



Government political ideology and green innovation: evidence from OECD countries

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Abstract

In this paper, we examine the relationship between government political ideology and green innovation. We employ data on 20 democratic countries with multi-party systems between 2010 and 2018. Green innovation is measured by the total patents in environment-related technologies. We find a negative relationship between left-leaning government and green innovation, suggesting that leftist governments are associated with low green innovations. This finding is consistent with the political assumption that leftist governments resist technological advancement because it may cause unemployment, whereas rightist promotes technological advancement to benefit the capitalist. We also find that the effect of political ideology remains the same during electoral years, implying that elections do not present any pressure on parties to change their course towards green innovation. Our result implies that partisan politics matters in finding solutions to unending environmental challenges. The results are robust to alternative measurements of variables and econometric identification strategies.

Keywords Environment · Environmental sustainability · Green innovation · Government political ideology

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1 Introduction

Existing studies have established the significant contribution of green innovation to a sustainable environment and economic growth (Cheng et al. 2021; Ibrahim & Vo 2021; Rosenberg 2004; Smulders et al. 2014). Consequently, emerging scholarship has indicated some economic and technological factors influencing green innovation, but mainly at the firm level (Fang & Zhang 2021; Jun et al. 2019; Y. Ma et al. 2021; Siedschlag et al. 2019; Smulders et al. 2014; Zhang et al. 2020). However, these economic and technological factors are driven by the government and formed by political parties. Bhattacharya et al. (2017) argue that politics is a significant driver of innovation because it is politicians who alter the economic environment through policies and regulatory decisions. These politicians are bound by their ideological orientation, which shapes policies. Political ideology is found to be a significant explanation for the variation in innovation adoption by the government (L. Ma 2017; Wang et al. 2019).

The research gap on government political ideology and green innovation lies in the need for empirical investigation at the country level, considering the influence of political orientation on national-level policies and their impact on green innovation. While existing studies have explored economic and technological factors influencing green innovation primarily at the firm level, there is a paucity of research examining the role of government political ideology in shaping national-level innovation strategies, particularly in the context of environmental technologies. Some scholars argue that political ideology shapes government policies and regulatory decisions (Bhattacharya et al. 2017), which in turn affect innovation adoption; there is limited empirical evidence on the relationship between political ideology and green innovation.

Therefore, in this paper, we contribute to the nascent literature on politics and innovation by examining the relationship between political ideology and green innovation. Specifically, we investigate whether the leftist–rightist political ideological orientation affects the level of innovation in environmental-related technologies at the country level.

Leftist governments typically prioritise the protection and welfare of the working class, potentially favouring immediate welfare provision over investments in long-term green innovation (Vivarelli 2014). Therefore, leftist governments are likely to increase transfer payments for the immediate welfare of citizens rather than invest in green innovation that might take a long time to yield benefits. Also, the application of green innovation is likely to reduce the demand for labour forces, which is against the core ideology of leftist government (Vivarelli 2014). Despite these tendencies, leftist parties often espouse pro-environmental policies (Neumayer 2003, 2004), reflecting a commitment to improving environmental quality. Although leftist government is less likely to be interested in general innovation, the case might be different when it comes to green innovation due to its pro-environmentalism.

Contrary to leftists, rightist governments are more likely to favour innovation because new technology increases profitability and benefits capitalists (Wang

et al. 2019). Rightist government is found to loosen regulations in the market and promote the process of new technology (Bjørnskov & Potrafke 2012). While rightist government may promote general innovation because of its associated benefit to its constituents, the case can differ regarding green innovation. Investment in green innovation is costly, with no immediate benefit (Homroy & Slechten 2019), especially for any particular person. Green innovation is regarded as a social responsibility (Chen 2008; Chen et al. 2006) which is meant to improve the environment and general public but not the selected few. Also, prior studies have shown that, compared with leftist, rightist governments care less about the environment (Neumayer 2003, 2004). Therefore, we argue that rightist government might promote general innovation but not that of green innovation¹.

The aforementioned characteristics of both the leftist and rightist governments in relationship to green innovation are intriguing and exciting, hence worthy of empirical examination. Therefore, we employ panel data on 20 countries between 2010 and 2018 to examine the relationship between political ideology and green innovation. Consistent with (Cusack & Engelhardt 2002; Knill et al. 2010; V. Tawiah 2022) we use the centre of gravity approach to construct political ideology. Green innovation is measured as the total number of patents in environment-related technologies scaled by GDP per capita. Data are sourced from OECD (2021). Our findings reveal a negative relationship between leftist governments and green innovation, indicating that countries governed by leftist-leaning administrations exhibit lower levels of green innovation compared to those led by rightist-leaning governments. Furthermore, our analysis does not support the electoral view that election alters the relationship between political ideology and green innovation. Additionally, we demonstrate that the lower levels of green innovation under leftist governments may lead to higher carbon emissions, challenging the perception of leftist parties as inherently pro-environmental (King & Borchardt 1994). Our results are robust to alternative measurement and different identification strategies including Two-step System-Generalised Method of Moments (S-GMM)

Our study makes incremental contributions to literature and practice in several ways. The study enriches the literature on green innovation by focusing on country-level outcomes. Existing literature on green innovation is largely dominated by firm-level studies (Chen 2008; Chen et al. 2006; Hermundsdottir & Aspelund 2021; Leyva-de la Hiz et al. 2019). We argue that it is the government that provides an enabling environment to drive innovation by the firms. As argued by Wang et al. (2019), it is the government that has the power and motivation to influence innovation progress; hence, the country-level innovation environment is essential.

This study contributes to the literature and practice in several ways. The paper enriches the understanding of green innovation by examining country-level outcomes, complementing existing firm-level studies and emphasizing the role of

¹ For example, Trump was a rightist, but it was unlikely that Trump supported green innovation, compared to Obama or Biden. This is because Trump suspended many funds for environmental protection, like mitigation of climate change

government in facilitating innovation (Chen 2008; Chen et al. 2006; Hermundsdottir & Aspelund 2021; Leyva-de la Hiz et al. 2019).

By focusing on the effect of political ideology on green innovation, this study extends the literature on environmental politics beyond generic innovation or environmental performance measures (Chang & Berdiev 2011; Garmann 2014; King & Borchardt 1994; Neumayer 2003, 2004; Wang et al. 2019; Wen et al. 2016). Notwithstanding the consistency of our study to Wang et al.'s (2019) finding, we argue that our study provides more accurate and reliable findings of political ideology on innovation because we focus on democratic countries. Lumping more countries with different democratic systems, as done by Wang et al. (2019), may bias the results. Arguably, partisan politics and ideological difference matters in countries with multi-party democratic systems (Facchini & Melki 2014). Our findings provide empirical evidence that leftist governments may not be as proactive in promoting green innovation as previously assumed, contrary to the findings of Wang et al. (2019).

We extend the electoral view theory by showing that election pressure does not change political parties' policies and activities towards green innovation. Finally, our further analysis of the net effect of political ideology and innovation on carbon emission provides evidence that the rightist government are likely to decrease carbon emissions through its positive effect on green innovation. This finding is relevant for policymakers as it shows that investment in green innovation pays off by reducing carbon emissions.

The remainder of the paper is structured as follows. Section 2 is a literature review of political ideology and green innovation. Section 3 presents the research methodology employed herein. Section 4 provides the empirical results and discussions of the findings. The conclusion and policy implication is presented in Section 5.

2 Literature review

Like any other innovation, green innovation is a commitment of today's resources for the benefit of the future (Bhattacharya et al. 2017). However, green innovation is different from other forms of innovation because of the higher rate of failure and the social dimension of its benefits (Homroy & Slechten 2019; Jun et al. 2019). Unlike other innovations, any environmental-related innovation may not have a direct economic impact on the profit of the firm. More so, the protection of the environment is perceived as a social responsibility rather than profit-making (Jun et al. 2019). Although existing studies show that political ideology affects innovation (Wang et al. 2019), it is unclear how political ideology affects green innovation.

Political ideology represents how each political party believes and expects a country to be managed and governed (Jost et al. 2009). The political-ideological theory states that each party holds contending views on how the country's activities and policies should be run (Alesina 1987; Hibbs 1977; Pearce 2006). As an institutional characteristic, the political ideology of the government can influence green innovation through budget allocation and policies.

Arguably, where and how public money should be spent largely depend on government ideology on how society should operate (Drazen & Eslava 2010). Traditionally, the leftist government is known for expansionary economic policies that provide transfer and welfare support to low-income and working-class society (Hibbs 1997). Consequently, prior studies argue that leftist government is less likely to invest in innovation because such expenditures do not provide immediate benefits to the working class (Wang et al. 2019). Furthermore, investment in innovation brings technological advancement and less demand for the labour force², which negatively affects the welfare of the working class (Vivarelli 2014). Therefore, a leftist government will lobby for the allocation of funds to support the immediate needs of the public than to invest in innovation. This could lead to less government incentive for innovation and technological advancement.

However, a leftist government may promote green innovation following its pro-environmentalism. Prior studies suggest that leftist government care more about the environment than rightist government (Chang & Berdiev 2011; Garmann 2014; King & Borchardt 1994; Neumayer 2003, 2004; Wen et al. 2016); therefore, their effect on green innovation could be different. Through environmental policies, the leftist government set a tone of environmental sustainability for the future. Neumayer (2003) argues that leftist governments formulate environmental policies to gain support from the lower social class, which is most negatively affected by the poor environment (Neumayer 2003). More so, given that businesses and enterprises are seen as the largest contributors to environmental problems (2003), and leftist governments have more preference for regulated markets (businesses and enterprises), it is quite logical to expect the leftist government to formulate stricter policies to regulate the activities of the market (Potrafke 2010). These strict environmental regulations can ignite firms to engage in green innovation to reduce environmental costs. Furthermore, the leftist government can allocate some budget to encourage green innovation to demonstrate its support for environmental sustainability (Neumayer 2004). The leftist government might back its environmental regulations with budget allocation to show leadership by example.

Contrary to leftist, the core of rightist ideology is the creation of wealth for different classes of people within society. As such, the rightist government is known to promote capitalist and private-sector growth rather than public-sector expansion. Wang et al. (2019) suggest that the rightist government will lobby for budget allocation into innovation to give high profits to capital owners than welfare to the working class. Following their core ideological orientation of private sector growth, a rightist government is likely to give firms more freedom to operate and innovate (Vivarelli 2014). As free-market reward innovation, firms will have more internalised incentives to engage in green innovation under rightist government than the leftist.

² According to Wang et al. (2019), a recent study by the US Department of Commerce with 2015 data shows that 15.5 million US workers' jobs will be affected by automation, which equals one-ninth of all US workers. The study divides the 15.5 million potential workers into two categories: 3.8 million who are likely to be unemployed and 11.7 million who exhibit adaptability.

Consistent with their ideological orientation, a rightist government can develop policies that directly and indirectly affect green innovation. For example, a rightist government may introduce tax incentives that give firms more cash flow to engage in green innovation (Audretsch et al. 2012). Other scholars argue that some policies that are not directly targeted to innovation may have a spill-over effect on innovation (Blind 2012). In a sample of 79 countries, Aidt et al. (2016) report that a change in government from leftist to rightist causes an increase in wealth, which spurs innovation (Smith et al., 2010).

However, a rightist government is less likely to exert a positive impact in the case of green innovation because green innovation does not only require very large investments; its return is very uncertain and most likely to be considered as a social venture rather than profit-generating. Due to this feature of green innovation, the drive for the rightist government to encourage innovation in the environment to benefit its constituents may be less. Green innovation does not bring an immediate and significant competitive edge for firms (Homroy & Slechten 2019). Therefore, even in a free market, the internalised benefit may not push firms to engage in green innovation.

In sum, while few studies have shown a significant relationship between political ideology and innovation, the aforementioned discussion leaves one unanswered question: Which political ideology positively affects green innovation, leftist or rightist?

3 Data and econometric modelling

3.1 Sample data

Our population covers all OECD countries. We focus on OECD countries to mitigate any potential unobserved heterogeneity effect on the results. Given that the difference in political–ideological orientation is best viewed in a multi-party democratic system (Facchini & Melki 2014), we limit our sample selection to OECD countries with a democratic and multi-party system of government. We also drop all countries with missing data, particularly on green innovation. Following prior studies on innovation (Lau et al. 2015; Wang et al. 2019), we use panel data from 20 countries between 2010 and 2018. The small sample size is consistent with prior studies on environmental politics (Chang & Berdiev 2011; Garmann 2014; Neumayer 2003, 2004). The sample period starts in 2010 and ends in 2018 because of data availability on green innovation. A list of sample countries is presented in Appendix A.

3.2 Model specification

Following prior studies, we perform different pre-regression analyses, including correlation, to determine the appropriate model for the dataset. We perform the Hausman's (1978) test to choose the appropriate panel estimator. The results indicate that the fixed effect is more appropriate than the random effect. Having established the

appropriateness of our dataset and selected the suitable estimator, we specify our baseline model as follows. Having established the appropriate econometric identification, we specify our baseline model as follows.

$$\begin{aligned} \text{Green innovation}_{it} = & a + \beta_1 \text{Political ideology}_{it} + \beta_2 \text{Economic growth}_{it} \\ & + \beta_3 \text{Economic development}_{it} + \beta_4 \text{Trade openness}_{it} \\ & + \beta_5 \text{Foreign direct investment}_{it} + \beta_6 \text{Carbon emission}_{it} + \beta_7 \text{Energy consumption}_{it} \quad (1) \\ & + \beta_8 \text{Technological advancement}_{it} + \beta_9 \text{Research and development}_{it} \\ & + \beta_{10} \text{Electoral system}_{it} + \beta_{11} \text{Government effectiveness}_{it} + \varepsilon_{it} \end{aligned}$$

where i and t refer to country and year, respectively. All variables are defined in Table 1.

3.3 Measurement of variables

3.3.1 Green innovation

We use the technology development indicator by OECD. This indicator represents the number of inventions (simple patent families)³ developed by the country's inventors, independent of the jurisdictions where patent protection is sought (OECD 2021). According to the OECD (2021), the dataset on technology development presents patent statistics and indicators suitable for tracking innovation in environment-related technologies. We use this indicator as green innovation because it allows the assessment of countries' and firms' innovation performance as well as the design of governments' environmental and innovation policies (OECD 2021). The use of the number of patents as a proxy for innovation is consistent with prior studies such as Lau et al. (2015) and Wang et al. (2019). The annualised data begin in 2010 and end in 2018; hence, our sample period is limited to these years. The total patents in environmental-related technologies consist of three sub-sets; (1) environmental management, (2) climate change, (3) sustainable ocean economy. Consequently, as additional analyses, we test the impact of political ideology on each of these subsets. By doing this, we demonstrate whether the effect of political ideology differs among the areas of green innovation.

3.3.2 Political ideology

Following prior studies (Knill et al. 2010; V. Tawiah 2022), our measurement of political ideology is based on Manifesto Project (MARPOR). The MARPOR provides information on the political ideology of political parties on a scale from -100 to $+100$. A score of -100 means leftist and $+100$ for rightist parties. To account for different parties forming one government or coalition government, we follow (Cusack & Engelhardt 2002; Gross & Sigelman 1984; Knill et al. 2010) by

³ We use one or greater family size.

Table 1 Variable description

Variable name	Definition	Sources
Green innovation	The total number of patents in environmental-related technologies	OECD statistics
Environmental management innovation	The number of patents in environmental-related technologies for environmental management	OECD statistics
Climate change innovation	The number of patents in environmental-related technologies for climate change	OECD statistics
Sea Ocean innovation	The number of patents in environmental-related technologies for Sea ocean	
Political ideology	It is calculated based on the partisan composition of government using the proportionate share approach (centre of gravity). It ranges from 0 to 200, with an increasing value indicating a left-leaning government	Comparative Manifesto Project, Cusack & Engelhardt (2002)
Econ. Growth	Annualised GDP growth rate	World Development Indicator
Trade openness	Sum of import and export as a percentage of gross domestic product	World Development Indicators
Foreign direct investment	The net inflow of foreign direct investment as a percentage of gross domestic product	World Development Indicators
Carbon emission	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement scaled by per capita	World Development Indicators
Energy consumption	Energy use refers to the use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. Measure in kg of oil equivalent per capita	World Development Indicators
Technological advancement	The number of internet users per 1000 population	World Development Indicators
Research development	The ratio of research and development expenditure to GDP	World Development Indicators
Electoral system	A categorical variable that takes 0 for presidential systems; 1 for assembly elected president systems, and 2 for parliamentary systems	Database of Political institutions
Government effectiveness	Government effectiveness measures the perception of the quality of public services and policy formulation and implementation, and the credibility of the government's commitment to such policies. It ranges from -2.5 to 2.5	World Governance Indicators
Election	A dummy variable equals 1 if there was an election in that year or 0 otherwise	Seki and Williams (2014)

generating political ideology based on the centre of gravity. We use partisan composition of the government (both parliamentary parties and composition of the cabinet) by Cusack and Engelhardt (2002), to calculate the centre of gravity on the ideological left–right dimension as the proportion of party members in government multiple by the political ideology of the party. The final centre of gravity ranges between -100 and $+100$. However, consistent with prior studies (V. Tawiah 2022) and other source of political ideology (e.g. Database of Political Institutions and Seki and Williams (2014)) as well as for easy interpreting and analyses we use the revert form which ranges between 0 and 200 where high values indicate left –leaning ideology. The centre of gravity approach captures the government ideology position but not a single party. The centre of gravity approach is relevant for our sample, given that most of the countries have collation governments. This approach is also consistent with Knill et al. (2010).

Prior studies suggest that position political parties on the ideology scale are challenging and not always accurate. Hence a single source may bias the results. Therefore, following Wang et al. (2019) we use political ideology scores by Cruz et al. (2021) at the Database of Political Institutions (DPI) as alternative measurement to check the robustness of the results. DPI captures a political party's swings along the ideological spectrum. Political ideology is measured on an ordinal scale of 1–3, where 1—right dominating government; 2—centrist government; 3—left dominating government. The un-tabulated results confirm our main findings.

3.3.3 Control variables

Consistent with prior studies (Pece et al. 2015) we control for different factors that are likely to influence green innovation. These factors include economic growth (Pece et al. 2015), trade openness and foreign direct investment (Perri & Peruffo 2016; Song et al. 2015); carbon emissions (Du et al. 2019); energy consumption (Chang & Berdiev 2011); technological advancement (Harms & Lutz 2006; Lau et al. 2015); research and development (Wang et al. 2019); electoral system (Bernauer and Koubi 2009); government effectiveness (Lau et al. 2015). Descriptions and sources of each variable are presented in Table 1.

4 Results and discussion

4.1 Univariate analysis

The descriptive statistics of the variables are presented in Table 2. The statistical information includes the mean, median, 75th, 90th, and standard deviation. The mean of *Total green innovation* is 24,442, suggesting that, on average, more than 20,000 patents related to environmental technologies were developed among the sample countries. However, we observed that the median is significantly smaller than the mean, and the standard deviation is larger, indicating high variation among the sample countries. We observe similar patterns for the three sub-set of green innovation, namely, *Environmental management innovation*; *Climate change innovation*,

Table 2 Summary statistics

Variables	(1) N	(2) Mean	(3) Median	(4) 75th	(5) 90th	(6) Std
Total green innovation	180	24,442	2,972	12,229	92,596	47,404
Env. Management innovation	180	2,811	350.0	1,514	13,016	5,163
Climate change innovation	180	546.5	75.17	266.9	1,764	1,150
Sea Ocean innovation	180	189.7	24.50	110.1	545.6	467.5
Political ideology	180	107.6	110.1	153.8	181.3	59.59
Economic growth	180	1.572	1.849	2.583	3.623	1.997
Trade openness	180	87.68	77.60	103.8	157.4	38.30
Foreign direct investment	180	2.992	1.876	3.684	7.071	9.462
Carbon emissions	180	0.225	0.193	0.279	0.410	0.120
Energy consumption	180	91.79	87.38	104.9	129.7	26.17
Technological advancement	180	80.81	83.23	89.94	94.62	11.65
Research and development	180	2.062	1.924	2.868	3.211	0.791
Electoral system	180	1.883	2	2	2	0.452
Government effectiveness	180	1.373	1.551	1.793	1.886	0.520
Number of countries	20	20	20	20	20	20

Sea Ocean innovation. Regarding *Political ideology*, the mean of 107.6 suggests that our sample contains a good proportion of both leftist and rightist governments. The small standard deviation of 0.959 suggests that the political ideology of most countries is constant over the sample period.

In Table 3, we present the Pearson pairwise correlation matrix among the variables. From the table, we observe that, except for the correlation among the measurement of innovations, none of the coefficients is higher than the standard threshold to possess any multi-collinearity problems (Field 2000; Tabachnick & Fidell 2013). The high correlation among the different aspects of different innovations implies that the four measurements can be used as an alternative for robustness checks. We also find a moderate-high negative correlation between political ideology and green innovation, providing precursory evidence of the study.

4.2 Multivariate analysis

4.2.1 Main results

The regression results are presented in Table 4. To account for the effect of economic size on the results, we scaled the number of innovations by gross domestic product per capita (GDP per capita). We also include the country and year effect to capture the time-varying country effect on green innovation. To demonstrate the robustness of our results, we run separate regression for each of the sub-sets of green innovation. The result of the total green innovation is presented in column 1 and that of Environmental Management innovation in column 2. Climate and Sea

Table 3 Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
Total innovation	1												
Env. Management innovation	0.98	1											
Climate innovation	0.96	0.92	1										
State and Ocean innovation	0.77	0.82	0.86	1									
Political ideology	-0.44	-0.3	-0.2	-0.2	1								
Economic growth	-0.05	-0.08	-0.02	-0.04	-0.06	1							
Trade openness	-0.44	-0.47	-0.42	-0.42	-0.06	0.18	1						
Foreign direct investment	-0.06	-0.08	-0.05	-0.07	-0.15	-0.05	0.18	1					
Carbon emissions	-0.24	-0.24	-0.19	-0.11	0.01	0.15	0.25	0.04	1				
Energy consumption	-0.26	-0.24	-0.19	-0.08	-0.05	0.17	-0.01	0.03	0.37	1			
Technological advancement	0.05	-0.01	0.16	0.1	-0.21	0.36	0.07	0.07	-0.46	0.18	1		
Research and development	0.06	0.09	0.15	0.27	-0.06	0.17	-0.03	-0.1	-0.49	0.11	0.43	1	
Electoral system	0.13	0.14	0.12	0.1	-0.05	-0.22	-0.11	0.02	-0.52	-0.04	0.23	0.29	1
Government effectiveness	-0.01	-0.03	0.11	0.11	-0.11	0.19	-0.11	0.08	-0.49	0.3	0.83	0.54	0.3

Table 4 Main results

Variables	(1) Total innovation	(2) Env.Mgt	(3) Climate	(4) Sea Ocean
Political ideology	− 4.681** (− 2.040)	− 15.242** (− 1.961)	− 1.997** (− 2.484)	− 0.829** (− 2.275)
Economic growth	47.383 (0.625)	9.260 (0.801)	− 0.228 (− 0.085)	− 0.259 (− 0.132)
Trade openness	− 3.449 (− 0.094)	6.107 (1.090)	− 1.445 (− 1.107)	0.807 (0.847)
Foreign direct investment	− 1.476 (− 0.096)	− 1.098 (− 0.469)	0.172 (0.314)	− 0.041 (− 0.103)
Carbon emissions	64.757 (0.738)	81.709 (0.611)	73.519 (0.558)	70.695 (0.312)
Energy consumption	− 17.319 (− 0.402)	− 4.924 (− 0.750)	− 1.484 (− 0.970)	− 0.115 (− 0.104)
Technological advancement	44.293 (1.107)	4.302 (0.705)	3.316** (2.331)	1.048 (1.010)
Research and development	321.306 (0.434)	25.633 (0.227)	24.879 (0.945)	13.437 (0.700)
Electoral system	− 451.034 (− 0.419)	− 8.736 (− 0.053)	− 19.744 (− 0.516)	3.091 (0.111)
Government effectiveness	120.402 (0.109)	− 250.171 (− 1.483)	71.357* (1.814)	− 50.307* (− 1.754)
Constant	− 21.177** (− 2.546)	30.038** (2.386)	− 17.148** (− 1.938)	− 8.262** (− 2.435)
Country effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes
Observations	180	180	180	180
R-squared	0.111	0.173	0.202	0.114

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Ocean innovation are in columns 3 and 4, respectively. The main variable of interest in all four columns is *Political ideology*.

The coefficient of *Political ideology* is negative and passes the significant test at 5 percent or better in all four columns. This result implies that green innovation decreases as the government leans to the left of the political–ideological spectrum. That is, the number of patents in environmentally related technologies is lower in the leftist governments compared with the rightist governments. Our results are consistent with the assertion that a leftist government is less likely to promote innovation because any technological advancement could lead to unemployment (Vivarelli 2014). Although leftist governments are perceived as pro-environmentalist, their core philosophy of welfare for the working class and high employment may cause them to allocate more funds for immediate benefit than to invest in green innovation, which yields benefits in the future.

Table 5 Effect of election

Variables	(1) Total innovation	(2) Env.Mgt	(3) Climate	(4) Sea Ocean
Political ideology	− 3.278** (− 2.265)	− 16.912*** (− 2.885)	− 1.854** (− 2.415)	− 0.326** (− 2.100)
Political ideology*Election	137.451 (0.611)	6.040 (0.176)	− 0.686 (− 0.086)	2.298 (0.394)
Election	− 30.468 (− 0.643)	− 35.975 (− 0.505)	1.497 (0.090)	− 6.363 (− 0.525)
Constant	2.008 (1.548)	1.631 (1.127)	8.964** (2.452)	1.391 (1.212)
Country effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	180	180	180	180
R-squared	0.114	0.177	0.202	0.116

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Most green innovations are spearheaded by the private sector, with right-leaning governments generally being more supportive of private-sector initiatives compared to leftist governments (Jost et al. 2009). Consequently, leftist governments are less inclined to offer incentives like tax credits for innovation. This aligns with findings from the political ideology literature (Wang et al. 2019), suggesting that leftist governments are less inclined to allocate budgets towards green innovation due to the longer-term nature of the benefits. Moreover, their environmental policies often lack sufficient incentives for firms to engage in innovative practices. In essence, our findings suggest that while leftist governments may espouse pro-environmental ideologies, these have yet to translate into tangible increases in green innovation, largely due to their prioritisation of immediate welfare concerns and lesser support for the private sector.

Some of the control variables meet our expectations, and others are insignificant. For example, consistent with Wang et al. (2019), we find a positive relationship between *Research and Development* and green innovation. Similarly, we find *Foreign direct investment* to positively influence green innovation, which is consistent with the spill-over effect argument. Contrary to our expectations, we did not find a significant relationship between economic growth and green innovation, and the same can be said of economic development in most cases.

4.2.2 The effect of election

The previous analysis of political ideology and green innovation in Table 4 largely ignores any external pressure that could cause the government to deviate from its core ideology. In practice, some governments may engage in policies and actions that are not core to their beliefs due to external pressures such as elections (Boone

Table 6 Net effect on carbon emission

Variables	(1) Carbon emissions	(2) Carbon emissions	(3) Carbon emissions	(4) Carbon emissions
Political ideology*innovation	− 0.004 (− 0.716)			
Total green innovation	− 0.002** (− 2.682)			
Political ideology*Env.		− 0.000 (− 0.476)		
Env, management innov.		− 0.004** (− 1.969)		
Political ideology*Climate innov.			− 0.001 (− 1.012)	
Climate innovation			− 0.003** (− 2.226)	
Political ideology*Sea innovation				− 0.000 (− 0.013)
Sea and Ocean innovation				− 0.000* (− 1.787)
Political ideology	0.000 (0.079)	0.001 (0.228)	− 0.002 (− 0.411)	− 0.001 (− 0.276)
Constant	0.228*** (26.849)	0.214*** (30.699)	0.227*** (40.880)	0.222*** (67.338)
Control included	Yes	Yes	Yes	Yes
Observations	175	175	175	175
R-squared	0.001	0.021	0.007	0.028

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

1996; Englmaier & Stowasser 2017; Quinn & Shapiro 1991; Young 1999). Accordingly, the electoral view theory suggests that elections present some form of pressure that forces the government to develop electorally motivated policies and actions which might be different from its ideology (Quinn and Shapiro 1991). Governments do this in response to electoral pressure to win votes. Consequently, prior studies have demonstrated that the narrative on environmental policies differs according to the target audience of the government (Elliott-Teague 2011). For example, a left-ist government that wants to win votes on environmental issues will allocate more funds towards green innovation around election year, and this could increase the number of patents in environmental-related technologies. Also, some promises by the opposition party during an election year could force a government to adopt policies that may not necessarily flow from the political party's core ideological orientation. Therefore, in this section, we test whether external pressure, such as election, affects the relationship between political ideology and green innovation. To do this, we introduce two new variables in equation 1; *Election* is a dummy variable that takes on either 1 for years where there was an election in the country or 0 otherwise.

The other variable is an interaction term between election and political ideology (*Political ideology*Election*). Following the electoral view theory, we expect the coefficient of the interaction term (*Political ideology*Election*) to be significant. The results are presented in Table 5. In all the different measurements of green innovation (see columns 1–4), the coefficient of the interaction term is insignificant. Similarly, the coefficient of *Election* is insignificant. However, *Political Ideology* is negative and significant. The results, therefore, imply that the election does not present significant pressure to change the relationship between political ideology and green innovation. One possible reason for the insignificant effect of elections is that environmental issues are yet to drive election results. Hence, political parties are not given the needed attention during electoral years. Overall, our results do not support the electoral view theory in the case of green innovation.

4.2.3 Net effect on carbon emission

In this section, we investigate whether green innovation under different political ideologies affects environmental performance. Building on the negative relationship between leftist government and green innovation, we expect that there could be a spill-over effect on environmental performance. That is, the impact of green innovation on environmental performance could be less or insignificant under a leftist government compared with a rightist government. We use carbon mission, measured by CO₂ emission per capita, as a proxy for environmental performance (Neumayer 2004; V. K. Tawiah et al. 2021). CO₂ emission is the commonly used measure of environmental performance in the literature. In this section, we follow Wang et al. (2019) to use political ideology scores by Cruz et al. (2021) at the Database of Political Institutions (DPI). Political ideology is measured on an ordinal scale of 1–3, where 1—right dominating government; 2—centrist government; 3—left dominating government. To capture only the effect of leftist and rightist ideology, we exclude all centrist government from the sample. After excluding all centrist government, we recode *Political ideology* as a binary variable where 1= leftist government and 0= rightist government. Next, we interact *Political ideology* with each of the measures of the green innovation (*Political ideology*innovation*) and run a separate regression using the following model. Arguably, the impact of green innovation and political ideology requires some time to manifest. Hence, we use the one-year lag of the explanatory variable.

$$\begin{aligned}
 \text{Carbon emission}_{it} = & \alpha + \beta_1 \text{Political ideology} * \text{Green innovaton}_{it-1} \\
 & + \beta_2 \text{Green innovation}_{it-1} + \beta_3 \text{Political ideology}_{it-1} + \beta_4 \text{Economic growth}_{it-1} \\
 & + \beta_5 \text{Economic development}_{it-1} + \beta_6 \text{Trade openness}_{it-1} \\
 & + \beta_7 \text{Foreign direct investment}_{it-1} + \beta_8 \text{Energy consumption}_{it-1} \\
 & + \beta_9 \text{Technological advancement}_{it-1} + \beta_{10} \text{Research and development}_{it-1} \\
 & + \beta_{11} \text{Electoral system}_{it-1} + \beta_{12} \text{Government effectiveness}_{it-1} + \varepsilon_{it}
 \end{aligned} \tag{2}$$

where i and t refer to country and year, respectively. All variables are defined in Table 1.

Table 7 Endogeneity

Variables	(1) Total innovation	(2) Env.Mgt	(3) Climate	(4) Sea Ocean
Political ideology	- 1.265** (- 2.312)	- 3.561*** (- 2.570)	- 3.263** (- 2.205)	- 2.860*** (- 3.364)
Lag total innovation	0.221*** (66.104)			
Lag environmental innovation		0.214*** (77.541)		
Lag climate innovation			0.198*** (29.853)	
Lag sea and ocean innovation				0.172*** (86.335)
Constant	16.020** (2.121)	40.601** (2.117)	10.232** (2.023)	53.479** (2.777)
Arellano Bond (AR1) <i>p</i> -value	0.000	0.002	0.007	0.001
Arellano Bond (AR2) <i>p</i> -value	0.345	0.324	0.321	0.365
Hansen test <i>p</i> -value	0.187	0.165	0.210	0.198
Controls included	Yes	Yes	Yes	Yes
Observations	160	160	160	160
Number of countries	20	20	20	20

z-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Given our previous findings of a decrease in green innovation under a leftist government, we expect the interaction term (*Political ideology*innovation*) to be insignificant. The results are reported in Table 6. The coefficient of the interaction term is insignificant in all the different measures of green innovation. Similarly, *Political ideology* is insignificant. However, green innovation is negative and significant in all cases. The results imply that although green innovation decreases carbon emissions (Eq. 1), under a leftist government, the impact of green innovation is insignificant because of the low number of innovations. In effect, our results signal that low green innovation under a leftist government has a negative spill-over effect on the overall health of the environment.

4.2.4 Robustness and Endogeneity (S-GMM)

Endogeneity between political ideology and green innovation is unlikely because it is less plausible for green innovation to influence the ideological orientation of the government. Despite this less possibility of reverse causality, there is still potential model misspecification due to the contemporary effect of previous years' green innovation and some omitted variable bias. Therefore, we employ different econometric identification to address these concerns in this section. Following Wang et al. (2019), we employ the Two System-Generalised Method of Moments (S-GMM) by Arellano and Bond (1991) to address omitted variable bias. The results, as presented in Table 7, show that our main finding that political ideology is significantly related to green innovation is robust. The results confirm our main findings that the number of innovations in environmental-related technologies tends to lower under the leftist government compared with the rightist government. The post-estimations test includes the Arellano-Bond test for AR(1), the Arellano-Bond test for AR(2) in first differences, and the Hansen test shows the robustness of the model.

4.3 Limitations and suggestions for future research

Despite the robustness of our findings, this study is not without limitations. The study focuses on democratic countries with multi-party systems between 2010 and 2018. While this approach allows for a nuanced examination of political ideology and green innovation, it may limit the generalizability of findings to other political contexts, such as authoritarian regimes or countries with different electoral systems. The use of patents in environmental-related technologies as a proxy for green innovation is a common approach but may not capture the full spectrum of innovation in sustainability. Future research could explore alternative measures, such as R&D expenditures or innovation surveys, to provide a more comprehensive understanding of green innovation activities.

Consistent with other studies in environmental politics, we admit that the measurement of political ideology appears to be crude, with much emphasis on leftists and rightists neglecting other emerging ideologies like greens and corporatism, among others. Political ideology is a complex and multifaceted construct that may vary within and across political parties. Future research could examine the heterogeneity

of ideological positions within parties and its implications for green innovation policies. Additionally, comparative studies across different ideological contexts could provide valuable insights into the mechanisms underlying the relationship between political ideology and green innovation.

5 Conclusion and policy implication

In this paper, we have examined the relationship between political ideology and green innovation. Unlike prior studies on innovation (Wang et al. 2019), we focus on a specific type of innovation where government policies are relevant and use a sample of democratic countries with multi-party systems. Our data cover 20 countries between 2010 and 2018. Green innovation is measured as the number of patents in environmental-related technologies and is sourced from OECD Statistics (2021). Data on political ideology are collected from the Manifesto Project (MARPOR) and the Database on Political Institutions. Consistent with the political ideology assumption that leftist and rightist governments differ on budget allocation and environmental policies, we argued that the level of green innovation could differ significantly based on the position of the government on the political–ideological spectrum.

Following this line of argument, we employ robust econometric modelling, which shows that political ideology significantly drives the level of green innovation in a country. More specifically, we find that green innovation is low under the leftist government compared with the rightist government. Although this is surprising, given that leftists are perceived to be more pro-environmentalists than rightists, we argue our results through the lens of budget allocation and leftist attitudes towards unemployment. Compared with the rightist government, the leftist government is less likely to allocate more funding to innovation because such expenditures do not provide immediate benefits to the working class (Wang et al. 2019). What is more, green innovation brings technological advancement and less demand for the labour force, which negatively affects the welfare of the working class, the constituents of leftist government.

We also test the electoral view theory on the relationship between political ideology and green innovation. According to this theory, an election may put pressure on the government to deviate from its core ideology in order to win more votes. Our results indicate that the electoral view theory does not hold in the case of green innovation, suggesting that our findings are not sensitive to election pressures. Finally, in further analysis, we demonstrate the spill-over effect of the relationship between political ideology and green innovation on environmental performance. We find that low level of green innovation under leftist government yields an insignificant relationship between green innovation and environmental performance measured by carbon emission. Our findings are robust to alternative measures of green innovation. Using robust econometric identification strategies such as the lag of variables and S-GMM, we demonstrate that our results are not sensitive to potential endogeneity problems.

Our study complements and extends the literature on green innovation to country-level studies and environmental politics. The findings of this study provide new

evidence to voters on their choice of political parties, especially if they are interested in the environmental health of the country. Our results show that leftist governments are less likely to promote green innovation, suggesting that their pro-environmentalism has not translated to innovative actions. Our findings also inform policy by showing that the effect of government ideology on green innovation can have a potential spill-over effect on carbon. This finding is relevant for policymakers as it shows that investment in green innovation pays off by a reduction in carbon emission.

Appendix A

Australia	Hungary
Austria	Italy
Belgium	Japan
Canada	Netherlands
Czech Republic	Norway
Denmark	Poland
Finland	Portugal
France	Spain
Germany	Sweden
Greece	UK

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Data availability All data are available at the mention sources

Declarations

Conflict of interest There is no conflict of interest on this paper.

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