, 2011).
- Nuclear power is the most expensive generation technology (e.g. Davis 2012; D'haeseleer 2013).

➤ Emerging nuclear countries have the second lowest GDP in 2017.

CO₂ emissions per capita



- Considered as low carbon generation source
- But high lifecycle emissions (Fritsche, 2007)
- Mixed empirical evidence on nuclear energy use and reductions in carbon emissions in the long-term (e.g. Al-Mulali, 2014; Apergis et al., 2010).

➤ Emerging nuclear countries have the second lowest CO₂ emissions per capita in 2017.

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Methodology

Multinomial logistic regression: predict categorical placement in or the probability of category membership based on independent variables.

Response variable: Nuclear strategy selected in 2017 (194 countries).

- Non-Nuclear (j=0, reference group), Nuclear-Newbie (j=1), and Nuclear (j=2).

The log odds of the outcomes are modeled as a linear combination of the predictor variables.

- Democracy rating free (F, base group) partly free (PF), not free (NF), GDP, and CO₂ emissions per capita.
- The estimated equations provide the parameter estimates which are relative to the reference group.

$$\eta_{i1} = \log \left(\frac{\pi_i^{(1)}}{\pi_i^{(0)}} \right) = \alpha^{(1)} + \beta_1^{(1)} F_i + \beta_2^{(1)} PF_i + \beta_3^{(1)} NF_i + \beta_4^{(1)} GDP_i + \beta_5^{(1)} CO_{2i}$$

$$\eta_{i2} = \log \left(\frac{\pi_i^{(2)}}{\pi_i^{(0)}} \right) = \alpha^{(2)} + \beta_1^{(2)} F_i + \beta_2^{(2)} PF_i + \beta_3^{(2)} NF_i + \beta_4^{(2)} GDP_i + \beta_5^{(2)} CO_{2i}$$

- Where we specify the non-nuclear group (3) as the reference group.

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Freedom House: log-odds-ratio and relative risk ratio

log odds ratio		exp(log odds ratio)=RRR	
Nuclear (j=2)	Nuclear Newbie (j=1)	Nuclear (j=2)	Nuclear Newbie (j=1)
<i>F</i>			
<i>PF</i>			
<i>NF</i>			
<i>GDP</i>			
<i>CO₂</i>			
<i>const.</i>			

exp(log odds ratio) = Relative Risk Ratio

Notes: RRR is the Relative Risk Ratio. Z-values are in parantheses; superscripts *a*, *b*, and *c* represent significance at 1%, 5%, and 10%, respectively. Free is the base category of the Freedom Rating indicator variable FR; the reference group is non-nuclear (j=0).

- For democratically not free countries (NF) relative to free countries (F), the relative risk of being in the Nuclear Newbies group (j=1) relative to the Non-nuclear group (j=0) would be expected to increase by a factor of 26.483 given the other variables in the model are held constant.
- **Democratically not free (NF) countries are more likely than free (F) countries to be in the Nuclear Newbies group (j=1) than in the Non-Nuclear group (j=0).**

Polity IV Project: log-odds-ratio and relative risk ratio

log odds ratio		exp(log odds ratio)=RRR	
Nuclear (j=2)	Nuclear Newbie (j=1)	Nuclear (j=2)	Nuclear Newbie (j=1)
$P > 66$			
$33 < P < 66$			
$P < 33$			
GDP			
CO ₂			
const			

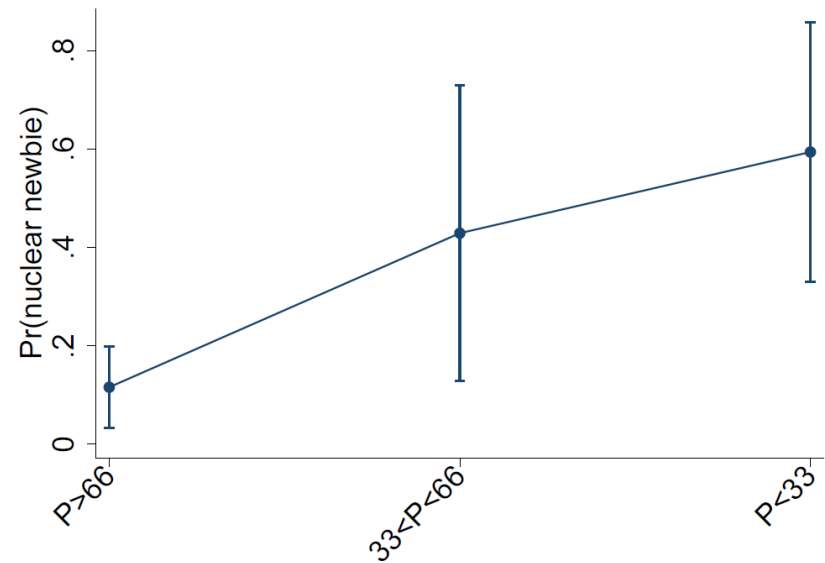
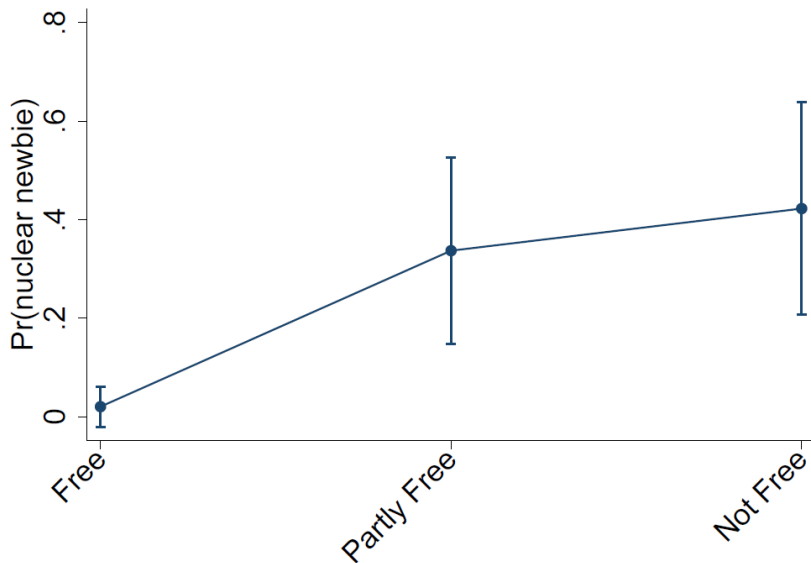
$\exp(\log \text{ odds ratio}) = \text{Relative Risk Ratio}$

Notes: RRR is the Relative Risk Ratio. Z-values are in parentheses; superscripts *a*, *b*, and *c* represent significance at 1%, 5%, and 10%, respectively. $P > 66$ is the base category of the Polity IV indicator variable P; the reference group is non-nuclear ($j=0$).

- For democratically not free countries ($P < 33$) relative to free countries ($P > 66$), the relative risk of being in the Nuclear Newbies group ($j=1$) relative to the Non-nuclear group ($j=0$) would be expected to increase by a factor of 7.989 given the other variables in the model are held constant.
- **Democratically not free ($P < 33$) countries are more likely than free ($P > 66$) countries to be in the Nuclear Newbies group ($j=1$) than in the Non-Nuclear group ($j=0$).**

Predicted probabilities

Predicted probability of choosing the strategy “to go nuclear”, at each level of democratic freedom holding CO₂ and GDP at their means: $\hat{\pi}^{(\text{Nuclear Newbie})} = \frac{\exp(L^{(\text{Nuclear Newbie})})}{1 + \exp(L^{(\text{Nuclear Newbie})}) + \exp(L^{(\text{Nuclear Newbie})})}$



Notes: Left (right) plot indicates each level of the Freedom House (*POLITY™IV PROJECT*) indicator.

- The predicted probability of being in the Nuclear Newbies group (j=1) increases with decreasing levels of democratic freedom for both measures of democratic development.
- **Totalitarian countries tend to invest in future nuclear power development.**

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Conclusion

The group of emerging nuclear countries have the lowest level of democratic development and the second lowest GDP in 2017.

The level of democratic development tends to be a significant predictor for the choice of a countries energy strategy to go nuclear.

Totalitarian countries tend to invest in future nuclear power development.

A closed political system with limited public participation and discussions favors nuclear energy production (Sovacool and Valentine, 2012).

Only if both freedom of expression and the media is free, citizens are able to understand more fully the risk of nuclear energy (Yamamura, 2012).

Politically less stable countries might have difficulties to garner both international support and investment to launch new nuclear energy programs (Jewell, 2011).

Thank you for your attention!

Contact:

Christian von Hirschhausen: cvh@wip.tu-berlin.de

Lars Sorge: lsorge@diw.de

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Backup

Vendors for potential newcomer countries

	Site	Proposed Vendor	Initial Startup Date	Proposed Construction Start	Current Startup Date
Under Construction					
Bangladesh	Rooppur	Rosatom	Nov 2017	April 2018	2023
Belarus	Ostrovets	Rosatom	2016/18		2019 (Q4)/2020 (Q3)
Turkey	Akkuyu	Rosatom	2015	2018	2023
UAE	Barakah	KEPCO	2017/18/19/20		2019/2020
Contract Signed or Advanced Development					
Lithuania	Visegrade	Hitachi	2020	Suspended	-
Turkey	Sinop	Mitsubishi/Areva		?	-
	Ingeada	SNPTC/Westinghouse		2019	-
Vietnam	Ninh Thuan	Rosatom	2020	Suspended	-
Committed Plans					
Egypt		Rosatom	2019	2018	2026/2027
Jordan		Rosatom		2019	2024
Poland				?	2029
Well Developed Plans					
Chile			2024	Suspended	-
Indonesia		Rosatom		Indefinitely Postponed	-
Kazakhstan		Rosatom or Westinghouse		?	-
Saudi Arabia			2020	?	2027

Source: Schneider et al. (2018)

Unclassified countries

Kuwait: is considering its own nuclear program for power and water, and in March 2009 moved to set up a national nuclear energy commission, in cooperation with the IAEA.

Yemen: is considering plans for using small nuclear reactors to 300 MWe in 2025-2030, then a commercial nuclear power plant with 1000-1500 MWe about 2035. It is working with IAEA on these plans. Meanwhile a research reactor is envisaged. An atomic energy law is in draft form.

Ghana: in late 2014 the target was to start building 700 MWe before 2020 for 2025 commissioning and expanding to 1000 MWe.

Senegal: in 2011 the president said that he had cancelled plans for nuclear power.

Uganda: Uganda's Vision 2040 roadmap incorporates the development of significant nuclear capacity as part of the country's future energy mix.

Ecuador: in August 2009 the government signed a nuclear cooperation agreement with Russia's Rosatom with a view to developing a nuclear power program and related projects.

North Korea: is not currently considered as having serious intentions to deploy nuclear power for electricity.

Georgia: no information available

Freedom House description

Political rights:

Countries and territories with a rating of 1 (highest level of political) enjoy a wide range of political rights, including **free and fair elections**. Candidates who are elected actually rule, **political parties are competitive**, the **opposition** plays an **important role** and **enjoys real power**, and the interests of **minority groups** are well **represented** in politics and government.

Civil liberties:

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Country groupings: methods

No clear consensus in the related literature and difficult to identify:

- Adamantiades and Kessides (2009): 40 developing countries have approached the UN to express their interest in starting nuclear power programs.
- Jewell (2011): 52 countries which have contacted International Atomic Energy Agency (IAEA) for help in starting a nuclear power program.
- Gralla et al. (2017): 17 countries planning to go nuclear based on information from the World Nuclear Association (WNA).
- Schneider et al. (2018): 15 potential newcomer countries listed in the World Nuclear Industry Status Report 2018.

WNA lists 62 countries on their emerging nuclear energy countries website:

1. Power reactors under construction (n=4)
2. Contracts signed, legal and regulatory infrastructure well-developed or developing (n=3)
3. Committed plans, legal and regulatory infrastructure developing (n=2)
4. Well-developed plans but commitment pending (n=6)
5. Developing plans (n=7)
6. Discussion as policy option (n=22)
7. Officially not a policy option at present (n=10)
8. Unclassified (n=8)

➤ 47 „Emerging Nuclear Energy Countries“ which fall into the categories (1) to (6) and (8).