Women in Power: The Role of Gender in Renewable Energy Policymaking

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April 8, 2025

Abstract

Do female policymakers encourage the production of renewable energy compared to their male counterparts? Using instrumental variables, we conduct a cross-country analysis of 39 high-income countries for the years 1997-2020 using quota laws and women's suffrage as instruments for women's participation in the parliament. We find that a 1 percentage point increase in the proportion of women in the legislature increases renewable energy production by 1.54 percentage points. This study suggests that fostering policies that boost women's participation in policy-making positions is beneficial, especially when considering the positive spillover to other countries.

Keywords: Female political representation, energy economics, climate change

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Acknowledgments

We are deeply grateful to Dr. Hillary Sigman for her invaluable comments, suggestions, and guidance thought out the paper. We also want to thank seminars participants at Rutgers University and the GSIPE seminar participants. Lastly, we want to thank the two anonymous referees for the insightful comments and suggestions provided.

1 Introduction

Recently, there has been an increase in the representation of females in the political field. In 2019, the proportion of women in the national legislature worldwide was 24.64% (WBI.a, 2020). Research has shown that different policy outcomes emerge in a society depending on the gender of the legislators; women favor their gender the most (Besley & Case, 2003; Chattopadhyay & Duflo, 2004; Clots-Figueras, 2011; Weeks, 2019). Research also shows that women choose lower risk levels than men and know and care more about the environment (Xiao & McCright, 2012; Funk & Gathmann, 2015; McCright, 2010). Additionally, female legislators provide more public goods and support environmental policies (Duflo et al., 2004; Fredriksson & Wang, 2011; Pearl-Martinez, 2014; Mavisakalyan & Tarverdi, 2019; Norgaard & York, 2005). There is evidence showing that government is among the main contributors to the rapid deployment of renewable energy around the world through the introduction of different laws and policies (Adelaja et al., 2010; Crossley, 2019; Johnstone et al., 2010; ?, ?; Shrimali & Kniefel, 2011). Therefore, legislator's gender influences the implementation of environmental policies.

This study investigates whether the legislator's gender has an impact on the production of renewable energy. We conduct a cross-country analysis of 39 high-income countries for the years 1997 to 2020. The adoption of renewable energy and the election of women to offices have an unclear causal relationship. Do female legislators pass more laws related to environmental protection, or are countries more likely to elect female legislators intrinsically more progressive? To circumvent this issue, we create a panel data with country and year fixed effects and instrument the endogenous variable, that is, the percentage of female legislators. We use passing a quota law and the number of years since women's suffrage in the country as instruments for the analysis. The results support the hypothesis that females in the legislature encourage the production of renewable energy. Using two different instruments, we find that a 1 percentage point increase in the proportion of women in parliament increases

the production of renewable energy by 1.54 percentage points, after controlling for a rich set of variables.

To allow for serial correlation within countries, we cluster the error term at the country level, reducing the sample to 39 clusters. Consequently, we adjust the standard errors using the wild bootstrap (Cameron et al., 2008). Our results remain unchanged after expanding the analysis to include Brazil, China, India, Indonesia, Mexico, the Philippines, South Africa, Thailand, and Turkey. These countries account for 96.11% of all renewable energy produced worldwide without hydro-power (Ritchie, 2017). We test the instruments separately and find the results are between 1.4 and 2.6 percentage points. Additionally, we randomize the quota law implementation to control for potential placebo effects. We further test the robustness of our estimates by excluding each quota-adopting country sequentially. In each case, the results remain statistically significant and closely aligned with the initial estimation.

This study contributes to the literature in several ways. First, it contributes to the literature on the impact of female legislators on the large-scale production of renewable energy, a public good (Pearl-Martinez (2014)). Second, decarbonizing the economy through large-scale renewable energy production is key to mitigating climate change and can be performed more rapidly than in other sectors (Pachauri et al., 2014). Thus, we show evidence that promoting the election of females in the legislature could produce and accelerate this positive externality. Nevertheless, caution must be exercised if these results are extrapolated to other countries. High-income countries are intrinsically different from middle and low-income countries. Finally, our project extends the literature on cross-country analyses that link the presence of females in the legislature with more humanitarian military interventions (Shea & Christian, 2017), stricter climate change policies (Mavisakalyan & Tarverdi, 2019), lower CO_2 emissions (Ergas & York, 2012), more protected areas (Pearl-Martinez, 2014), more environmental agreements (Norgaard & York, 2005), higher health-expenditure by governments (Clayton & Zetterberg, 2018), more childcare expenditure policies (Weeks, 2019), and less corruption

and bribe acceptance (Dollar et al., 2001; Swamy et al., 2001).[1]

The remainder of this paper is organized as follows. Sections 2 and 3 describe the relationship between the percentage of female legislators and renewable energy production. Section 4 presents the data and descriptive statistics. Section 5 describes the econometric analysis. Sections 6 and 7 present the estimation results and robustness checks, respectively. Finally, we present our conclusions in Section 8, adding possible future research opportunities.

2 Energy and the Government

Fossil fuel combustion and industrial processes accounted for 78% of the total CO_2 emissions for the period 2000-2010 (Pachauri et al., 2014). The *Renewable Global Status Report* (Raturi, 2019) established that 74 countries committed to having some percentage of their energy production based solely on renewable sources.

Figure 1 illustrates the evolution of (average) renewable energy production over time for all the countries in our sample. In high-income countries, renewable energy production has increased steadily since the late nineties [2].

Several studies using different samples, time spans, and policies conclude that governments around the world, pushing for regulatory policies and fiscal incentives, are the main drivers for the rapid increase in renewable energy production in the world. Regulatory policies include feed-in-tariffs (FITs), electric quota obligations (also known as renewable portfolio standards), net metering, and tendering (Raturi, 2019). Fiscal policies include investments, tax incentives, and public financing, such as public investments, loans, grants, and capital subsidies. For example, Crossley (2019) gathered legislation from 113 countries that promote renewable energy production. The author found that countries have passed these laws for several reasons. For example, 37 countries state as an objective in their renewable energy

[1] Find a summary of these papers in Table A1 in the Appendix.

[2] The same plot only for the European countries, is presented in the Appendix Figure A1

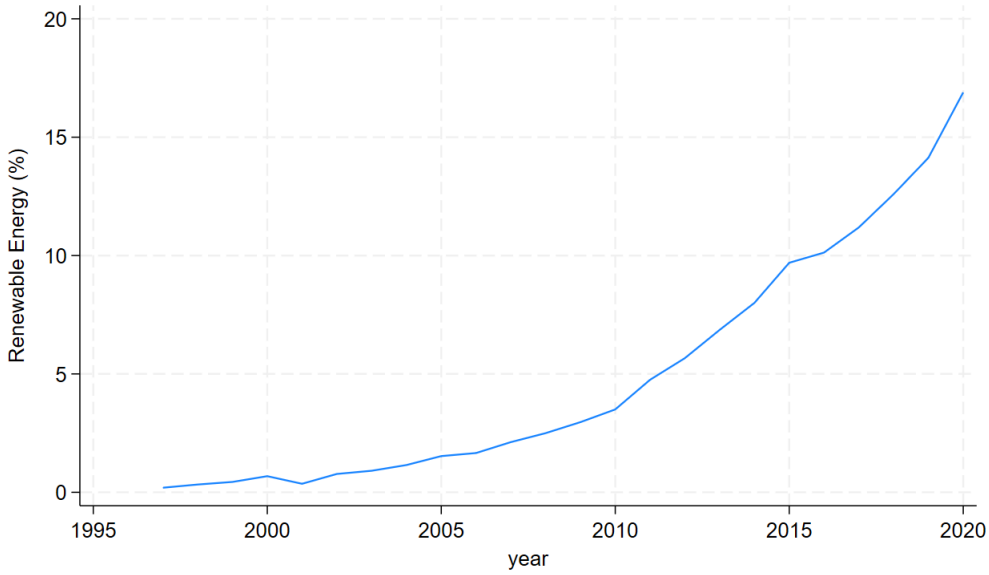

Figure 1: Percentage of renewable energy production for all countries. Source: IEA (2020)

laws to promote sustainable development; 35 countries state as an objective the reduction of fossil fuel use and the reduction of oil dependency from other countries (Huang, Alavalapati, Carter, & Langholtz, 2007); 55 countries declare as an objective the protection of the environment; and 24 countries have laws supporting the expansion of the renewable energy production industry *per se*. Johnstone et al. (2010) conducted a panel data analysis of 25 OECD countries over the period 1978-2003. The authors analyzed the effect of several public policies on renewable energy innovation, using patent counts as a proxy for innovation.[3] They concluded that public policy is a major contributor to renewable energy innovation. Furthermore, Adelaja et al. (2010) and ? (?) reached the same conclusion; Adelaja et al. (2010) studied the wind energy market in the United States, while ? (?) conducted a cross-country analysis for 27 countries of the EU and the United States. Similarly, Shrimali and Kniefel (2011) showed that different policies (RPS, State Government Green Power Purchasing, and Clean Energy Fund) play an important role in the deployment of renewable energy production in the United States.

[3]Wind, solar, ocean, geothermal, biomass, and waste.

In 2019, 43 countries used tax credits as a stimulus, and 101 countries used public financing (Raturi, 2019). By conducting a cross-country analysis of 27 countries in the EU and the United States for a span of 18 years from 1990 to 2018, ? (?) found that feed-in-tariffs and tax policies help the deployment of renewable energy production. Similarly, Liu et al. (2019) conducted a cross-country analysis of 29 countries from 2000 to 2015 and concluded that fiscal and financial incentives, market-based instruments, policy and support, and RD&D improve renewable energy deployment. Finally, Shrimali and Jenner (2013) conducted a cross-state analysis for the United States over the years 1998-2009, finding that tax credits, among other policies, increase the production of solar photovoltaic power by reducing its costs.

3 Previous literature on female leaders

As remarked by Hessami and da Fonseca (2020), the literature has moved from the idea of politicians "just" reflecting the median voter preferences to continue in their seats, to a more accepted idea that some characteristics of the politician, such as gender and race, matter when implementing policies. In the same vein, using League of Conservation Voters data for the period 1970-1995, Fredriksson and Wang (2011) show that voters do not "affect" environmental policies pushing them to the middle. Instead, voters "elect" politicians who are aligned with their preferences and concerns, opposing the median voter theory. Research has found that women are more likely than men to provide public goods, favor their own gender, and push for policies that represent their own gender preferences the most (Chattopadhyay & Duflo, 2004; Clots-Figueras, 2011; Weeks, 2019). For example, Besley and Case (2003) analyze whether women legislators prioritize policies different from those of men in the USA and find that women in power positions pass more laws regarding family assistance and child support. According to the IPCC Report 2022 IPCC (2022), women are less likely to be climate change deniers in comparison to men. The report also finds a positive relationship

between higher female political participation and stringency in climate policies.

A broad body of literature finds that female legislators seek to protect the environment. For example, in the Human Development Report, Pearl-Martinez (2014) used a sample of 90 countries and found that countries with a higher percentage of women in parliament are correlated with more protected land areas. Mavisakalyan and Tarverdi (2019) use a panel of 91 countries for the period 2005-2012 and find that more female representation in parliament leads to stricter climate change policies and a reduction in CO2 emissions. Norgaard and York (2005) studied 130 countries and found that more women in parliament are more likely to ratify environmental treaties. Similarly, (Fredriksson & Wang, 2011), using The League of Conservation Voters, found that female legislators push for stricter environmental policies.

Finally, research has shown that women care more about the environment. McCright (2010) used the Gallup survey from 2001 to 2008 and found that women manifest more concern and have more knowledge about climate change than men do. Similarly, Xiao and McCright (2012), using the Gallup survey, found that women care more about health problems caused by changes in the environment. The authors showed that this greater concern is due to women having different risk perceptions than men do. Moreover, Funk and Gathmann (2015) studied the differences between men's and women's preferences by analyzing how their votes differ in several topics in Switzerland. The authors found that women are 10 percentage points more likely to spend money on policies that protect the environment than men. Finally, recent concerns of women towards the environment have also increased over time. Using the "World Values Survey" (Inglehart et al., 2018A, 2018B), we find that women worldwide have increased their concern over environmental pollution and the degree of responsibility assigned to the government. Therefore, it is possible that female legislators are trying to protect the environment to advance the interests of the female population.

4 Data and Descriptive statistics

We use panel data for a sub-sample of high-income countries for the years 1997 to 2020. Table A2 in the Appendix shows the list of all the countries in our sample. We focus on the high-income countries as categorized by the World Bank. These countries account for 56.19% of total renewable energy production without hydropower (Ritchie, 2017). Adding Brazil, China, and India accounts for 91.26% of the total renewable energy production (Ritchie, 2017). Thus, we include these countries as a robustness check.

Our variable of interest is renewable electricity production without hydropower and biomass. The data was collected from the IEA (IEA, 2020). We define this variable as the proportion of electricity generated by renewable plants to total electricity production. Renewable plants include geothermal, solar, tidal, and wind plants.

We exclude hydropower following Verdolini et al. (2018) and Popp et al. (2011), as they argue that it is a mature renewable energy source, in which most deployment has already occurred. Nevertheless, we add hydropower to the main specification(equation 3) as a robustness check. We also add the production of biomass and biofuels plants as a robustness check.

The main independent variable is the proportion of women in parliament. The World Bank defines this variable as "the percentage of parliamentary seats in a single or lower chamber held by women" (WBI.a, 2020).[4] The proportion of women in national parliaments in the world in 1997, considering single or lower chambers, was 11.69%, in 2019, it increased to 24.64% (WBI.a, 2020). During that period, the proportion of women in the single or lower chamber increased by 83.25% in high-income countries. The evolution of seats held by females in parliament for our sample is presented in Figure 2.

Despite gaining more seats over time, the total participation rate of women remains fairly low. Consequently, several countries have implemented gender quota laws to reduce this gap.

[4]This variable considers presidential and parliamentary government systems.

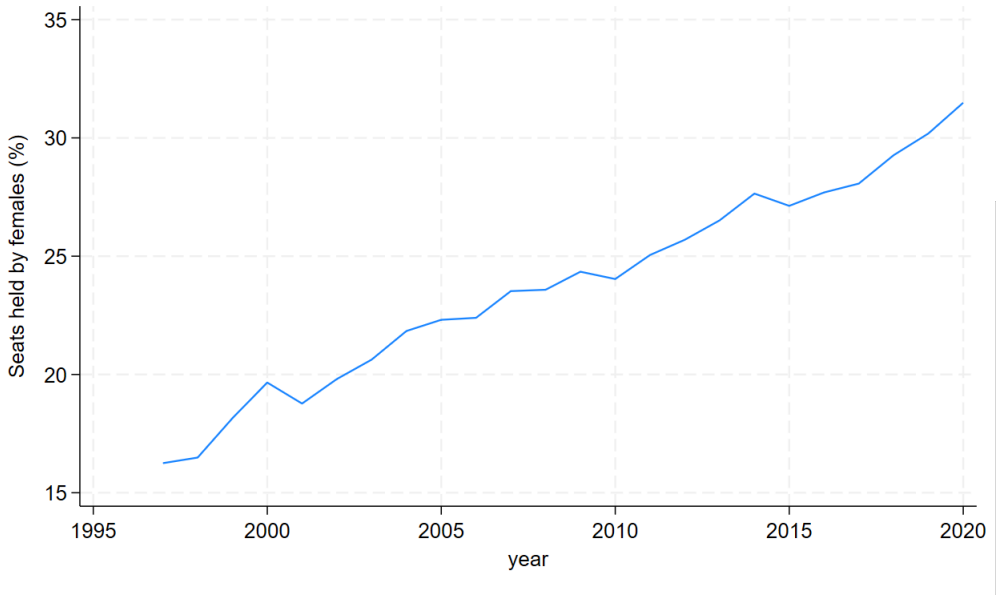

Figure 2: Percentage of seats held by females for High-income countries. Source: WBI.a (2020)

In our sample, 15 countries passed a gender quota law (see Table A3 in the Appendix for further details). We use a dummy for when a quota law was passed in the lower or single house as an instrument (IDEA, 2020; ECLAC, 2020). We consider only the quotas that specify a percentage of seats for females. Table 1 shows when a quota law was adopted.

Data for the "years since women's suffrage" is collected from historic newspapers (Historic, 2020), which refers to the years when women were allowed to vote nationally. This variable is used as a second instrument. The instrument was constructed as follows. First, we obtained the year in which suffrage was expanded to women for each country in the sample (refer to Table A4 in the Appendix for more information). Second, we compute the difference between the years of the data (1997-2015) minus the year suffrage was expanded to women.

We also use the (logarithm of the) GDP *per capita* at constant 2015 dollars as another control (WB.c, 2020). In addition, we use Freedom House's Civil Liberties Index. This index ranges from 1 to 7, where 7 represents the lowest level of freedom, and 1, is the highest.

Table 1: Year of Quota Law Adoption

Country	Year
Belgium	1994
Chile	2015
Croatia	2008
France	1999
Greece	2012
Ireland	2012
Italy	2017
Korea, Rep.	2000
Luxembourg	2016
Panama	2007
Poland	2011
Portugal	2006
Slovenia	2005
Spain	2007
Uruguay	2009

This table shows the year when high-income countries adopted a quota law. Source: (IDEA, 2020; ECLAC, 2020). For more information, refer to Table A3 in the Appendix.

Thus, an increase in the index reflects a decrease in civil liberties (House, 2020).

Furthermore, we add the political orientation (right-wing, left-wing, or centrist) of the party that wins the election (Cruz et al., 2016). The election-winning party is categorized as right-wing if the party is self-defined as conservative, Christian democratic, or right-wing.[5] A left-wing party is designated as such if it considers itself socialist, social-democratic, communist, or left-wing. Finally, a party is considered centrist if it is self-defined as such. Parties that do not conform to the previous categories are ruled out. We transform the categorical variables into dummies. Lastly, we add another specification on whether the system is parliamentary or presidential (CIA, 2020) (see Appendix Table A10 for more details). Specifically, we create

[5]More precisely, Cruz et al. (2016) use "chief executive's party's."

Table 2: Descriptive Statistics

	Mean	Standard Deviation	Min.	Max
Pct. renewable energy production	4.61	8.16	0	60.94
Pct. renewable energy with Biomass	7.22	10.47	0	78.27
Pct. renewable energy with Hydropower	28.19	27.94	0	99.54
Quota law	0.20	0.40	0	1
Pct. women legislature	23.48	10.91	3.01	48.33
GDP *per capita*	33679.32	20180.2	5668.06	112417.9
Right-wing	0.37	0.48	0	1
Center	0.13	0.34	0	1
Left-wing	0.50	0.50	0	1
Civil liberties	1.35	0.56	1	4
Parliamentary	0.78	0.41	0	1
Years since women's suffrage	75.88	20.69	21	127
N	797	797	797	797

a variable that equals one if the system is non-parliamentary.

Table 2 presents descriptive statistics of the data used in the regression analysis. On average, the percentage of renewable energy production without hydropower for the countries in our sample is 4.61%. However, there is a large discrepancy among countries, with one country having a maximum of 61% of renewable production. Considering renewable energy with hydropower and biomass, the average production increases to 28%. The percentage of females in the legislature is 23%. Even though female representation has increased gradually

over time, as shown in Figure 2, it is still far from achieving gender parity.

5 Methodology

Our econometric specification is the following[6]:

$$y_{it} = \alpha + \rho W_{it} + \beta X_{it} + \delta_i + \gamma_t + \epsilon_{it} \tag{1}$$

where y_{it} is the proportion of renewable energy sources in a country's overall electricity production i at time t. The proportion of seats held by women in the national parliament of country i at time t is represented by the variable W_{it}. X_{it} is a set of time-variant variables linked to both the percentage of female legislators and the use of renewable energy: the logarithm of GDP *per capita* of country i at time t, the government of country i at time t is right-wing, centrist, or left-wing, and the civil rights index. Time invariant country fixed effects and time dummies for 1997 to 2020 are represented by δ_i and γ_t, respectively. Finally, ϵ_{it} is the error term.

Identifying the impact of higher female participation in parliament on the level of renewable energy production is not straightforward. Are countries that favor more renewable energy more likely to elect women to the legislature because they are inherently more progressive, or do women want more renewable energy? This is complicated to analyze without conducting an experiment. The optimal identification strategy would be to randomly select some countries to assign them a certain number of women in their parliaments and then analyze their differences in renewable production outcomes.

Additionally, there could be some omitted-variable bias, such as, cultural or historical persistence. In order to try to mitigate this problem, we apply an IV- approach and add year and country fixed effects. Furthermore, we control for variables that simultaneously impact

[6]We use the Stata command from Schaffer (2020).

both the number of female legislators in the parliament and the production of renewable energy (X_{it}). To achieve this objective, we employ two instruments: quota laws and years since women's suffrage.

The variable "countries with legislated candidate quotas in the lower or single house," is obtained from the IDEA (2020); ECLAC (2020) websites. The instrument is equal to one if the law requires that a certain number of seats be reserved for women's (Z_{1it}). Table A3 in the Appendix describes the quota laws for each country. We also employ "years since women's suffrage" (Z_{2it}) (Grier & Maldonado, 2015; Hicks et al., 2016; Mavisakalyan & Tarverdi, 2019).

Thus, the first stage of our estimation is:

$$W_{it} = \alpha^{'} + \phi_1 Z_{1it} + \phi_2 Z_{2it} + \beta^{'} X_{it} + \delta_i^{'} + \gamma_t^{'} + \eta_{it} \tag{2}$$

And the second stage:

$$y_{it} = \alpha + \rho \hat{W}_{it} + \beta X_{it} + \delta_i + \gamma_t + \epsilon_{it} \tag{3}$$

For the instrument to work, it must be first relevant. In this case, the gender quota laws and the years since women's suffrage must have a positive and significant effect on the proportion of women in the parliament. Second, the instruments must comply with the exclusion restriction. This means that the instruments must be as good as randomly assigned and can only affect the percentage of renewable electricity output by the variable we want to instrument, that is, the proportion of females in parliament.

The exclusion restriction may not hold if countries that pursue diversity strongly enough to pass a quota law also care more about the environment. Nevertheless, quota laws are passed to increase diversity, which differs from progressiveness. More progressive countries want to increase the number of females in policy-making positions and increase the production of renewable energy. A quota law increases the former but not necessarily the latter. For

example, Haiti passed a quota law in 2012, granting 30% of its seats to women (ECLAC, 2020). Nevertheless, their Freedom House's Civil Liberties Index score for the same year was 5, meaning that it was considered only partially free (House, 2020). Second, we only consider countries in which the law requires at least a percentage of their seats to be held by females. Third, women in legislative bodies have been underrepresented for decades, therefore, passing a quota law has, in principle, the sole effect of reducing gender inequality. The channel we are exploiting by using this instrument is the following: passing a quota law increases the number of females in parliament, who push for different policies than men.[7].

Hicks et al. (2016) and Mavisakalyan and Tarverdi (2019) show that women's suffrage is correlated with having more women in parliament (a strong first stage); therefore we use this variable as one of the instruments to estimate equation (2) and (3). The presence of more equitable nations does not automatically imply a higher prevalence of progressive nations. While progressive countries are characterized by greater fairness, it should be noted that fairness alone does not guarantee progressiveness. This is particularly relevant when considering the historical context, as women's suffrage occurred around 1933 in our sample. The mechanism exploited is as follows: an expansion in the right to vote for women implies that women can choose according to their beliefs, shape policy outcomes, and increase their participation. However, we expect the "years since women's suffrage" to have a highly diluted impact on current outcomes.

We cluster the sample at the country level to allow residuals to have an unrestricted correlation within countries and time (Angrist & Pischke, 2008). Our sample has 39 clusters categorized as high-income by the World Bank. However, there are disparities between them. For example, Table 2 illustrates that Denmark and Uruguay have more than 40% of their energy produced by renewable sources (without considering hydropower), whereas the

[7]It could be the case that a reverse causality and/or a measurement error problem arises. However, we do not believe this is the case. For the latter, the data is obtained from official and external sources. For the former, we cannot think of a reason why an increase in the production of renewable energy increases female participation in parliament.

average of the entire sample is 4.6%. Finally, 15 out of 39 countries in the treatment have passed a quota law. Hence, we have a small number of treated clusters. Furthermore, the number of clusters is less than 42 (Angrist & Pischke, 2008), and they are not homogeneous. Roodman et al. (2019) recommend finding p-values via bootstrap if either of these conditions holds because they lead to over-rejection. We follow Cameron et al. (2008) and use a wild-bootstrap. We present bootstrap p-values in the main estimation results.[8]

6 Results

The OLS estimation results are presented in the first column of Table 4. The coefficient for the variable "proportion of women in parliament", including all controls, is -0.06 (0.13), which is not statistically significant. There could be some omitted variable bias negatively correlated with the variable of interest; therefore, we instrument this variable using quota laws and years since women's suffrage.

Tables 3 and 4 present the first and second-stage estimates of the main specification (equation 3). This study focuses on high-income countries defined by the World Bank, which account for approximately 56% of the total worldwide production of renewable energy (without hydropower) (Ritchie, 2017).

The first stage is presented in Table 3, where we use quota laws and years since women's suffrage as instruments for the proportion of women in parliament. Our preferred specification is the fourth column, which includes all the controls. In this specification, the introduction of a gender quota law increases the proportion of women in parliament by 2.3 percentage points. Allowing women to vote a year earlier increases the proportion of women in the parliament by 0.6 percentage points. Both coefficients are significant at 5%. We also find that the instruments used are robust to different specifications, as shown in Columns 1-4 of

[8]We use the boottest Stata command with 9999 draws (Roodman et al., 2019).

Table 3: First Stage Estimation

Pct. of women in parliament				
	(1)	(2)	(3)	(4)
Quota Law	2.347**	2.352**	2.331**	2.269**
	(1.089)	(1.095)	(1.083)	(1.096)
years since	0.569***	0.572***	0.571***	0.566***
women's suffrage	(0.060)	(0.090)	(0.090)	(0.093)
Log GDP *per capita*		-0.201	-0.214	-0.239
		(3.405)	(3.441)	(3.440)
Right-wing			-0.161	-0.194
			(0.557)	(0.551)
Centrist			0.693	0.675
			(1.038)	(1.077)
Civil liberties				-0.416
				(0.871)
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797
F-value	84.35	28.16	28.53	25.21

This table shows the effects of both instruments, passing a quota law and the number of years since women's suffrage, on the percentage of women in parliament. Standards errors are clustered at the country level in parentheses. Significance levels: ***0.01 **0.05 *0.1.

Table 3.

According to the results of the second-stage estimation in Table 4, we find that a one percentage point increase in the proportion of women in parliament increases the percentage of renewable energy production by 1.5 percentage points as shown in Column 5, which is the preferred specification. The coefficient is significant at 1%, after controlling for the type of government, the degree of civil liberty, and the log of GDP *per capita* in 2015 constant dollars.

The majority of the controls are not statistically significant. The coefficients for the

Table 4: IV Estimation of Renewable Energy

Percentage of renewable energy production

	OLS	IV estimation			
	(1)	(2)	(3)	(4)	(5)
Pct. women parliament	-0.058	1.258***	1.542***	1.545**	1.539***
	(0.130)	(0.203)	(0.266)	(0.267)	(0.279)
	[0.698]	[0.0]	[0.0]	[0.0]	[0.0]
Log GDP *per capita*	-9.882		-11.205*	-11.099*	-11.088*
	(5.757)		(6.470)	(6.580)	(6.558)
	[0.113]		[0.087]	[0.095]	[0.095]
Centrist	-2.095			-3.167	-3.171
	(1.345)			(2.175)	(2.174)
	[0.186]			[0.254]	[0.263]
Right-wing	-0.338			0.114	0.100
	(0.628)			(0.779)	(0.810)
	[0.638]			[0.825]	[0.844]
Civil liberties	-1.227				-0.163
	(0.714)				(1.560)
	[0.101]				[0.956]
Country fixed effects	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y
N	797	797	797	797	797

Column 1 presents the OLS results. Columns 2 through 5 present the IV results of the effect of women in parliament on renewable energy production, using two instruments passing a quota law and years since women's suffrage. Standard errors are clustered at the country level in parentheses. Wild bootstrap p-values in square brackets. Significance levels: ***0.01 **0.05 *0.1.

type of party and GDP have an unexpected sign, especially, considering that an increase in the former happens when the Government moves further to the "left". Having a right-wing government has a positive (yet not significant) impact on the production of renewable energy compared to that of a left-wing government. The opposite happens with a centrist government. Regarding the Civil Liberty Index, 1 is the highest level of freedom. Thus, decreasing a unit in the Civil Liberties Index (i.e., an improvement in the Civil Liberties

Index) implies a higher effect on renewable energy, although it is not significant. Finally, the fact that the logarithm of GDP *per capita* is negative is also counter-intuitive. However, given that we focus on high-income countries may explain this result. For example, the level of renewable energy depends on large-scale projects that may require external funds. Furthermore, despite being counter-intuitive, our results are similar to those of Dong (2012) and Yin and Powers (2010). The results from the reduced form estimation are presented in the Appendix Table A5.

We also perform the Sargan-Hansen test of overidentification, and we are not able to reject the null hypothesis (the p-value is equal to 0.375). Therefore, at least one of the instruments is exogenous and is not correlate with the error term.

We try both instruments separately and find that a one percentage point increase in the proportion of women in parliament increases the percentage of renewable energy production between 1.4 and 2.6 percentage points, using years since women's suffrage and passing a quota law respectively. The first stage results are presented in the Appendix Table A6 and A8. The second stage is presented in Table A7 and A9, respectively.

We also test whether having more women in the legislature has a more pronounced effect on parliamentary rather than presidential systems (see Table A10 for more details). Legislators under a parliamentary system may participate more actively and decisively than those under a presidential system. Specifically, we create a variable that equals one if the government is non-parliamentary. Then, we create an interaction term ("$Parliamentary * Prop.\ women\ parliament$") that considers the proportion of seats represented by women and non-parliamentary government. We present the point estimates in Table A11, column (1). The point estimate for such interaction is not significant, so the effect of being in a non-parliamentary system is inconclusive. However, the effect of the proportion of women in the parliament is almost unchanged.

7 Robustness Checks

First, we conduct a placebo test by making the quota law adoption random [9]. The "random" effects should not impact the production of renewable energy. The results are presented in Table A13. There is no significant effect of the proportion of women in parliament on the production of renewable energy if we use the "fake" gender quota laws as an instrument. This validates our causal interpretation.

Second, we drop each treated country at a time and run the main specification (3) at a 95% confidence level. The results are presented in Table A14 in the Appendix. None of the countries drive the results alone; the point estimations are close to each other and are always significant at 1% or 5%.

Furthermore, we add three more countries, Brazil, China, and India, which, together with the original sample, account for 91.26% of the global renewable electricity production without hydropower (Ritchie, 2017)). The coefficient of the percentage of women in parliament decreases slightly, from 1.5 to 1.4, and is significant at the 1% level. Lastly, we add nine more countries: Brazil, China, India, Indonesia, Mexico, the Philippines, South Africa, Thailand, and Turkey to the original sample. These countries account for 96.11% of the renewable energy production without hydropower worldwide (Ritchie, 2017). The coefficient on the percentage of women in parliament decreases from 1.5 to 1.2 and is still significant at 1%. The results can be seen in Table A15, Columns 1 and 2, respectively.

Finally, we estimate equation (3) using the proportion of renewable energy production including hydropower as the dependent variable. The coefficient of the proportion of women in parliament is 1.4, after controlling for the type of government, the degree of civil liberty, and the log of GDP *per capita* in 2015 constant dollars. The effect is significant at 1%. The estimation almost does not change, and this is consistent with the idea that hydropower is considered a mature energy source where most of the deployment has already occurred

[9] See Table A12 in the Appendix to check the exact quota law dates.

(Verdolini et al., 2018; Popp et al., 2011). The results are presented in the Appendix in Table A16. We also do the above analysis using the proportion of renewable energy production including biomass and results are presented in Table A17 in the Appendix.

This section ratifies the relevance of the instrument to the main causal findings. The introduction of a quota law increases the number of women in parliament, which potentially, through an increase in the number of policies and laws adopted (as discussed in Section 3), is one mechanism for increasing the production of renewable energy. However, these results can be extrapolated only to high-income countries. Middle and low-income countries have several dissimilarities. Although having more women in policy-making positions has a positive impact, it does not necessarily translate into an increase in renewable energy production.

8 Conclusion

More women in policy-making positions leads to an increase in the production of renewable energy without hydropower, after controlling for several factors. These results add to the literature on cross-country analyses that link women in parliament to several outcomes. By using an IV panel with fixed effects and considering 39 high-income countries for the years 1997-2020, we reinforce the argument that women in policy-making positions support the environment by increasing renewable energy production.

By using two different instruments, passing a quota law and years since women's suffrage to control for possible omitted variable bias, we find qualitatively similar results. Women in parliament increase the production of renewable energy production by 1.54 percentage points, after controlling for the log of GDP, type of government, and Civil Liberties Index.

It has been documented that female legislators support different policies compared to male legislators. Thus, enhancing government performance necessitates a focus on increasing the participation of women, as well as promoting diversity in a broader sense. Furthermore,

this study shows that having more women in parliament has a positive and significant effect on the production of renewable energy, perhaps because of an increase in the number of environmental protection-related legislations and laws proposed by women. Consequently, having more female representatives has an important effect on the decarbonization of the economy, which is a positive externality for the rest of the world. Introducing or strengthening quota legislation is a strategy to enhance representation.

Due to the inherent differences between middle and low-income countries and high-income countries, these results cannot be extrapolated to other types of countries. Therefore, although having more women in positions of influence would undoubtedly boost diversity, it would not always result in the production of more renewable energy.

A potential avenue for further investigation would involve examining diversity across countries and delving into the reasons behind the specific developmental trajectories observed in high-income countries. This would explore the presence of alternative mechanisms and how they vary across middle-income and low-income countries. Additionally, it would investigate why middle-income nations were at the forefront of the deployment of renewable energy before things slowed down.

9 Competing interest

Declarations of interest: none.

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Appendix

Summary of the cross-country analysis of the effect of women in power positions on several outcomes.

Table A1: Summary of Cross-country and Gender Analysis

Authors	Outcome variable	Years	Countries	Paper
Shea and Christian	Humanitarian military intervention	1946-2003	59	The Impact of Women Legislators on Humanitarian Military Interventions
Ergas and York	CO_2 emission *per capita*	2004	103	Women's Status and Carbon Dioxide Emissions:A quantitative Cross-national Analysis
Pearl-Martinez	Protected land areas	2004	90	Women at the Forefront of the Clean Energy Future
Norgaard and York	Environmental treaty ratification	1999	130	Gender uality and State Environmentalism
Clayton and Zetterberg	Government spending	1995-2012	139	Quota Shocks: Electoral Gender Quotas and Government Spending Priorities Worldwide
Weeks	Government spending on family policies	1980-2011	22	Quotas Matter: The Impact of gender Quota Laws on Work-Family Policies
Swamy, Knack Lee, and Azfar	Corruption level and bribe acceptance	1981, 1990	93	Gender and corruption
Dollar, Fisman and Gatti	Corruption level	1985, 1990 and 1995	100	Are Women Really the "Fairer" Sex? Corruption and Women in Government
McElhaney and Mobasseri	Environmental, governance and social	2012	1500 firms	Women Create A Sustainable Future
Mavisakalyan and Tarverdi	Environmental policies and CO_2 emissions	2005 - 2010	91	Gender and climate change: Do female parliamentarians make difference?

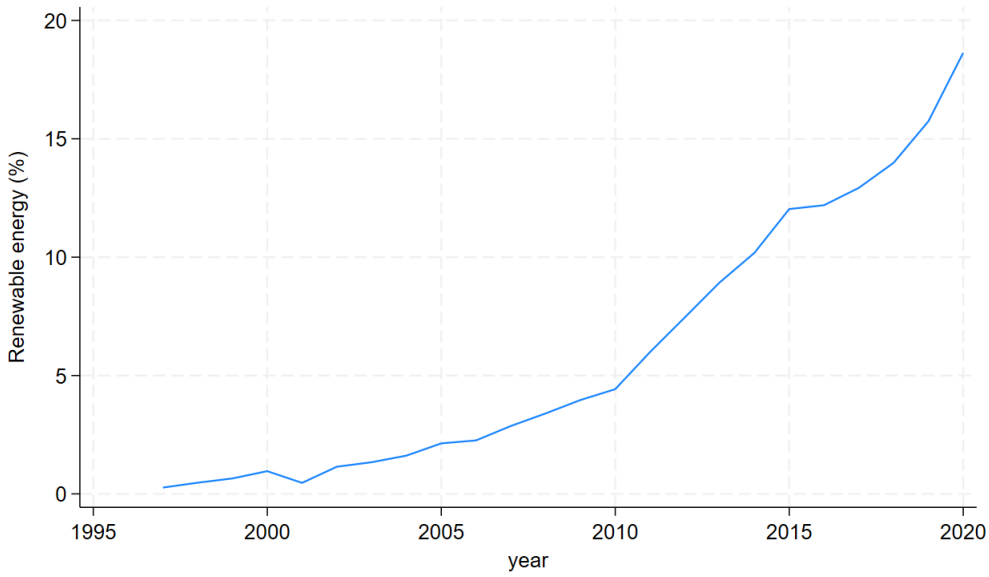

Figure A1: Percentage of renewable energy production for all European countries in our sample. Source: IEA (2020)

Table A2: Countries in the sample

Australia	Korea Republic
Austria	Latvia
Belgium	Lithuania
Canada	Luxembourg
Chile	Malta
Croatia	Netherlands
Cyprus	New Zealand
Czech Republic	Norway
Denmark	Panama
Estonia	Poland
Finland	Portugal
France	Slovakia
Germany	Slovenia
Greece	Spain
Hungary	Sweden
Iceland	Trinidad and Tobago
Ireland	United Kingdom
Israel	United States
Italy	Uruguay
Japan	

Summary of the quota laws.

Table A3: Quota Law Description

Country	Year	Description
Belgium	1994	Political parties should not have more than 2/3 candidates of the same gender in their lists - first gender quota
Chile	2015	Neither the male candidates nor the female candidates may exceed 60% of the respective total - Constitutional reform
Croatia	2008	If a gender (male or female) has less than 40% of representatives in the political arena, it is considered "under-represented" - Gender Equality Law
France	1999	Gender parity was obtained - Constitutional amendment
Greece	2012	One-third of parties' candidate list must have candidates of each gender - Presidential Decree 26/2012
Ireland	2012	30% of the candidates have to be women, and 30% have to be men - Electoral Act amended
Italy	2017	candidates must be placed according to an alternate order of gender (Law no. 165/2017 , article 3)
The Republic of Korea	2000	Women candidates in political parties must have at least 30% of representation in their lists - Political party law reform
Luxembourg	2016	The lists of the political parties must include at least 24 (out of 60) candidates of each sex (Ch. II. art. 2.3, Law of December 15, 2016).
Panama	2007	The law requires that at least 30% of seats are reserved for women - Código Electoral de 2007 CIII, A 236-239
Poland	2011	At least 35% of the candidates have to be women, and at least 35% have to be men - Election Code
Portugal	2006	Each gender has to have a minimum representation of 33% - Equality Law 3/2006
Slovenia	2005	A gender quota of 20% was introduced before the 2006 Election - Local Elections Act 2005 - art. 70
Spain	2007	Each gender has to have a minimum representation of 40% in the parties' candidate lists - Organic Law 3/2007
Uruguay	2009	If the first candidate in the party list is a man, then the second candidate has to be a women, and vice-versa

Sources: International Institute for Democracy and Electoral Assistance (IDEA, 2020) and/or Gender Equality Observatory for Latin America and the Caribbean (ECLAC, 2020).

Table A4 shows the year when suffrage was extended to women.

Table A4: Years of suffrage extension to women

Australia	1962	Republic of Korea	1948
Austria	1918	Latvia	1917
Belgium	1948	Lithuania	1917
Canada	1960	Luxembourg	1919
Chile	1949	Malta	19479
Croatia	1945	Netherlands	1919
Cyprus	1960	New Zealand	1893
Czech Republic	1920	Norway	1913
Denmark	1915	Panama	1946
Estonia	1917	Poland	1918
Finland	1906	Portugal	1976
France	1945	Slovakia	1920
Germany	1918	Slovenia	1945
Greece	1952	Spain	1931
Hungary	1918	Sweden	1919
Iceland	1915	Trinidad and Tobago	1946
Ireland	1922	United Kingdom	1928
Israel	1948	United States	1920
Italy	1945	Uruguay	1932
Japan	1946		

Source: Historic (2020)

In Table A5 we present the results from the reduced form estimation, as specified in equation (4):

$$y_{it} = \dot{\alpha} + \dot{\delta}_i + \dot{\gamma}_t + \dot{\beta} X_{it} + \dot{\phi}_1 Z_{1it} + \dot{\phi}_2 Z_{2it} + \dot{\epsilon}_{it} \tag{4}$$

The reduced form estimation indicates that the quota law and years since women's suffrage have a positive and significant effect on the production of renewable energy, which is consistent with our previous analysis. This provides further evidence that the instrument is valid. Nevertheless, we are not interested in the effect of the instruments on the production of renewable energy *per se*. Instead, we are interested in how passing a quota law or how years since women's suffrage increases the number of females in the legislature and how that increases the renewable energy production.

Table A5: Reduced Form Estimation

Prop. Renewable energy production				
	(1)	(2)	(3)	(4)
Quota Law	5.721***	5.952***	5.976***	5.879***
	(1.988)	(1.785)	(1.616)	(1.627)
years since women's suffrage	2.627***	1.939***	1.838***	1.829***
	(0.551)	(0.654)	(0.639)	(0.641)
Log GDP *per capita*		-10.818***	-10.726***	-10.765***
		(4.515)	(4.504)	(4.521)
Centrist			-2.122**	-2.152**
			(1.010)	(1.004)
Right-wing			-0.114	-0.166
			(0.492)	(0.488)
Civil liberties				-0.657
				(0.679)
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

The OLS results of the effects of passing a quota law on the production of renewable energy are presented. Standards errors are clustered at the country level in parentheses. Significance levels: ***0.01 **0.05 *0.1.

The first stage is presented in Table A6, in which we use quota laws as an instrument for the proportion of women in parliament. Our preferred specification is the fourth column, which includes all the controls. In this specification, the introduction of a gender quota law increases the proportion of women in parliament by 2.3 percentage points. The coefficient is significant at 5%. We also find that the instrument used is robust to different specifications, as shown in Columns 1-4 of Table A6.

Table A6: First Stage Estimation

Pct. Of Women in parliament				
	(1)	(2)	(3)	(4)
Quota Law	2.347**	2.352**	2.331**	2.269**
	(1.089)	(1.095)	(1.083)	(1.096)
Log GDP *per capita*		-0.201	-0.214	-0.239
		(3.405)	(3.441)	(3.440)
Centrist			0.693	0.675
			(1.038)	(1.077)
Right-wing			-0.161	-0.194
			(0.557)	(0.551)
Civil liberties				-0.416
				(0.872)
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

This table shows the impact of adopting a quota law on the percentage of women in parliament. Standards errors are clustered at the country level in parentheses. Significance levels: ***0.01 **0.05 *0.1.

According to the results of the second-stage estimation in Table A7, we find that a 1 percentage point increase in the proportion of women in parliament increases the percentage of renewable energy production by 2.6 percentage points as shown in Column 5, which is the preferred specification. The coefficient is significant at 5%, after controlling for the type

of government, the degree of civil liberty, and the log of GDP *per capita* in 2015 constant dollars.

Table A7: IV Estimation of Renewable Energy

Percentage of renewable energy production				
	IV estimation			
	(1)	(2)	(3)	(4)
Pct. women parliament	2.437**	2.531**	2.564**	2.591**
	(1.334)	(1.345)	(1.283)	(1.344)
	[0.020]	[0.017]	[0.016]	[0.020]
Log GDP *per capita*		-10.308	-10.177	-10.146
		(9.618)	(9.823)	(9.879)
		[0.385]	[0.392]	[0.390]
Centrist			-3.900	-3.899
			(3.400)	(3.448)
			[0.808]	[0.238]
Right-wing			0.300	0.337
			(1.254)	(1.298)
			[0.220]	[0.776]
Civil liberties				0.421
				(2.531)
				[0.824]
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

Columns 1 through 4 present the IV results of the effect of women in parliament on renewable energy production, using passing a quota law as an instrument. Standard errors are clustered at the country level in parentheses. Wild bootstrap p-values in square brackets. Significance levels: ***0.01 **0.05 *0.1.

The IV results and the first stage using "years since women's suffrage" as an instrument can be seen in Table A9 and Table A8, respectively. Allowing women to vote a year earlier increases the proportion of women in the parliament by 0.59 percentage points. In the second stage, the coefficient is 1.4 after controlling for the type of government, the degree of civil

liberties, and the log of GDP *per capita* in 2015 constant dollars. Thus, a one percentage point increase in the percentage of women in parliament increases the production of renewable energy without hydropower by 1.4 percentage points. The coefficient is significant at 1%.

Table A8: First Stage Estimation

	Pct. of women in parliament			
	(1)	(2)	(3)	(4)
years since women's suffrage	0.604***	0.601***	0.600***	0.592***
	(0.056)	(0.094)	(0.094)	(0.096)
Log GDP *per capita*		0.164	0.151	0.100
		(3.539)	(3.577)	(3.572)
Right-wing			-0.207	-0.255
			(0.599)	(0.586)
Centrist			0.709	0.681
			(1.044)	(1.088)
Civil liberties				-0.622
				(0.912)
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

This table shows the effects of the number of years since women's suffrage was allowed on the percentage of women in parliament. Standards errors are clustered at country level in parentheses. Significance levels: ***0.01 **0.05 *0.1.

Table A9: IV Estimation of Renewable Energy

Percentage of renewable energy production				
	(1)	(2)	(3)	(4)
Prop. women parliament	1.173***	1.442***	1.442***	1.436***
	(0.221)	(0.312)	(0.314)	(0.324)
	[0.0]	[0.0]	[0.0]	[0.0]
Log GDP *per capita*		-10.129	-10.007	-10.031
		(6.996)	(7.026)	(6.971)
		[0.139]	[0.148]	[0.143]
Right-wing			0.067	0.043
			(0.739)	(0.769)
			[0.865]	[0.899]
Centrist			-3.104	-3.113
			(2.068)	(2.064)
			[0.239]	[0.245]
Civil liberties				-0.297
				(1.485)
				[0.868]
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

The IV results of the effect of women in parliament on renewable energy production are presented, using as an instrument years since women's suffrage. Standards errors are clustered at the country level in parentheses. Wild bootstrap p-values, in square brackets. Significance levels: ***0.01 **0.05 *0.1.

Table A10: Government type

Government type	Countries
Constitutional federal republic	United States
Constitutional monarchy	Luxembourg
Federal parliamentary democracy under a constitutional monarchy	Australia Belgium Canada
Federal parliamentary republic	Austria Germany
Parliamentary constitutional monarchy	Denmark - Japan Netherlands - Norway Spain - Sweden - UK
Parliamentary democracy	Israel
Parliamentary democracy under a constitutional monarchy	The Bahamas - Barbados New Zealand
Presidential republic	Chile - Cyprus - Republic of Korea Panama - Uruguay
Semi - presidential republic	France Lithuania - Portugal
Parliamentary republic	Croatia - Czech Republic - Estonia Finland - Greece - Hungary Iceland - Ireland - Italy Latvia - Malta - Poland Slovakia - Slovenia - Trinidad and Tobago

This table shows the type of government each country has, as defined by the CIA (2020).

Table A11: IV Estimation of Renewable Energy production

Pct. renewable energy production	
	(1)
Prop. women parliament	1.277**
	(0.391)
	[0.013]
Parliamentary*prop. women Parliament	0.573
	(0.569)
	[0.510]
Log GDP *per capita*	-8.093
	(7.611)
	[0.275]
Right-wing	0.104
	(0.786)
	[0.834]
Centrist	-3.668
	(2.320)
	[0.250]
Civil liberties	-0.921
	(1.745)
	[0.655]
Country fixed effects	Y
Year fixed effects	Y
N	797

The IV results of the effect of women in parliament on renewable energy production are presented. The type of government is included as an extra control in column (1). "Parliamentary∗prop. women parliament" equals one if the government is non-parliamentary, e.g., a presidential republic, zero if it's parliamentary. Standards errors are clustered at the country level in parentheses. Significance levels: ***0.01 **0.05 *0.1.

This table shows the random draw that we treat as the new quotas laws. These new fake quota laws are used as instruments to test whether this random effect has any impact.

Table A12: Random quota law

Country	Quota Law
Belgium	1997
Chile	2015
Croatia	2008
France	1999
Greece	2012
Ireland	2012
Italy	2017
Rep. of Korea	2000
Luxembourg	2016
Panama	2007
Poland	2011
Portugal	2006
Slovenia	2005
Spain	2007
Uruguay	2009

Source: own creation.

Table A13: Robustness checks

	Percentage of renewable energy production
	Quota_{Random}
	(1)
Prop. women parliament	0.826
	(0.774)
	[0.185]
Log GDP *per capita*	-9.97
	(5.876)
	[0.179]
Right-wing	-0.112
	(0.595)
	[0.825]
Centrist	-2.698
	(1.750)
	[0.209]
Civil liberties	-0.677
	(1.249)
	[0.662]
Country fixed effects	Y
Year fixed effects	Y
N	797

The IV results on the effect of women in parliament on the percentage of renewable energy are presented. Column 1 uses a fake random quota law as an instrument. Standards errors are clustered at the country level in parentheses. Wild bootstrap p-values, in square brackets. Significance levels: ***0.01 **0.05 *0.1.

Table A14: IV Estimation of Renewable Energy production: Dropping each country at a time

Prop. of renewable energy production	
Main specification	2.59**
	[0.020]
Belgium	2.36***
	[0.009]
Croatia	2.33***
	[0.008]
Chile	2.672**
	[0.021]
France	2.409**
	[0.019]
Greece	2.602**
	[0.044]
Ireland	2.219**
	[0.033]
Italy	2.551**
	[0.018]
Rep. of Korea	2.773**
	[0.022]
Luxembourg	2.304**
	[0.018]
Panama	2.593**
	[0.018]
Poland	2.772**
	[0.033]
Portugal	3.182**
	[0.045]
Slovenia	3.078**
	[0.028]
Spain	2.562**
	[0.037]
Uruguay	1.972**
	[0.013]
Country fixed effects	Y
Year fixed effects	Y

The IV results of the effect of women in parliament on renewable energy production are presented. In each line, the respective country is dropped. Significance level is set at 95%. Wild bootstrap p-values, in square brackets. Significance levels: ***0.01 **0.05 *0.1.

Table A15: IV Estimation of Renewable Energy Production - Extended Sample

Prop. of renewable energy production		
	(1)	(2)
Prop. women parliament	1.367***	1.193***
	(0.240)	(0.233)
	[0.0]	[0.0]
Log GDP *per capit*a	-4.496**	-4.153
	(4.000)	(4.268)
	[0.234]	[0.318]
Right-wing	0.159	-0.671
	(0.699)	(0.769)
	[0.798]	[0.458]
Centrist	-3.005	-2.712
	(1.991)	(1.628)
	[0.220]	[0.164]
Civil liberties	-0.184	-0.970
	(1.305)	(1.051)
	[0.911]	[0.404]
Country fixed effects	Y	Y
Year fixed effects	Y	Y
N	855	929

The IV results of the effect of women in parliament on renewable energy production are presented. Both instruments are used: passing a quota law and years since women's suffrage. In column 1, we added three more countries: Brazil, China, and India, which, along with the original sample, account for 91.26% of all the renewable energy production done worldwide. Column 2 also includes Brazil, China, India, Indonesia, Mexico, the Philippines, South Africa, Thailand, and Turkey. This extended sample accounts for 96.11% of all renewable energy production done worldwide. Standard errors are clustered at the country level in parentheses. Wild bootstrap p-values, in square brackets. Significance levels: ***0.01 **0.05 *0.1.

In the following table, we present the point estimation results using the percentage of renewable energy with hydropower as a dependent variable.

Table A16: IV Estimation of Renewable Energy with Hydropower

Prop. Renewable energy production with hydropower				
	(1)	(2)	(3)	(4)
Prop. women parliament	0.878***	1.500***	1.477***	1.428***
	(0.217)	(0.302)	(0.299)	(0.298)
	[0.001]	[0.0]	[0.0]	[0.0]
Log GDP *per capita*		-24.546***	-24.224***	-24.279***
		(7.539)	(7.268)	(7.218)
		[0.003]	[0.003]	[0.003]
Right-wing			-1.587	-1.743
			(1.065)	(1.105)
			[0.204]	[0.182]
Centrist			-4.727*	-4.779*
			(2.165)	(2.088)
			[0.074]	[0.062]
Civil liberties				-1.885
				(1.783)
				[0.340]
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

The IV results of the effect of women in parliament on renewable energy production with hydropower is presented, using both instruments, passing a quota law and years since women's suffrage. Standards errors are clustered at the country level in parentheses. Wild bootstrap p-values, in square brackets. Significance levels: ***0.01 **0.05 *0.1.

In the following table, we present the point estimation results using the percentage of renewable energy with biomass as a dependent variable.

Table A17: IV Estimation of Renewable Energy with Biomass

Prop. Renewable energy production with biomass				
	(1)	(2)	(3)	(4)
Prop. women parliament	1.572***	1.768***	1.770***	1.757***
	(0.272)	(0.341)	(0.343)	(0.358)
	[0.0]	[0.0]	[0.0]	[0.0]
Log GDP *per capita*		-7.728	-7.634	-7.630
		(8.716)	(8.873)	(8.832)
		[0.365]	[0.387]	[0.387]
Right-wing			0.130	0.092
			(1.105)	(1.135)
			[0.873]	[0.898]
Centrist			-2.818	-2.829
			(2.583)	(2.566)
			[0.384]	[0.389]
Civil liberties				-0.447
				(1.864)
				[0.866]
Country fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
N	797	797	797	797

The IV results of the effect of women in parliament on renewable energy production with biomass is presented, using both instruments, passing a quota law and years since women's suffrage. Standards errors are clustered at the country level in parentheses. Wild bootstrap p-values, in square brackets. Significance levels: ***0.01 **0.05 *0.1.