The Impacts of Female Political Representation and Economic Freedom on National CO2 Emissions

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Abstract

Climate change is one of the most pressing issues faced globally, and a solution seems far off, if not impossible. This paper aims to examine the impacts of economic freedom and female political representation on CO2 emissions to give policy implications to help reduce national emissions. Unique to previous literature is implementing an interaction term between the two independent variables. To do this, an IV regression was used. This is used as opposed to an FE model as it accounts for the endogeneity present. The regression findings suggest that economic freedom has a significantly positive effect on emissions, while female political participation has a statistically insignificant positive impact. The joint effect is positively significant. The results suggest that greater environmental policies are required to reduce emissions and that any attempt to increase economic growth via economic freedom must account for potential environmental trade-offs. The results also highlight a need for an integrated policy approach between economic freedom, greater environmental protection, and the inclusion of women in the process.

Keywords: *economic freedom, female political participation, interaction, CO2 emissions, IV, environmental protection, policy.*

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Introduction

Climate change is caused by the rapid increase of greenhouse gases, primarily carbon dioxide (CO2), in the atmosphere from human sources. It has become one of the most pressing challenges humanity faces today (Abbass et al., 2022). The World Health Organisation (WHO) estimates that as many as 3.6 billion people live in areas that are highly susceptible to the impacts of climate change and that between 2030 and 2050, there will be an additional 250,000 deaths per year resulting from climate change (WHO, 2023). Many human activities need to decarbonise, such as the fossil fuel, transport, and agricultural industries (Fekete et al., 2021). Each industry and emitter has its unique challenges in rapidly decarbonising, but the one commonality is that all fall under government regulation. Thus, it is worth exploring how governments prioritise decarbonisation and whether they are willing to prioritise it over economic growth, which is almost exclusively at odds with decarbonising efforts (Leitão & Lorente, 2020).

The fight against climate change has been slow, but countries are now reacting with greater urgency in their attempts to reduce their emissions. As it stands, present literature is undecided upon one singular method that works effectively. Instead, there are a multitude of technologies, government approaches, corporate initiatives, and personal changes, which, when combined, can help to reduce overall emissions. This collective effort is crucial in addressing the complexity of the climate change issue.

From this varied pool of literature, an essential and relatively unanswered question is how the makeup of a government, specifically gender, impacts national emissions. Literature examining female decision-makers' impact on emissions more often focuses on the corporate world rather than the government, with several exceptions (Ergas & York, 2012) (Lv & Deng, 2019). These papers find that increased female political representation (FPR) and environments in which they can enact policies lead to a reduction in carbon emissions. The same general result is expected from this paper. Previous literature shows that women favour more socially conscious policies (Shaukat et al., 2016) in corporate settings and are more likely to support environmental protection when in government (Ergas & York, 2012). The lack of literature examining the impact of female decision-makers in government compared to corporate settings

leaves a significant gap in the literature. To fill the gap, this paper will not only examine how female political participation impacts emissions but will also examine the relationship between economic freedom (EC) and emissions to further add to its relevance and uniqueness. In this paper, FPR will take the form of the overall percentage of ministerial positions held by women. The overall percentage of national parliament seats held by women will be used as a robustness check. This will give additional perspective into how the level of power determines the impact on CO2 emissions.

Economic freedom is defined as a personal choice, voluntary exchange, freedom to compete, and protection of persons and property (Gwartney & Lawson, 2003). As per the Heritage Foundation, EF is defined as the right of every human to control their own labour and property. This means that individuals are free to consume, produce and invest however they please without government intervention. This essentially means that in the presence of absolute economic freedom, individuals choose how and which goods are produced. How economic freedom impacts emissions is not concrete, with arguments that larger government size will cause inefficient operations, increasing emissions, or that governments are crucial in designing and promoting environmental regulations, renewable energy, and green innovation, which reduces them (Sart et al., 2022). Literature on the impact of economic freedom on emissions is more extensive than that of female political empowerment. The consensus on the effect, however, is not uniform. Papers such as (Nwani et al., 2023), (Adesina & Mwamba, 2019), and (Jain & Kaur, 2022) find that economic freedom acts to reduce carbon emissions, whereas, (Joshi & Beck, 2018) found that in more developed nations, emissions increase. This is something of note; in literature, relatively little has been done to examine the different effects of economic freedom in developed nations compared to developing nations. Carlsson and Lundström (2001) note in their study the importance of treating the two groups separately since they respond differently to changes in economic freedom. This is another way in which this paper will add significant insights to the literature, by providing evidence of the differing impacts of economic freedom on developing versus developed nations.

The third question to be asked is whether there is a combined impact of greater EF and female political representation and what this combined impact is, if present. The paper will include an interaction term between FPR and EF, which is an addition to this field. A similar approach was taken by Atif et al. (2012), where the impact of board gender identity on renewable energy consumption was examined. Then, they interacted together to determine the combined impact on firm performance. Using a similar approach, this paper will answer whether there is a

combined effect and, if present, what the effect is. Firstly, if there is a combined effect, then by proving its presence, policy can be built around the findings to more effectively plan to reduce emissions. Utilising an interaction term should capture more complex and specific effects than can be captured with two separate models. This, combined with a separation of developed and developing nations, will allow for important insight into how one variable can be an instrument to increase the other with the aim of reducing emissions. The interaction term is defined as the combined effect of both economic freedom and female political representation on CO2 emissions.

The research question of this paper is as follows: ***'How do economic freedom and female political representation impact national CO2 emissions, and is there an additional effect when combined?'***. This question will be answered by analysing panel data from 163 countries and territories from the year 2012 to 2022. The IV model will be utilised in favour of FE since there are endogeneity concerns for several variables. FE will also be used as a robustness check.

The findings will be displayed as the results from the base model, the results relating to economic freedom, results for female political participation, and finally the interaction term.

Concerns of endogeneity are present, such as CO2, economic freedom, and the number of women in parliament, which are impacted by a large variety of variables. Firstly, there is the issue of omitted variable bias. Variables such as cultural attitudes towards environmental policies and the role of women in society could potentially influence both emission levels and FPR. Other variables such as level of economic development would influence both emissions and economic freedom. Beyond simple omitted variable bias, reverse causality may also be present. A country with low emissions and good environmental protection, for instance, may not feel the need to implement such tough emissions standards or reform in government to address emissions. This would cause reverse causality. Another issue potentially present is that CO2 emissions, FPR, and EF may be determinants of each other. For instance, if a country that attempts to promote a greater number of women into government may also be more likely to promote greater economic freedom and introduce policies which act to reduce emissions. Overall, the presence of endogeneity will produce biased estimates and subsequently and policy recommendations may be misleading. To address this, an IV regression was utilised in favour of FE. This is in line with previous literature and (Atif et al, 2021).

The paper is organised as follows:

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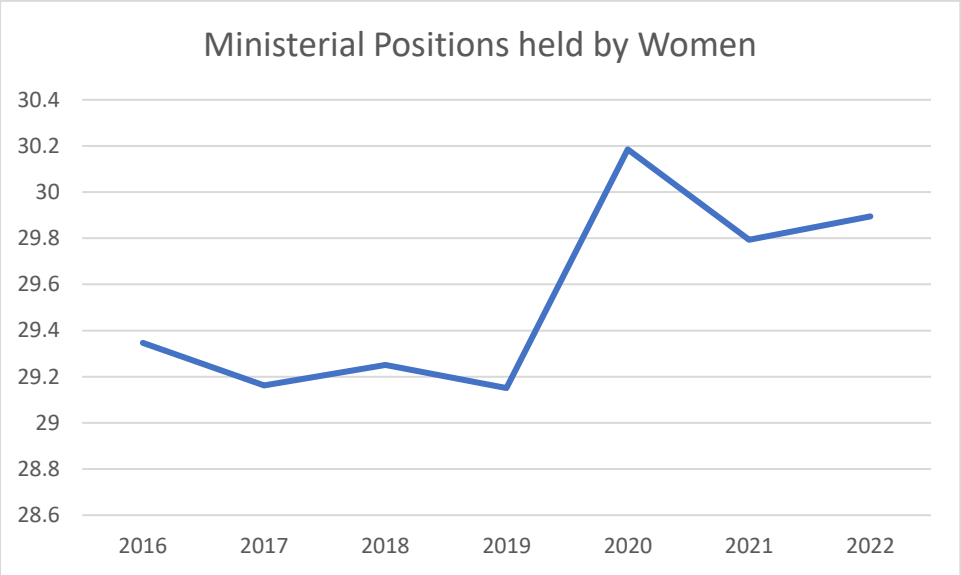
Literature review & Motivation

Climate change and its primary contributor, increasing CO2 emissions from human sources, is a heavily researched area owing to the disastrous effects of unabated, runaway carbon emissions. Not only will the effects of climate change be examined, but also how, through the lens of various mechanisms such as economic policies or government interventions, the worst effects can be avoided and those most vulnerable can be protected. This paper will examine how certain conditions impact CO2 emissions and, from the results, discuss how mechanisms related to the findings can be used to reduce carbon emissions and mitigate the effects of climate change. Specifically, it will examine how greater female participation at the ministerial level impacts the nation's CO2 emissions. Then, a relationship between EF and emissions will be examined, and finally, an interaction between the two independent variables will be used. This is a unique perspective to take as both fields are under-researched to different degrees. There is limited literature on female political representation and the impact on environmental variables or, explicitly, CO2 emissions. There is a more significant body of literature examining economic freedom and CO2 emissions, but predominantly, studies are in tandem with other variables such as renewable energy usage (Shahnazi & Shabani, 2021). By combining the effect of economic freedom and female political representation, this will be a unique addition in an area which grows in importance with each climate target missed.

The current body of literature focusing on women and their impact on environmental variables such as emissions is limited. With gender equality being an issue of growing importance and

often inaction around the world, it is essential to understand its effects on emissions as the demographic makeup of decision-makers changes.



Graph 1.

Graphic 1 shows the trend of ministerial positions held by women globally as a percentage, with a slight upward trend. The demographic change and how this will translate to carbon emission levels is an important area to explore. Previous literature has focused on the mechanisms which explain why women are more likely to promote environmentally friendly policies (Aden, 2023) and whether more gender-equal countries have lower emissions (Ergas & York, 2012). There have been several papers examining the impact of female board inclusivity on firm-level emissions (Kyaw et al., 2022), renewable energy usage (Hossain et al., 2021), and the wider environmental impacts of greater female representation on firm boards (Liu, 2018). However, little literature examines the impact of having greater female representation in political decision-making and the subsequent effects on emissions.

Based on research from previous literature, this paper expects to find that a greater female political presence in ministerial positions will have a negative effect on the volume of carbon emissions a nation emits. This is based on findings from papers in similar research areas. For instance, when female participation increases on corporate boards, the consumption of renewable energy increases (Kyaw et al., 2022). Beyond this, a paper written by Nadeem et al. (2020) aimed to determine whether there was truth to saying women are better for the environment by analysing the effect of greater board gender diversity on environmental innovation. Their results show that women are indeed more environmentally friendly. When

analysing a sample of over 10,000 US firms, they found that the higher the percentage of women on corporate boards, the greater the positive effect on environmental innovation. This suggests that when women are in positions of power, they support and promote greener policies. However, these are corporate boards, and the same relationship may not exist in national politics.

The effects of female political participation on environmental protection and emissions abatement are comparatively understudied. One of the few papers to address the idea, a 2019 paper (Lv & Deng, 2019) examines the relationship between female political empowerment (FPE) on both short and long-term carbon emissions. Their results in both timeframes found a significant and negative relationship between greater FPE and carbon emissions. Another paper that addresses female political power and CO2 emissions is 'Women's Status and Carbon Dioxide Emissions: A Quantitative cross-national Analysis' (Ergas & York, 2012). They also aim to examine the long-standing assumption that women are better for the environment than men and do so by focusing on the connection between women's political status and emissions. Their dependent variable of CO2 emissions is regressed against their independent variable of the percentage of national parliament seats made up of female politicians. They include control variables like urbanisation and GDP per capita. They find that women usually exhibit more significant concern for the natural environment and the causes and consequences of climate inaction, and once in government, they create the conditions necessary to fight climate change and reduce emissions effectively.

From previous literature, it can be expected that increasing the share of ministerial seats held by women will have a negative effect on CO2 emissions. This paper will provide important insight into the matter as the relationship between female ministerial positions and emissions is understudied. This paper will address the gap in the literature while also providing additional insights into economic freedom and a unique aspect of an interaction variable. Literature on the relationship between economic freedom is more abundant than that which examines the relationship between female political representation and emissions, but a clear consensus is not present. There are various hypotheses regarding the effect on emissions and the mechanisms which impact the relationship. Most previous literature agrees that economic freedom has a positive relationship with carbon emissions.

Schröder and Storm (2020) wrote a paper on the relationship between economic growth and climate change causing carbon emissions. They found that current understandings and aims of

economic growth fuel environmental degradation and that economic growth is linked with increased emissions. To avoid catastrophic climate change, government intervention must decouple current growth from emissions. With most governments, however, designing policies to maximise economic growth, this is a difficult proposition. However, allowing the market to reduce emissions naturally is not feasible either. As quoted by Carlsson and Lundström (2000), 'among economists, there is a rather strong consensus that economic freedom is positively correlated with economic growth'. When there is less government oversight to set restrictions on environmentally damaging practices, companies are less likely to take measures to reduce emissions.

The paper by Carlsson and Lundström (2000) studies how political and economic freedom affects CO2 emissions through economic growth. They examine the relationship between economic freedom and carbon emissions using both random and fixed effects approaches. This method allowed them to utilise the Hausman test as a robustness check. The paper is well written and delves into the details of the mechanisms that evidence economic freedom impacting carbon emissions. They conclude that the total effect of economic freedom is to increase CO2 emissions. However, they also found that economic freedom can promote growth and a better environment in a 'win-win' situation in low-income countries. The paper finds that outside of specific environments, economic freedom is positively correlated with CO2 emissions.

Joshi and Beck (2018) tested the impact of economic freedom on CO2 alongside political freedom and found the same answer to previous literature. When governments increase economic freedom to promote overall economic growth, this results in greater CO2 emissions. For industrial growth to occur while emissions are reduced, governments must moderate and restrict.

The Environmental Kuznets Curve is a popular mechanism to examine economic growth. Shahnazi and Shabani (2021) followed a similar strategy to Joshi and Beck (2018). By not only analysing the impact of GDP on CO2 emissions but also economic freedom, urbanisation, and renewable energy usage, a more complete understanding of CO2 emissions can be gained. Their methodology was based on a specific econometric model which accounts for variables affecting carbon emissions using the Kuznets environmental curve. They used panel data from 28 EU countries to run their regressions using the model with urbanisation, GDP, and economic freedom variables. This strategy, much like this paper, uses methods based on successful

previous literature. Their findings were different to those of Joshi and Beck (2018) as they found the relationship between economic freedom and CO2 was U-shaped. They found a threshold at which increased economic freedom will lead to increased CO2 emissions. This was a slightly different conclusion to previous papers as different initial economic freedoms will impact the way a further increase impacts CO2 emissions. Thus, this paper hypothesises that economic freedom will have a positive effect on CO2 emissions as, without government intervention and regulation, more profitable and environmentally damaging business models will be implemented.

One area of literature that has not been examined is the combined impact of increased female political representation and greater economic freedom. This is an interesting area of research to consider for its policy implications. A sizeable number of papers dedicated to the effects of economic freedom on carbon emissions are done in tandem with other variables such as political freedom (Carlsson & Lundstrom, 2001) (Joshi & Beck, 2018), information and communication technologies (Nwani et al., 2023), and renewable energy consumption (Betila, 2023) (Alola et al, 2022). In all papers, the combined effect of the two variables has not been studied. An interaction term can more accurately analyse the impact of the two variables and provide more appropriate policy advice.

The basis for the interaction term comes from Atif et al. (2021), a study on how gender diversity in corporate boards impacts renewable energy consumption. In the paper, an interaction term is used to test the impact of combined board diversity and renewable energy consumption on firm performance. The effects of board gender diversity are first tested against renewable energy consumption to test hypotheses around the area, and then a second regression using the interaction term assesses the combined impact. A similar approach for this paper will be utilised.

Using an interaction term creates a unique addition to existing literature. It will provide evidence and policy suggestions related to the effects of economic freedom and female political representation in relation to CO2 emissions. It is expected that the joint effect of greater female political participation will have an increasing effect on national CO2 emissions. The rationale behind this is that as female political representation acts to reduce CO2 emissions, increasing economic freedom undermines this by reducing the power and efficacy of the government where the increase in female representation is seen.

This paper will differ from existing literature for several reasons. Firstly, it will add to the existing literature on both how female political representation and economic freedom impact CO2 emissions, and secondly, it will add a unique interaction term. As with many papers before on economic freedom and CO2 emissions (Carlsson & Lundstrom, 2001) (Shahnazi & Shabani, 2021) (Carlsson & Lundstrom, 2003), this paper will cover more than one issue. By first studying the effect of female political representation on CO2, this paper will add to a small pool of existing literature. Studying the effects of economic freedom on emissions and examining how different development levels of individual nations impact the results will add relevant information to the current literature pool. Lastly, by using an interaction term and analysing the results, the paper will add a unique element to the literature and provide novel results that will lead to new conclusions regarding the two variables.

Data

The data consists of panel data of annual national CO2 emissions from 2012 to 2022. The choice of years is owed to the availability of accurate CO2 emissions data, the availability of well-recorded independent and control variables, and the presence of a significant enough period to allow for the impact of variation between the X and Y terms to be present. Data for Carbon emissions was taken from 'Our World in Data.' Data for other variables were primarily taken from World Bank datasets, in line with many previous papers, (Joshi & Beck, 2018) and (Kruse, 2014). Data for 2023 is inconsistent among many variables, so 2022 was the most recent year analysed. 2012 was chosen as a start date because of the inconsistent data collection and availability of independent variable data before this date. Several variables, such as environmental spending and the democracy index, had poor data before 2012, so to allow for the most accurate results, 2012 was chosen as the start period. The years chosen are then based on the availability of complete data sets. The nations selected are the top 163 emitting countries and territories globally, according to Climatetrace. The sample size is large enough to include a broad sample of developed and developing nations. Of the countries omitted, the majority are either micro or island states or those where reporting is poor owing to war or other factors that complicate reporting and recording of emissions and other variables.

Table 1 presents basic information on the variables.

Notation	Variable	Description
CO2	CO2 Emissions	National annual CO2 emissions measured in Million tonnes
Economic Freedom	Economic Freedom	Economic Freedom Index from 0 - 100

Female Political Representation	Female Ministerial Positions	Log of Proportion of Women in Ministerial Level Positions as a Percentage
Female Political Participation (Alternate Measure)	Female Political Participation	Number of Women in National Parliament as a Percentage
Female Labour Force	Female Labour Force Penetration	Female Labour Force Participation Rate as a Percentage
GDP	Gross Domestic Product	Log of GDP per Capita in Current US Dollar Value
Rate of Urbanisation	Rate of Urbanisation	Share of the Population Living in Urban Areas as a Percentage
Democracy level	Democracy Index	Democracy Index from 1 to 10
Renewable Energy Usage	Renewable Energy Consumption	Log of Renewable Energy Consumption as a Percentage of Final Energy Consumption
Tariffs	Tariff Levels	Log of Tariff, Applied, Weighted Mean, on all Products as a Percentage
Colonised	Colonisation	A Dummy Variable which equals 1 if a country has been colonised
Population	Total population	Total national population by year measured in thousands
Average Years of Female Schooling	Amount of female education	The mean number of years girls have been educated
Common Law	Basis of legal system	A dummy variable which equals 1 if the country's legal system is based on English common law
French Civil Law	Basis of legal system	A dummy variable which equals 1 if the country's legal system is based on French civil law
German Civil Law	Basis of legal system	A dummy variable which equals 1 if the country's legal system is based on German civil law
Scandinavian Civil Law	Basis of legal system	A dummy variable which equals 1 if the country's legal system is based on Scandinavian civil law
Country Development	Country development level	A dummy variable which equals 1 if a country is developed and 0 if developing

Table 2 presents the descriptive statistics of the data.

VARIABLE	**OBSERVATIONS**	**MEAN**	**STANDARD DEVIATION**

CO2	1594	2.32e+08	9.86e+08
FREEDOM	1545	61.32583	10.63775
MINISTERIAL POSITIONS	1101	2.870221	.6830907
FEMALE PARTICIPATION	1572	23.61735	12.11978
FEMALE WORKFORCE	1605	50.07383	14.63381
LNGDP	1566	8.911491	1.400519
URBANISATION	1595	59.38643	21.3193
DEMOCRACY	1584	5.54327	2.199515
LNRENEWABLE_ENERGY	1437	2.979444	1.365567
LNTARRIFS	1168	1.185868	.8658661
COLONISED	1254	121.9203	127.5439
POPULATION	1441	5.10e+07	1.73e+08
YRS_SCHOOLING	1425	8.403721	3.584616
COUNTRYDEV	1608	.2394279	.426867
COMMON_LAW	1608	.0957711	.2943687
FRENCH_CIVIL_LAW	1608	.1436567	.3508504
GERMAN_CIVIL_LAW	1608	.034204	.1818093
SCANDINAVIAN_LAW	1608	.0273632	.1631901
COUNTRYDEV	1608	0.2394279	.426867

Dependent variable

The dependent variable is the annual CO2 emission per country, measured in million tonnes by Our World in Data. Per Our World in Data, by the mid-20th century, global emissions had grown gradually to 6 billion tonnes, but by 1990, they had reached more than 20 billion. They have continued to grow rapidly to over 35 billion tonnes per annum today. These emissions have slowed their rate of growth but have yet to reach their peak. Europe and the USA have historically accounted for most CO2 emissions and, on the cusp of the 20th century, emitted 90% of global emissions. Today, the USA and Europe account for less than a third of all emissions. This gives particular interest to the results from this study as an increasing share of emissions are coming from developing countries while many developed nations are reducing theirs. How the overall makeup of parliamentary ministerial positions held by women and

economic freedom impact these increasing and decreasing emission rates will be crucial to understanding if emissions are to be reduced and the effects of climate change abated.

The recent data available is sourced from the UN Statistics Office, which compiles data from national agencies and annual questionnaires. Data specific to cement production and gas flaring is taken from UN data, with supplementation from the US Department of Interior Geological Survey and the US Department of Energy Information Administration. Uncertainties in estimating global CO2 emissions exist, ranging from 2% to 5%. Overall, any conclusions must keep this in mind, as reporting by individual governments may change results. The measure of CO2 does not account for where emissions-producing goods are consumed but credits emissions to the country of production. This should be kept in mind as it may skew emission numbers away from developed nations as they offshore more carbon-intensive industries to developing nations with reduced emission-based legislation (Meng et al., 2023).

Independent variables

The first independent variable is Economic Freedom. In literature regarding economic freedom, the Economic Freedom Index from The Heritage Foundation is widely utilised (Adesina & Mwamba, 2019), (Joshi & Beck, 2018), (Parsikevicius et al., 2021), (Knedlik & Kronthaler, 2007), and (Kim, 2011). Four key aspects with 12 equally weighted variables are scored from 0-100 to calculate a country's score. The four fundamental aspects are the rule of law, government size, regulatory efficiency, and market openness. The 12 variables are property rights, judicial effectiveness, government integrity, tax burden, government spending, fiscal health, business freedom, labour freedom, monetary freedom, trade freedom, investment freedom, and financial freedom. Each variable has several sub-variables which generate the given score. The Heritage Foundation defines Economic freedom as a ‘philosophy of governance that rejects dogma and embraces a diverse range of strategies for economic advancement’ (Kim, 2024). An alternative Economic Freedom ranking is available, but a significant amount of previous literature, as previously discussed, uses the Heritage Foundation.

The second independent variable is female political representation. A considerable amount of literature has analysed the increasing number of women involved in governance worldwide and how this increasing representation affects policy outcomes (Hessami & Fonseca, 2020) (Clayton, 2015). In this paper, two measures of representation will be used. First is the percentage of Ministerial positions in government filled by women, and the second is the

percentage of seats held by women in national parliaments. Both are from World Bank data sets. The figures reported by the World Bank are as accurate as possible regarding the overall percentage of women in government. However, it is difficult to accurately report on all changes owing to ill health, resignation, and, for some smaller countries, a lack of coverage of individual changes as per the World Bank. Ministerial positions, by definition, are more important and impactful, and subsequently enjoy greater reporting in both national and international media than ordinary parliamentary officials, allowing for them to be more accurately collected.

Control variables

The first of the control variables is urbanisation. This is a measure of urbanisation of a country as a percentage of overall population living in urban areas from Our World in Data. It is an important variable to include as it affects emissions directly as more urban areas tend to have higher CO2 intensity than rural areas. It also impacts the independent variables as greater urbanisation is linked with greater levels of industrialisation and trade (Carlsson & Lundstrom, 2000), and higher levels of female education (Bataineh, 2019).

The second control variable is a democracy index. This source also comes from Our World in Data and ranks countries on a scale from 1 to 10. It is a good control as the level of democracy will impact economic freedom as per (Haan & Sturm, 2000), which finds a relationship where greater democracy increases levels of economic freedom. It is found by (Joshi & Beck, 2018) that the relationship between democracy and emissions is nonlinear, and that emissions initially increase with increasing democratic scores but that the effect declines.

The third control variable is renewable energy consumption. The data is taken from the World Bank and measures the overall percentage of energy consumption that comes from renewable sources. It is a relevant and important variable as it directly impacts CO2 and there is evidence that countries with more policies to promote renewable energy, are likely to have a greater share of women represented in parliament (Salamon, 2023).

The last control variable is population. It is an important control to include as population size due to the likely influence it will have on CO2 emissions. Beyond this, the size of population may influence government priorities which will influence economic freedom levels and the percentage of parliament made by women.

Country development is a dummy variable which allows for nations to be separated into developed and developing nations. It is important to give greater clarity as to how each variable

impacts emissions in different environments. Its inclusion will allow for more accurate policy implications as they can be more effectively implemented where they will be most effective.

Instrument Variables

Four control variables were used; colonial rule , legal system origin, years of schooling for women, and female participation in the workforce.

Colonial rule regards to how many years a country spent under European colonial control. Data is from Our World in Data. This is a valid instrument that impacts economic freedom but does not directly influence CO2 emissions. Being under colonial rule has been used in literature such as (Bertocchi & Canova, 2002), (Faria & Montesinos, 2009). It produced an f-test score of 55.4725. The high F-test score implies a strong and relevant instrument.

Legal system origin is the type of legal system which a national legal system is based on. There are four different origins, such as English common law, German civil law, Spanish civil law, and Scandinavian civil law. Data is from La Porta et al (1999). It produces a F-test score of 26.7384.

Years of schooling for women is the average number of years of schooling women receive. The data is taken from Global Data Labs and generates a F-test score of 8.9602.

The last instrument variable is female participation in the labour force. This is the percentage of women who are active in the national labour force. The data is taken from the World Bank and has an F-test score of 9.4260.

The generally accepted minimum F-test score for a strong and relevant instrument variable is 10. Years of schooling and female participation in the labour force are below this score and subsequently should not be used as instrument variables. They may be unsuitable for several reasons. There is potential for both to impact CO2 emission levels. The years of schooling may impact emissions as a higher score could indicate a larger and more carbon intensive economy as the labour force is larger and more well educated. For the same reason female participation in the labour market may impact co2 emissions levels.

The F-test score for legal system origin was high at 26.7384. This implies that the instrument is strong and relevant and would make a good choice as an instrument variable for this model. However, the F-test score for colonialism was higher and therefore a better choice of instrument. From the F-test scores and general literature, colonialism is the best choice of instrument variable.

Even with a strong F-test score, concerns of endogeneity remain. Using IV regression is an effective method in removing endogeneity bias but does not fully remove endogeneity concerns. Prominently omitted variable bias cannot be fully eliminated and therefore the concern of endogeneity will always be present. Any remaining endogeneity can create biased estimates which therefore reduce the relevance of conclusions and may create misleading policy advice. However, by utilising IV regression model, choosing suitable control variables, and using a strong instrument variable will help to mitigate endogeneity.

Methodology

To examine the impacts that female political representation and economic freedom have on national CO2 emissions, the following two empirical models were estimated:

Model 1

First stage:

$$freedom_{i,t} = \pi_0 + \pi_1 Ministerial_{i,t} + \pi_2 Urbanisation_{i,t} + \pi_3 democracy_{i,t} + \pi_4 lnRenewableEnergy_{i,t} + \pi_5 population_{i,t} + \pi_6 colonised_{i,t} + \pi_7 \Sigma(year\ fixed\ effects) + \pi_8 \Sigma(country\ fixed\ effects) + v_{i,t}$$

Second stage:

$$co2_{i,t} = \beta_0 + \beta_1 \widehat{freedom}_{\iota,t} + \beta_2 lnMinisterial_{i,t} + \beta_3 urbanisation_{i,t} + \beta_4 democracy_{i,t} + \beta_5 lnRenewableEnergy_{i,t} + \beta_6 population_{i,t} + \pi_7 \Sigma(year\ fixed\ effects) + \pi_8 \Sigma(country\ fixed\ effects) + +u_{i,t}$$

Model 2

First stage:

$$freedom_{i,t} = \pi_0 + \pi_1 lnMinisterial_{i,t} + \pi_2 urbanisation_{i,t} + \pi_3 democracy_{i,t} + \pi_4 lnRenewableEnergy_{i,t} + \pi_5 population_{i,t} + \pi_6 colonised_{i,t} + \pi_7 (colonised\ x\ freedom) + \pi_8 \Sigma(year\ fixed\ effects) + \pi_9 \Sigma(country\ fixed\ effects) + +v_{i,t}$$

Second stage:

$$co2_{i,t} = \beta_0 + \beta_1 \widehat{freedom}_{i,t} + \beta_2 lnMinisterial_{i,t} + \beta_3 urbanisation_{i,t} + \beta_4 democracy_{i,t} + \beta_5 lnRenewableEnergy_{i,t} + \beta_6 population_{i,t} + \beta_8 (colonised\ x\ freedom)_{i,t} + \pi_9 \Sigma(year\ fixed\ effects) + \pi_{10} \Sigma(country\ fixed\ effects) + +u_{i,t}$$

The model used was IV 2sls regression, as it more effectively addresses endogeneity than FE or RE models. Model 1 tests the impacts of both independent variables on the dependent variable. Model 2 works to test the combined impact of both independent variables on the

dependent variable by using an interaction term. Both models will utilise a dummy variable which allows for the exclusion and inclusion of developed or developing countries to examine the differing impacts. The variable of interest in this study is CO2. It is measured as a nation's total emission in the year t. B_0 is used to represent the constant if all variables are equal to zero.

B_2 and π_1 in both models are the first independent variables: the natural log of ministerial positions held by women (lnMinisterial) and, alternatively, as a robustness check, the proportion of parliamentary seats held by women (female_participation).

The dependent variable in the first stage of the first step of both models is economic freedom, measured on a 1 – 100 scale generated by The Heritage Foundation which, as discussed in the data section, is in line with literature regarding economic freedom. In the second stage of both models, β_1 represents economic freedom when the instrument variable of colonialism has been applied.

In model 2, β_8 represents the interaction term between economic freedom and female political representation. Economic freedom and Female Political Participation will interact to form an interaction variable, which will be regressed against CO2 to test whether the two variables have a combined effect.

Year and country fixed effects are self-explanatory; each variable has been explained in Table 1. The error term in step 1, $v_{i,t}$ represents the unobserved factors that impact economic freedom that the chosen control variables have not explained or controlled for. In the second stage, the error term is represented by $u_{i,t}$ and represents all unobserved factors which impact CO2 and are not controlled for by the chosen control variables. In both models and stages, 'i' represents a certain country and 't' a specific time.

The natural log format is used for four variables; GDP, Tariffs, renewable energy, and ministerial representation. Several forms of alternative measurement and a new control variable are introduced for robustness checks. As a robustness check, each control variable was assessed for collinearity with co2 and GDP was found to be very collinear. For this reason, it was excluded from the model. This will be expanded upon further in the robustness section. Adding tariff as a control was another robustness check. By controlling for an additional variable omitted variable bias is partially addressed and reducing endogeneity and trade policy effects are more accurately accounted for. The other robustness check is a new measurement of female political representation which is the share of national parliaments consisting of women. Lastly, an FE model will be run to check whether results between the two models vary significantly.

If the results are significantly different then it will provide unofficial evidence that endogeneity is influencing FE results which would support using the IV regression model.

The control variables are chosen based on previous literature (Joshi & Beck, 2018; Shahnazi & Shabani, 2021; Mavisakalyan & Tarverdi, 2019). Included as controls are various variables designed to limit the impact of exogenous variables.

The usage of renewable energy has apparent impacts on a nation's CO2 emissions. (Adams & Acheampong, 2019) found that greater democracy had a positive impact on reducing CO2 emissions which gives reasons for its inclusions. The implementation of non-carbon tariffs has a positive effect on increasing carbon emissions and may act to reduce the efficacy of other climate-based policies (Cary, 2020). The chosen control variables reflect choices made in previous literature with a more novel inclusion of tariffs also present. The variables are eclectic and should work well to reduce the impact of exogenous variables.

Four instrument variables were tested within the report. These are female labour participation rates and the average years of female education as an instrument for female political participation, and a dummy variable which equals one if a country has ever been a colony of a European power and the colonial legal origin has been used as instruments for economic freedom. Beyond this, a dummy variable to identify if a country is either developed or developing is utilised to give greater depth to results.

Studying this question is challenging because of endogeneity issues. For instance, omitted variable bias or unobserved heterogeneity. I have answered this by utilising the IV regression model with a strong instrument variable of colonial history. There are still challenges such as omitted variable bias, unobserved heterogeneity, and potentially reverse causality. The choice of control variables is in line with previous literature but there is still a high likelihood of omitted variable bias.

Results

The impact of economic freedom and female political participation on co2 emissions will now be examined. Column 1 in table 3 is the IV regression of model 1. The second column includes a dummy variable that excludes developing countries. The last column includes the same dummy as column 2 but excludes developed countries. The first stage tables will be included in the abstract.

Table 3.

	(1) co2	(2) co2	(3) co2
Economic Freedom	12451355.8***	38778704.7***	6666380.7**
	(3301211.5)	(8230195.3)	(3210229.1)
Female political representation	34298119.6	114247636.7	22607248.1
	(40287760.1)	(74706316.3)	(38994140.4)
Rate of Urbanisation	4512844.4***	-238619.8	3204645.4**
	(1352766.1)	(3395832.3)	(1286164.4)
Democracy Ranking	-66492121.9***	-254928345.0***	-87370591.7***
	(16613579.3)	(88361405.7)	(16180632.2)
Renewable Energy usage	-34178030.2*	136237455.3**	-32412213.6*
	(19940081.3)	(60320476.8)	(18596023.5)
Population	4.350***	15.21***	4.138***
	(0.129)	(0.448)	(0.120)
Constant	-648917984.9***	-1.64235e+09***	-137974847.0
	(192391184.9)	(394404797.0)	(199444955.0)
Observations	640	102	538
R^2	0.645	0.931	0.694

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The above results from column 1 suggests that first, economic freedom has a positive and statistically significant effect on emissions (at a 1% significance level). This means that a one unit increase in economic freedom will cause a 12451355.8 tonne increase in co2 emissions. This is consistent and statistically significant evidence that an increase in economic freedom leads to an increase in co2 emissions. Female political participation however, contrary to expectations, has a positive coefficient, but at a statistically insignificant level (at 10%). This implies that female political participation does not have a detectable or meaningful impact on co2 emissions.

Comparing columns 2 and 3, we can see that the effect of economic freedom is varied. The coefficient of female political participation remains similar and the sign remains positive, but both are still statistically insignificant. We can see however that the coefficient and significance level of economic freedom differ. While column 1 is statistically significant at a 1% level, column 3 is significant to a 5% level. The coefficient of column 2 is larger at 38778704.7

compared to column 3 at 6666380.7. This means that a one unit increase in economic freedom in a developed country will cause 32,112,324 more tonnes of co2 to be emitted.

Table 3 provides evidence on how the two independent variables impact CO2 emissions independently. Table 4 will examine how they interact together to impact CO2 emissions through an interaction variable. Column 1 displays the results of model 2. The second and third columns include a dummy variable to account for country development levels with column 2 representing a developed country and column 3 showing development.

Interaction term

Table 4.

	(1) co2	(2) co2	(3) co2
Economic Freedom	-12074955.9	-114957097.8**	-4208914.7
	(14592251.5)	(45898837.3)	(15976024.1)
Interaction Term	8376545.5*	46048742.5***	3808854.9
	(4855073.5)	(13539272.8)	(5481315.0)
Female Political Representation	-470555088.1	-3.11837e+09***	-202047929.8
	(295366312.4)	(953212866.6)	(325642856.1)
Rate of Urbanisation	4404723.8***	1661631.6	3232651.4**
	(1352083.7)	(3325036.1)	(1286510.1)
Democracy Ranking	-68477776.1***	-285482703.8***	-87178931.6***
	(16627265.9)	(85740623.7)	(16179367.5)
Renewable Energy Usage	-37540637.5*	98242430.0*	-33592089.4*
	(20003721.6)	(59284010.5)	(18669246.6)
Population	4.341***	15.45***	4.135***
	(0.129)	(0.439)	(0.120)
Constant	844990203.8	9.34507e+09***	502486195.7
	(886908181.0)	(3.25290e+09)	(942995332.0)
Observations	640	102	538
R^2	0.646	0.935	0.694

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results from column 1 indicate that the combined effect of economic freedom and female political participation on CO2 emissions is positive and statistically significant (at a 10%

significance level). This result shows that a combined effect is present. The sign is in line with expectations and the magnitude of the coefficient means that the effect of economic freedom or female political representation on co2 emissions increased by 8376545.5 tonnes with a one unit increase in the other interacting variable.

Column 2, developed countries, is also positive and statistically significant at a 1% significance level. Column 3 however is statistically insignificant meaning that the combined effect does not have a meaningful impact on emissions. This will be further expanded in policy implications. The magnitude of column 2 means that when the combined effect is present the effect of economic freedom or female political representation on co2 emissions increased by 46048742.5 tonnes with a one unit increase in the other interacting variable.

Robustness Checks

The following section will examine several different checks of robustness performed. These range from tests such as alternative measures of important variables, additional controls, and fixed effects models being estimated.

Alternative measure of female political participation

First is the new measure of female political participation. In model 1, female political participation is measured as the proportion of ministerial positions taken by women. As a robustness check the measure of female political participation will be changed to the proportion of parliamentary seats held by women. The reason for doing this is to assess whether participation in politics has an impact on emissions or whether the effects from women being more likely to favour socially conscious policies are only present when women are in positions of power. A noted limitation by the World Bank of the data set is that measuring women's contribution to political decisions making, simply examining the number of women in parliament may be insufficient as they may face obstacles in achieving their parliamentary goals (World Bank, n.d). The results of using the new measure of female political participation are presented in table 5 with the original model with ministerial as the independent variable in column 1 and the new measure in column 2. Columns 3 and 4 will display the new measure with the dummy variable as developed and developing respectively.

Table 5.

	(1) co2	(2) co2	(3) co2	(4) co2
Economic Freedom	12451355.8***	13519837.3***	31365067.2***	8276778.4***

	(3301211.5)	(2816897.4)	(5864788.3)	(2682606.8)
Female Political Representation	34298119.6			
	(40287760.1)			
Rate of Urbanisation	4512844.4***	3976151.7***	242032.9	2517898.3**
	(1352766.1)	(1094234.3)	(3227484.6)	(1009857.5)
Democracy Ranking	-66492121.9***	-58654277.5***	-160364493.1***	-81248117.0***
	(16613579.3)	(13543116.9)	(54408463.2)	(12866974.4)
Renewable Energy Usage	-34178030.2*	-27367019.6*	146879350.6***	-25727871.2*
	(19940081.3)	(15647260.4)	(50460672.8)	(14258150.7)
Population	4.350***	4.344***	15.68***	4.093***
	(0.129)	(0.108)	(0.356)	(0.0977)
Alternate Measure of Female Political Representation		4042490.9**	1881374.8	4929594.0***
		(1705441.6)	(3766862.2)	(1622123.3)
Constant	-648917984.9***	-749817180.9***	-1.65933e+09***	-302762646.7*
	(192391184.9)	(160211931.6)	(308417189.8)	(166495999.5)
Observations	640	942	153	789
R^2	0.645	0.634	0.942	0.692

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

From the table we can see that female participation has a positive and statistically significant effect on emissions (at a 5% significance level). The coefficient means that for a one unit increase in female representation in parliament, co2 levels increase by 4042490.9 tonnes. This is surprising and not in line with previous literature. Columns 3 and 4 show that in both it has a positive effect on emissions but only in developed nations is it a statistically significant result (at 1% significance level). This implies that the greater the number of women in parliament, the greater emissions will be. This is counter to previous literature.

Interaction term:

Column 1 in table 6 represents model 2 with the alternative measure of female political representation. Column 2 shows the original ministerial measure of parliamentary positions. Columns 3 and 4 represent the alternative measure in developed and developing nations respectively.

Table 6.

	(1) co2	(2) co2	(3) co2	(4) co2
Economic Freedom	14871019.8***	-12074955.9	34331624.2***	11246155.7**
	(4505985.1)	(14592251.5)	(7859977.4)	(4406255.3)
Interaction Term	-141748.0	8376545.5*	2177252.5	-603256.9
	(847437.4)	(4855073.5)	(1349984.0)	(824741.0)
Alternate Measure of Female Political Representation	5543179.8**		914643.4	6774827.7***
	(2428398.6)		(5122423.0)	(2331678.2)
Rate of Urbanisation	4416883.9***	4404723.8***	-1375035.8	3320769.6**
	(1380379.4)	(1352083.7)	(3997604.7)	(1307281.4)
Democracy Ranking	-72111021.3***	-68477776.1***	-283493443.0***	-92102074.8***
	(17040169.6)	(16627265.9)	(92370451.6)	(16478438.6)
Renewable Energy Usage	-25123201.7	-37540637.5*	116770836.6*	-18086964.5
	(20980041.7)	(20003721.6)	(65609929.6)	(19658685.2)
Population	4.375***	4.341***	15.22***	4.163***
	(0.130)	(0.129)	(0.468)	(0.120)
Female Political Representation (Ministerial)		-470555088.1		
		(295366312.4)		
Constant	-798152389.7***	844990203.8	-1.11239e+09**	-427783639.7*
	(227820440.3)	(886908181.0)	(485905804.7)	(234244870.2)
Observations	629	640	102	527
R^2	0.648	0.646	0.931	0.699

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In the first column we see that the interaction term is negative and statistically insignificant (at a 10% significance level). Column 2 is positive and statistically significant (at 10% significance level). By using parliamentary seat share as a measure of female political representation, the interaction term becomes statistically insignificant and negative in its effect on emissions. The interaction term is also statistically insignificant in both developed

and developing countries (at a 10% significance level). However, the sign on developing countries is negative.

New Tariff control variable

The second check was adding a new control variable. The chosen variable is tariff levels in natural log form. According to (Cary, 2020) the implementation of tariffs acts to increase domestic carbon intensities. Adding an additional control variable is in line with previous literature of the subject matter but also generally in econometric papers, (Eren, 2022; Atif et al, 2021). Table 7 will display in column 1 the original regression, column 2 with tariffs included and 3 and 4 will show the effect in developed and then developing nations respectively.

Table 7.

	(1) co2	(2) co2	(3) co2	(4) co2
Economic Freedom	12451355.8***	13170726.4***	37544299.6***	2516515.5
	(3301211.5)	(4289349.2)	(8389259.5)	(4278235.2)
Female Political Representation	34298119.6	26785108.3	104453647.4	13659213.2
	(40287760.1)	(48826636.0)	(75063807.2)	(47612828.9)
Rate of Urbanisation	4512844.4***	5416679.7***	-275420.6	3784029.0**
	(1352766.1)	(1737243.7)	(3400177.5)	(1642767.9)
Democracy Ranking	-66492121.9***	-75073122.4***	-249860045.1***	-113664304.9***
	(16613579.3)	(21329755.3)	(88277559.1)	(21086880.8)
Renewable Energy USage	-34178030.2*	-11790987.3	134528257.6**	-453946.2
	(19940081.3)	(25968732.2)	(61044518.2)	(24132943.7)
Population	4.350***	4.352***	15.38***	4.096***
	(0.129)	(0.150)	(0.488)	(0.138)
Tariff Levels		-31156486.3	-92228427.3	-100006711.3**
		(44151364.6)	(97868334.8)	(41985185.9)
Constant	-648917984.9***	-697270837.0**	-1.51125e+09***	293128931.0
	(192391184.9)	(311133618.5)	(436865388.5)	(324274796.4)
Observations	640	498	101	397
R^2	0.645	0.633	0.931	0.695

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The inclusion of the control of tariff does not change the results greatly. There is a slight change in the magnitude of both independent variables but both retain their direction and level of significance. As per previous literature, tariffs act to increase emissions and compared to column 1, column 2 has an increase in co2 emissions of 719,370.6 tonnes. We can also see that adding tariffs into the model has differing effects depending on country development levels. Developed nations are statistically significant at a 5% significance level while the effect is statistically insignificant in developing countries. The results are relatively similar and the only change is a slight increase in the coefficient. The model is robust to changing controls.

Interaction term:

In table 8 column 1 represents model 2 with tariffs added as a control variable. Column 2 represents the same model without tariffs included. Columns 3 and 4 represent developed and developed countries respectively.

Table 8.

	(1) co2	(2) co2	(3) co2	(4) co2
Economic Freedom	-17077401.4 (18857972.6)	-12074955.9 (14592251.5)	-109708133.9** (45757710.7)	-17439893.2 (20834715.0)
Interaction Term	10080149.1* (6120300.6)	8376545.5* (4855073.5)	44498588.0*** (13606871.2)	6848336.4 (6997414.6)
Female Political Representation	-593068222.0 (379494879.9)	-470555088.1 (295366312.4)	-3.01273e+09*** (955967197.1)	-397039389.6 (422328482.0)
Rate of Urbanisation	5138368.5*** (1742237.4)	4404723.8*** (1352083.7)	1677086.1 (3345344.4)	3731175.7** (1642761.0)
Democracy Ranking	-77381955.4*** (21336314.0)	-68477776.1*** (16627265.9)	-283790729.2*** (86068784.8)	-112957658.2*** (21087775.3)
Renewable Energy Usage	-17783202.9 (26174676.8)	-37540637.5* (20003721.6)	102597105.9* (59896216.9)	-4202747.9 (24422101.2)
Population	4.332*** (0.151)	4.341*** (0.129)	15.48*** (0.473)	4.084*** (0.139)
Tariff Levels	-38356150.7 (44285763.1)		-18179196.5 (97408515.6)	-104222070.8** (42182955.9)
Constant	1.20939e+09	844990203.8	8.97052e+09***	1.50564e+09

	(1.19858e+09)	(886908181.0)	(3.23296e+09)	(1.28062e+09)
Observations	498	640	101	397
R^2	0.634	0.646	0.936	0.695

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Adding tariffs as a control does not impact the sign or significance level of the interaction term. However, the magnitude when tariffs are included is significantly larger. This means that the effect of economic freedom or female political representation on co2 emissions increased by 10080149.1 tonnes with a one unit increase in the other interacting variable when tariffs are introduced. This is a difference of 1,703,603.6 tonnes. This is a significant difference. There is also a difference between developed and developing nations. The sign is the same but the significance level and magnitude are different. Developed nations have a greater combined impact than developing nations and the result is statistically significant (at a 1% significance level), whereas developing countries are statistically insignificant.

GDP

When checking for collinearity, GDP received a VIF score of 54.33. The general rule is that a value above 10 implies high collinearity. For this reason, GDP was removed from the model. Column 1 and 3 show model 1 and 2 respectively without GDP included as a control variable. Columns 2 and 3 show the same models with GDP added.

Table 9.

	(1) co2	(2) co2	(3) co2	(4) co2
Economic Freedom	12451355.8***	10198647.1***	-33845135.7	-38859319.9
	(3301211.5)	(3514193.1)	(63639028.9)	(78181040.2)
Female Political Representation	34298119.6	54709573.4	-649747517.0	-786125113.6
	(40287760.1)	(39792806.8)	(1.20503e+09)	(1.56485e+09)
Rate of Urbanisation	4512844.4***	719600.7	26212986.9	23326761.0
	(1352766.1)	(1533078.4)	(21769066.2)	(18063542.6)
Democracy Ranking	-66492121.9***	-119533301.5***	-11145547.5	-13870948.4
	(16613579.3)	(18855041.8)	(11936726.0)	(13804377.8)
Renewable Energy Usage	-34178030.2*	34271636.3	-10585588.0	-14424719.9
	(19940081.3)	(23032193.0)	(26036470.6)	(33858926.9)
Population	4.350***	4.331***	3.288***	3.218***

	(0.129)	(0.127)	(0.429)	(0.478)
GDP		188643890.4***		-31874882.2
		(34728105.2)		(64854815.2)
Interaction Term			10766965.6	13042305.5
			(19887316.0)	(25874858.0)
Constant	-648917984.9***	-1.90944e+09***	1.30696e+09	1.92020e+09
	(192391184.9)	(292975318.6)	(3.27408e+09)	(4.71777e+09)
Observations	640	632	640	632
R^2	0.645	0.662	0.997	0.996

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We can see that the inclusion of GDP does not change the sign or significance of our variables of interest and only slightly impacts magnitude. However, with the high degree of collinearity and high potential for reverse causality between co2 and GDP, it was omitted from the model. The high reverse causality may arise from increases in GDP creating more CO2, while environmental policies which reduce co2 may act to reduce economic growth and GDP.

Fixed Effects

Endogeneity is a potential concern in any model. A potential informal test for endogeneity is to compare the results of fixed effects to IV. If there are significant differences in results then endogeneity is present. If this is the case then IV is the correct model specification. Columns 1 and 2 represent an FE estimation of model 1 and 2 respectively. Columns 2 and 4 represent models of IV regression. Columns 1 and 2 represent model 1 while columns 3 and 4 represent model 2.

Table 10.

	(1) co2	(2) co2	(3) co2	(4) co2
Female Political Representation	-8594293.2	34298119.6	19210495.7	-470555088.1
	(6061473.0)	(40287760.1)	(39492815.8)	(295366312.4)
Economic Freedom	3389547.3***	12451355.8***	4662480.5**	-12074955.9
	(1071521.2)	(3301211.5)	(2083476.2)	(14592251.5)
Rate of Urbanisation	20352999.6***	4512844.4***	19776059.6***	4404723.8***
	(4580857.9)	(1352766.1)	(4653502.5)	(1352083.7)
Democracy Ranking	-22613925.3***	-66492121.9***	-22518884.2***	-68477776.1***
	(8171048.7)	(16613579.3)	(8175083.8)	(16627265.9)

Renewable Energy usage	8521544.8	-34178030.2*	8803143.0	-37540637.5*
	(14062464.2)	(19940081.3)	(14073086.4)	(20003721.6)
population	2.779***	4.350***	2.779***	4.341***
	(0.428)	(0.129)	(0.428)	(0.129)
Female Political Representation # Economic Freedom			-447851.6	
			(628568.0)	
Interaction Term				8376545.5*
				(4855073.5)
Constant	-1.15297e+09***	-648917984.9***	-1.19962e+09***	844990203.8
	(292554803.7)	(192391184.9)	(299895795.4)	(886908181.0)
Observations	821	640	821	640
R^2	0.131	0.645	0.132	0.646

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We can see significant differences in results. In model 1 we can see that female political representation is statistically insignificant but that the signs are opposite. Economic freedom in model 1 is of the same sign and statistical significance but very different magnitudes. The interaction term between economic freedom and female political representation is also different. Using FE results in a statistically insignificant and negative coefficient for the interaction term while using IV produces a positive and statistically significant coefficient (at 10% significance level). There are clear and significant differences between the results when using FE and IV which informally suggests that endogeneity is present. This supports the use of IV as an instrument.

Control variables

In table 11 column 1 represents female participation in the workforce. Column 2 represents average years of female schooling, column 3 is years of being colonised and the chosen instrument for this variable, and column 4 is the colonial origin of a country's legal system.

Table 11.

	(1) co2	(2) co2	(3) co2	(4) co2
Female Political Representation	49458148.7	49399789.2	34298119.6	28807341.5
	(45153140.4)	(47072513.5)	(40287760.1)	(36270930.1)

Economic Freedom	11925169.7***	12255220.1***	12451355.8***	12583669.3***
	(2839568.0)	(2929476.9)	(3301211.5)	(2943146.1)
Rate of Urbanisation	5125107.8***	5229342.8***	4512844.4***	5203998.8***
	(1281246.1)	(1320035.1)	(1352766.1)	(1270854.8)
Democracy Ranking	-71825719.2***	-73398670.6***	-66492121.9***	-71649408.4***
	(15051032.9)	(15639705.8)	(16613579.3)	(14983898.0)
Renewable Energy Usage	-38991056.6**	-37694480.8*	-34178030.2*	-35194954.0*
	(18966026.6)	(19658462.8)	(19940081.3)	(18516300.1)
Population	4.854***	4.857***	4.350***	4.848***
	(0.117)	(0.119)	(0.129)	(0.117)
Constant	-663885221.0***	-686250656.0***	-648917984.9***	-661167527.5***
	(171034201.3)	(180315900.0)	(192391184.9)	(169711731.1)
Observations	821	791	640	821
R^2	0.683	0.683	0.645	0.683

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

F-test scores:

Female workforce = 9.42064

Average years of female schooling = 8.9602

Years of colonisation = 55.4725

Origin of national legal system = 26.7384

As all instruments are either above the benchmark F-test score or only slightly below, results are widely similar for variables of interest. The reason that years of colonisation was chosen as the main instrument is because of its large F-test score.

First stage regression:

Table 12.

	(1) freedom	(2) freedom	(3) lnMinisterial	(4) lnMinisterial
Rate of Urbanisation	0.377***	0.328***	-0.00425	-0.0248
	(0.127)	(0.126)	(0.0316)	(0.0281)
Democracy Ranking	1.127***	1.006***	0.0481	0.0393
	(0.218)	(0.220)	(0.0530)	(0.0488)

Renewable Energy Usage	0.822**	1.081***	0.0738	0.0153
	(0.416)	(0.412)	(0.0963)	(0.0881)
Population	-1.76e-08	-1.43e-08	-5.40e-09**	-4.90e-09*
	(1.29e-08)	(1.27e-08)	(2.75e-09)	(2.70e-09)
Female Labour Force Participation Rate	-0.00963			
	(0.0428)			
Average Years of Female Schooling		0.0277		
		(0.304)		
Colonised Dummy			0.000797	
			(0.000802)	
Common Law Legal Origin				0.654
				(0.559)
French Civil Law Legal Origin				1.834
				(1.985)
German Civil Law Legal Origin				2.101
				(1.443)
Scandinavian Civil Law Legal Origin				2.671
				(1.801)
Constant	37.00***	37.58***	2.190**	2.850***
	(3.899)	(3.780)	(0.915)	(0.818)
Observations	1234	1194	654	838
R^2	0.960	0.962	0.758	0.738

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To conclude robustness, the model is not robust to an alternative measure of female political representation. This may be for several reasons. There may be issues with data collection such as measurement error or gaps in the data. Alternatively, the choice of alternative measurement may be poor. The impact on co2 emissions from women being in ministerial positions and those in parliament on emissions and how they impact policy from their

positions may vary significantly enough that they are not interchangeable. This will be discussed further in the limitations section.

The model was robust to adding tariffs as a control variable. The significance level and sign of the coefficient remained the same and the change in magnitude was minimal. While removing GDP did not change results significantly, the likelihood of reverse causality and introduced endogeneity was too high to keep the control in the model.

When using FE as an alternative model specification, the results varied significantly from the IV model specification. While not a formal test of endogeneity, it does provide evidence that endogeneity is present and that IV is the correct model choice. Lastly, four instrument variables were tested, and the colonial rule dummy was the strongest. While all instruments were either just below the 10 F-score cutoff, or significantly above, the colonial rule dummy was the best fit for the model. Overall, the model stood up well to robustness checks. Any future research should keep in mind the differing results when using alternative measures of female political representation.

Discussion

There were three main expected results in the paper. First, economic freedom would have a positive effect on emissions. Second, female political participation would have a negative impact on emissions. Lastly, the combined effect of both variables would be to have a positive impact on emissions.

I expected that economic freedom would have a positive impact on emissions and that there would be differing impacts based on the development level of the nation based upon previous literature on the subject. Specifically, (Joshi & Beck, 2018) (Carlsson & Lundström, 2000) (Schröder & Storm, 2020). The results found that economic freedom increased emissions by 12451355.8 tonnes with a one-unit increase. The effects were different in developed nations compared to developing as the results were more significant and of a larger magnitude. This implies that economic freedom acts to increase emissions to a greater extent in developed nations.

The second expectation is that female political participation will act to reduce emissions. Literature was widely supportive of this expectation, with papers such as (Lv & Deng, 2019), (and Ergas & York, 2012) finding female political representation decreased emissions. This was not the result this paper found. Female political representation had a positive but non-

significant impact on emissions. This may be due to women in positions of power being unable to implement or support policies based upon a need to support more popular issues. There was also no difference between developed nations and developing nations. Again, this is not consistent with previous literature.

The last expectation was that the combined effect of economic freedom and female political representation would increase emission. As this interaction term is unique to current literature there is nothing to base expectations on. The logic behind the expectation is that the increase in economic freedom and its implied reduction in government oversight would negate any reducing effect on emissions generated by a greater share of ministerial positions being filled by women. This expectation was correct. The interaction term was positive and statistically significant. The results implied that the combined effect of the two variables would increase emissions by 8376545.5 tonnes extra when there is a one unit increase in the other variable. Beyond this, the effect was only significant in developed nations where the magnitude was larger than the overall effect. In developing countries, the result was positive to a lesser degree than in developed nations and statistically insignificant.

Policy Implications

The findings from the study have some important implications for government policymakers to consider about how economic freedom and female political representation impact national co2 emissions. As per the limitation's sections, there are still existing endogeneity issues and so implications should be read with that in mind.

1. Reducing economic freedom is better for emissions

   The results from table 3 show how an increase in economic freedom, positively and significantly increases co2 emissions. From this we can see that greater government oversight on the economy is necessary. While governments typically prioritise economic growth and economic freedom is often seen as a mechanism to achieve this (Gwartney & Lawson, 2016). The results from this paper clearly show that to reduce co2 emissions, economic growth through the mechanism of increased economic freedom is not feasible. As mentioned in the limitations section, owing to the non-transparent nature of the economic freedom ranking, absolute conclusions cannot be drawn. Despite not understanding specifics about how economic freedom rankings are calculated there are several assumptions that can be made. First is the need for environmental regulations. In the presence of increased economic freedom where

individuals are able to consume and produce carbon intensive goods, there is little incentive to consume or produce less carbon intensive products which are often more expensive. There is a need for regulation to provide incentive and often make mandatory, less carbon intensive products and processes. It may be necessary for policy makers to implement either stricter or introduce new environmental policies to reduce emissions. This could take the form of carbon taxes or a ban on products that unnecessarily produce emissions.

Another implication is how this mechanism impacts developed and developing nations differently. The impact of economic freedom on CO2 emission was greater and more significant in developed nations than in developing nations. This evidence could suggest that developed countries should prioritise environmental policies comparative to developing nations.

2. Female political participation has differing impacts depending on measurement

   According to results obtained in this paper a greater share of ministerial positions held by women has an insignificantly positive effect on CO2 emissions. When using the share of parliament seats held by women there is a significantly positive effect on emissions. These results show the need for different policy options. The statistical insignificance of the share of women in ministerial positions implies that it has no realised effect on CO2 emissions. Despite literature demonstrating that women prioritise environmental protection, they are unable to effectively act on this. Previous literature has also found that women in politics and in powerful positions often feel unable to support the policies they care about to 'fit in' (Sarah & Mona, 2008). Policy therefore should focus on providing an environment where women are more able to enact policy they support rather than policies which will better their careers.

3. The combined effect of economic freedom and female political representation

   The result of the combined impact of both economic freedom and female political participation is positive and statistically significant. From running both variables independently, we know that policies which promote economic freedom to encourage economic growth led to an increase in emissions, and that simply having greater female political representation alone cannot reduce emissions despite their propensity to

support environmental policies. The positive effect of the interaction term suggests that increased female political representation and greater economic freedom do not align towards reducing emissions. To reduce emissions, policies that align economic freedom with environmental sustainability must be prioritised and promoted with an empowerment of female politicians to drive these initiatives. An example could be to fund R&D into sustainability in areas of the economy where the influence of female politicians can be leveraged. For instance, by promoting programmes such as 'Women in green technology,' female politicians can spearhead initiatives they care about that reduce emissions, provide emission reducing technology, and promote economic growth while not increasing emissions. This would lead to a reduction in economic freedom while still promoting economic growth and simultaneously giving female politicians influence and a way to reduce emissions.

As the impact is statistically significant in developed countries but not in developing countries, it would suggest that these policies would only be effective in the developed nations. There are already examples of such policies in Scandinavia (Ingebritsen, 2012). Since the combined effect is insignificant in developed nations, these policies would likely prove ineffective.

Limitations

Whilst this study will provide important and unique insight into how both economic freedom and female political representation impact co2 emissions, it is important to acknowledge the limitations.

In regards to data there are several limitations. Most sources of data came from either the World Bank or Our World in Data which are both sources used extensively in previous literature (Hall & Lawson, 2014), (Ergas & York, 2012), and (Doan et al, 2024). One source of data which is a potential limitation of the study is the economic freedom index. As per (Gwartney & Lawson, 2003), the measurement for the economic freedom index from the Heritage Foundation is 'based on measurement procedures that are both less precise and less transparent' than other indices. As economic freedom is one of the two independent variables, limitations within the data will greatly impact the overall results. The lack of transparency around how the index is generated makes policy implications around economic freedom difficult to make. Beyond making policy implications more difficult, the lack of transparency may mask bias in the data

collection and methodology behind the rankings. If this is the case, that bias will be transferred into the study unknowingly. It also makes comparison between other studies which have used different economic freedom rankings difficult.

The unique addition to the literature from this paper is the interaction term between economic freedom and female political representation. With economic freedom potentially compromised because of the non-transparent ranking system, this reduces the validity and relevance of the interaction term and the paper overall. This will also make reproducing the paper and interaction term difficult. To rectify this limitation, in subsequent research a more transparent ranking should be utilised.

Another potential limitation comes in the way of omitted variable bias and endogeneity. Using the IV regression method versus FE helps to reduce endogeneity bias. However, a potential source bias and endogeneity that cannot be accounted for simply by using IV is omitted variable bias. Despite using relevant control variables and a strong instrument variable, controlling for all variables which impact national CO2 emissions is likely functionally impossible. A variable such as GDP is relevant to CO2 emissions, but as previously discussed, there is likely reverse causality, which requires its removal. Despite the necessity of removing GDP, its removal will add to omitted variable bias and, therefore, overall model endogeneity.

Another limitation of the paper regards the results of using alternative measures of female political representation. The alternative measure of the share of parliamentary seats held by women compared to ministerial positions had significantly different results. The magnitude was smaller for the parliamentary share, but unlike the ministerial share, it was statistically significant (at a 5% significance level). This result means that the model is not robust to different measures of female political representation. The difference in results implies that the type of representation matters in terms of emissions. This is potentially indicative of issues with data as not only do the different measurements give different results, but neither are in line with significant amounts of previous literature. For future research, the implications of measures of female political participation should be taken into account and their interchangeability too.

Conclusion

This thesis investigates the impact of both economic freedom and female political participation on CO2 emissions. It also aims to determine the combined impact of the two variables. Using data primarily from the World Bank and Our World in Data, the paper spans

10 years from 2012 to 2022. The paper employs an IV regression technique to analyse the two outcome variables of economic freedom and female political representation.

The main findings of the paper are as follows. Firstly, economic freedom has a positive and statistically significant effect (at a 1% significance level) on CO2 emissions. The effect is statistically significant at a 1% and 5% significance level for developed and developing countries, respectively. However, the magnitude of the effect is greater in developed countries than in developing. These results suggest that a reduction in government intervention and environmental regulations acts to increase CO2 emissions and that this effect is greater in developed nations than in developing countries. The results support the implementation of policy which increases government involvement in the market in the way of stronger environmental protection policies. As mentioned in the introduction section, there is little consensus amongst previous literature as to the effect of economic freedom on CO2 emissions. This paper gives evidence that economic freedom increases CO2 and that this impact is felt more strongly in developed nations. This is in line with literature such as (Joshi & Beck, 2018), who found that when economic freedom increased, the scale of the national economy also increased, increasing emissions.

For an increase in female political participation, there was a statistically insignificant (at a 10% significance level) and positive effect on CO2 emissions. The effect is also positive and statistically insignificant in both developed and developing nations, with a larger magnitude of effect present in developed countries. These results suggest that the share of ministerial positions held by women does not have a realised impact on emissions. This could be for several reasons, but some previous literature has discussed how women in positions of power feel unable to implement or support policies they care about (Sarah & Mona, 2008). The results suggest that there is a need for greater support for women in these positions of power and a need to foster a political environment where women feel able to support and enact environmental policies.

In a situation with high economic freedom and high female political representation, there is a statistically significant (at a 10% significance level) and positive effect on emissions. The effect is statistically significant (at a 1% significance level) and positive in developed nations but positive and statistically insignificant in developing nations. The results suggest that when economic freedom is increased, and the share of ministerial seats being held by women is high, emissions will increase. To address this, policies that tie together economic freedom,

sustainability issues, and female empowerment should be prioritised. By doing so, the positive effects of economic freedom on emissions will be reduced, and women will be able to enact these changes.

Several limitations of the study were identified. These included the use of a data source for economic freedom with non-transparent methodology in ranking which potentially introduces bias into the study and makes difficult any attempts to replicate or compare this study to others. A suggestion for future research is to utilise alternative rankings with a more transparent methodology behind the ranking. Another limitation is the presence of endogeneity created by omitted variable bias. It is unlikely that a future study could control for all variables that impact CO2 emissions as the scope is so large, but alternative controls could be utilised alongside those from this study to further isolate the effects of economic freedom and female political representation on emissions.

To conclude, this study contributes to the existing body of literature for several reasons. Firstly, it provides a greater understanding of how economic freedom impacts CO2 emissions and gives greater insight into how this effect differs between developed and developing nations. Secondly, it provides evidence of the impact of female political representation. Lastly, this paper provides a novel element in its interaction term between the two. As climate change and addressing its effects becomes ever more pressing, greater research will be required into the mechanisms which impact emissions. A better understanding of how mechanisms interact will also be required and this paper provides a methodological blueprint on how to achieve this.

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Appendix I

First stage IV Model 1

	(1) freedom
Female Political Representation	-0.691**
	(0.299)
Rate of Urbanisation	0.0327
	(0.218)
Democracy Ranking	1.085***
	(0.372)
Renewable Energy usage	0.674
	(0.628)
Population	3.41e-09
	(1.76e-08)
Colonised Dummy	-0.323***
	(0.0803)
Constant	47.69***
	(6.668)
Observations	499
R^2	0.964

F-test	55.4725

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix II

Table 6.

First stage IV Model 2

	(1) freedom
Female Political Representation	-0.737*
	(0.397)
Rate of Urbanisation	0.0351
	(0.219)
Democracy Ranking	1.085***
	(0.373)
Renewable Energy Ranking	0.679
	(0.630)
Population	3.60e-09
	(1.77e-08)
Colonised Dummy	-0.325***
	(0.0813)
Colonised Interaction	0.000445
	(0.00255)
Constant	47.74***
	(6.682)
Observations	499
R^2	0.964
F-test	55.4725

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$