Corrupting Renewable Energy: A Cross-National Analysis of CO₂ Emissions

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Abstract

Many nations are investing heavily in renewable energy sources to support their development. However, there is debate among researchers concerning whether renewable energy leads to reductions in CO₂ emissions. Renewable energy sources should reduce CO₂ emissions, yet some researchers have observed a “displacement paradox,” in which renewables are used alongside fossil fuel energy instead of displacing it, and therefore CO₂ emissions are not substantially reduced. We argue that corruption may be partially responsible for the displacement paradox. We use two-way fixed effects regression from 1990 to 2015 to test how executive and public sector corruption moderates the effect of renewable energy consumption on CO₂ emissions per capita for 160 nations. We find support for our hypothesis, as the interaction terms reveal that corruption slows the beneficial effect of renewable energy consumption on CO₂ emissions. When nations control corruption within their borders, the positive impact of renewable energy is more than doubled.

Keywords: carbon dioxide emissions, climate change, corruption, cross-national, governance, quantitative methods

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1. Introduction

Sustainable energy transitions are key to reducing carbon dioxide emissions. Nations across the world are investing heavily in renewable energy sources to support their development (York & McGee, 2017; York et al., 2010). On the one hand, some researchers argue that renewable energy sources have the potential to support energy needs in less environmentally damaging ways (Mol et al., 2009). Renewable energy should decrease reliance on carbon-producing energy sources and therefore decrease CO₂ output in a nation (Shafiei & Salim, 2014; Vasylieva et al., 2019). This is because renewable energy sources require far less heavy extraction and use of resources that create pollution and other environmental issues (Prasad & Munch, 2012). On the other hand, some researchers are more skeptical, arguing that renewable energy is often used alongside fossil fuel energy instead of displacing fossil fuels, which would not make substantial decreases in CO₂ emissions (Thombs, 2018; York & McGee, 2017).

However, theories of state capacity and governance suggest that structural factors within a nation, like corruption, may undermine the success of renewable energy sources in reducing CO₂ emissions (Cole, 2007; Lohmann, 2009). Thus, we argue that corruption in the executive and public sectors may be responsible for the inability of nations to displace fossil fuel energy with renewable energy to reduce CO₂ emissions. Executive corruption involves members of the executive branch of a government personally benefiting monetarily from granting favors, stealing, or misappropriating public funds (Coppedge et al., 2016; Dahlberg et al., 2021). Members of the executive sector include presidents, governors, cabinet members, prime ministers, dictators, and supreme rulers, and those who directly follow presidential orders (Dahlberg et al., 2021). Public sector corruption involves public sector employees incurring personal monetary gain for granting favors or stealing public resources (Dahlberg et al., 2021). Members of the public sector include government officials, civil servants, and public workers (Dahlberg et al., 2021; Palmer, 2005). Corruption in the executive and public sector may help explain the inability of nations to supplant fossil fuel energy with renewable energy because (1) government collusion with already established and entrenched fossil fuel business sector may enhance fossil fuel extraction and consumption, (2) there may be no laws or policies to replace fossil fuels with renewable energy sources, or laws or policies may be ignored due to corruption, and (3) corruption reduces the amount of funds available for environmental protection and technological expansion, which all can undermine renewable energy initiatives and production.

While research has focused on the paradoxical relationship between renewable energy and economic growth (Bilgili et al., 2016; Thombs, 2017; York & McGee, 2017), there are no studies to our knowledge that consider how a nation's level of corruption impacts the effect of renewable energy consumption on CO₂ emissions.

To address this gap in the literature, we use two-way fixed effects regression analysis for 160 nations from 1990 to 2015 to test how executive and public sector corruption moderates the effect of renewable energy consumption (total energy consumption by renewable energy sources in a nation as a percentage of total energy consumption) on CO₂ emissions per capita.

The structure of this article is as follows: First, we review cross-national literature concerning CO₂ emissions and previous research on renewable energy consumption and internal state factors. Next we formulate our argument for why there should be interaction effects between renewable energy consumption and corruption. Then we review the data and methods for this project. Finally, we present our analysis, findings, and conclusions.

2. Renewable energy consumption, corruption, and CO₂ emissions

Many researchers have focused on the relationship between renewable energy consumption and CO₂ emissions (York & McGee, 2017). For example, Vasylieva et al. (2019) find that increasing renewable energy decreases greenhouse gas emissions in European Union (EU) countries. Shafiei and Salim (2014) find that non-renewable energy consumption increases CO₂ emissions while renewable energy consumption decreases CO₂ emissions. Focusing just on the United States (US), Prasad and Munch (2012) find that introducing renewable electricity policies including public benefit funds decreased carbon emissions in 19 US states.

However, there is much debate concerning how resource efficiency may impact CO₂ emissions. Many have pointed out that generating energy more efficiently may increase the amount of resources used, creating a Jevons paradox (York & McGee, 2016). The Jevons paradox finds that consumption continues to rise despite new technologies and policies that increase efficiency. Related to the Jevons paradox, renewable energy may not entirely displace fossil fuel production but be used alongside fossil fuel energy, which would not make substantial decreases in CO₂ emissions without policy intervention (Sinn, 2012; York, 2012). This phenomenon is called the displacement paradox, whereby renewable energy is added to fossil fuel energy but not used in place of it (York, 2012). Thus, renewable energies may only have a substantial impact on CO₂ emissions if they are a large enough proportion of the total energy supply (Chiu & Chang, 2009). For example, Thombs (2018) finds that increasing production in non-fossil fuel energy does not necessarily reduce emissions over time. While he finds some evidence that increasing renewable energy can displace fossil fuel energies, he argues that nations should create policies to help renewable energy sectors grow, and that supporting newer technologies can make renewable energies more efficient, making them more competitive (Thombs, 2018).

Others have found that the effect of renewable energy consumption varies by level of economic development. For instance, Thombs (2017) finds that renewable energy consumption has its largest negative effect on total carbon emissions and carbon emissions per unit of GDP in low-income countries compared to higher-income nations. Likewise, York and McGee (2017) find an interaction effect between GDP per capita and the percentage of renewable electricity production. Their findings suggest that when wealthy nations focus on electricity from renewable sources they suppress nuclear power instead of fossil fuel energy, whereas lower-income nations shift from fossil fuels to renewable energy (York & McGee, 2017).

Less research has focused on how internal factors of the state might impact CO₂ emissions. Several researchers find that democracy reduces CO₂ emissions (Gallagher & Thacker, 2008; Page & Redclift, 2002). Prasad and Munch (2012) find that state-level policies within US states have led to strong reductions in CO₂ emissions, lending support to the idea that policies, when regulated, can have a positive effect on reducing climate change. Most notably, Gani (2012) finds that higher levels of political stability, rule of law, and control of corruption are associated with lower levels of CO₂ emissions per capita. Similarly, Bae et al. (2017), in their analysis of 15 post-Soviet nations, find that reducing corruption can reduce CO₂ emissions, but the effect of GDP growth on CO₂ emissions is so strong that CO₂ will increase regardless of a nation's level of corruption. Vasylieva et al. (2019) find that increasing control of corruption reduces greenhouse gas emissions in EU countries. Furthermore, Wang et al. (2018) find that control of corruption decreases CO₂ emissions, and can weaken the relationship between economic growth and CO₂ emissions in BRICS² economies. Additionally, Zhang et al. (2016) find an inverted U-shaped curve between corruption and CO₂ emissions in Asia. Finally, Hargrove et al. (2019) find that environmental treaty ratifications are associated with larger decreases in emissions in nations with higher levels of state governance (i.e., control of corruption, rule of law, government effectiveness, and regulatory quality) rather than lower levels. These studies demonstrate a general correlation between levels of corruption and CO₂ emissions.

However, no research to our knowledge tests specifically whether corruption negates or slows the beneficial impact of renewable energy consumption on CO₂ emissions. This is surprising because many researchers have argued that corruption can make nations less efficient at meeting the needs of their citizenry (Alon et al., 2016; Bardhan, 1997; Enste & Heldman, 2017; Hall et al., 2020; Povitkina, 2018; Rose-Ackerman, 1996, 1997, 1999, 2017; Warren, 2004).

2 BRICS = Brazil, Russia, India, China, and South Africa. The BRICS economies are a group of emerging economies that are known for their influence on other nations in their region.

Corruption breaks down the functioning of nations through the illegal distribution of goods, services, jobs, and money in exchange for political support, which can undermine environmental efforts.

Previous literature has identified that a major issue reducing the effectiveness of renewable energy consumption in decreasing CO₂ emissions is the failure of nations in phasing out or replacing fossil fuel energy sources with renewable energy sources (Thombs, 2018; York & McGee, 2017). Thus, renewable energy may not displace fossil fuel production and be used only in addition to renewable energies. Corruption may be one of the factors limiting the transition from fossil fuel energy to renewable energy. There are three major reasons why this may be the case.

First, corruption may push resources toward dirty energy and use renewable source investment as a form of window-dressing (Moe, 2015; Singh & Bourgouin, 2013; Sovacool et al., 2016). Government collusion with entrenched fossil fuel businesses may support fossil fuel extraction and consumption, undermining renewable energy initiatives and production (Wright & Nyberg, 2015). Simultaneously, renewable energy sources may be created and expanded to shield investors, funding bodies, or voters from fossil fuel activities (Ritchie & Dowlatabadi, 2015).

Second, there may be no laws or policies to replace fossil fuels with renewable energy sources, or laws or policies may be ignored due to corruption. Government intervention may be critical in the transition from fossil fuel energy sources to renewable energy sources (Thombs, 2018; York & McGee, 2017). But if such political will does not exist or if it is being undermined to favor fossil fuel-related activities of companies, renewable energy consumption will not be able to outweigh the detrimental impacts of fossil fuel consumption. This is especially true if the introduction of renewable energy sources simply provides more energy, rather than replacing existing energy sources.

Third, corruption reduces the amount of funds available for environmental protection and technological expansion, which would allow renewables to be more efficient and competitive against fossil fuel energies (Cole, 2007; Lohmann, 2009). Technologies and funding can help make it easier and less costly to make the transition to renewable energies. Any activities negating this process will therefore reduce the potential of renewable energy for reducing CO₂ emissions.

Corruption at multiple levels can factor into this process. Government executives may abuse their legislative powers by accepting bribes to create loopholes that benefit extractive and polluting activities of companies. They may also embezzle funds dedicated to areas that would enhance renewable energy growth. Furthermore, executives can siphon money from international aid intended for investment in renewable energy. On the ground, public sector officials may partake in corrupt exchanges to look past required permits as well as being complicit in the theft

of resources for environmental protection or technological expansion. Public officials are often incentivized to take bribes due to low salaries and lack of strong enforcement. Through diversion of funds and subverting legislation and regulation, both public and executive corruption can lead to inefficiency and continued support for fossil fuel activities. Thus, we expect that executive and public sector corruption reduces the effectiveness of renewable energy consumption in decreasing CO₂ emissions.

3. Methods and data

We use two-way fixed effects regression with robust standard errors clustered by country to analyze our data. Robustness checks with generalized least squares random effects regression models yield consistent results. Our sample includes 160 nations across all income levels with 2,746 country–year observations from 1990 to 2015 (Coppedge et al., 2016; World Bank, n.d.). We use two-way fixed effects analysis as it controls for both time-invariant and unobserved factors and allows for comparisons within countries over time (Jorgenson & Clark, 2013; Jorgenson et al., 2010).

Table 1. Descriptive statistics

Variables	Description	Mean (std. dev.)	Range
Dependent Variable			
CO ₂ per capita (metric tons) (natural log)	CO ₂ emissions per capita per year measured in metric tons ^a	0.309 (1.77)	−5.44–4.62
Independent Variables			
Renewable energy	Renewable energy as a percentage of total energy consumption ^a	28.60 (33.93)	0–100
Executive corruption	Index of corruption in the executive sector ^b	.49 (.30)	.011–.978
Public corruption	Index of corruption in the public sector ^b	.48 (.30)	.004–.979
GDP per capita (natural log)	GDP per capita ^a (constant 2010 USD)	8.31 (1.54)	4.89–12.17
Manufacturing	Manufacturing value added as a percentage of total GDP ^a	13.12 (8.75)	0–192
Population urban	Percentage of the population that lives in an urban area ^a	51.12 (25.77)	2.08–100
Foreign direct investment (natural log)	Net inflows of foreign private investment as a percentage of total GDP ^a	0.33 (1.84)	−12.51–6.96
Access to electricity	Percentage of the population with access to electricity ^a	80.08 (30.24)	−0.01–100

Data sources: ^a World Bank (n.d.); ^b Teorell et al. (2019).

Our sample is limited to 160 nations using listwise deletion of missing data (see Appendix 1 for the full list of nations). We check for regression assumptions including linearity, multicollinearity, heteroscedasticity, outliers, influential cases, specification error, and endogeneity (Allison, 2009). We use Breusch-Pagan tests to check for heteroscedasticity. The Breusch-Pagan test indicates that heteroscedasticity is present, therefore we transform variables with skewed distributions (see Table 1) and report robust standard errors to deal with potential issues of heteroscedasticity. A summary of all included variables and descriptive statistics can be found in Table 1.

3.1. Dependent variable

Carbon dioxide emissions per capita: The carbon dioxide data and all other variables are obtained from World Bank (n.d.) unless otherwise noted. CO₂ emissions per capita (metric tons per capita per year) measures the total CO₂ emissions stemming from the burning of fossil fuels and the manufacturing of concrete standardized by population. CO₂ per capita represents the average emissions per person in a country, representing individual consumption. Following previous cross-national studies, this variable is logged to correct for its skewed distribution.

3.2. Main independent variables

Renewable energy consumption: Renewable energy consumption is the total consumption of energy from renewable energy sources in a nation as a percentage of total energy consumption. The use of renewable energy should decrease reliance on carbon-producing energy sources and thus decrease CO₂ output in a nation. Renewable energy ranges from 0% to 100%.

Executive and public sector corruption: The other main independent variables measure executive corruption and public sector corruption. These indices were created by the Quality of Government Institute and the Varieties of Democracy data collaboration group within the political science department at the University of Gothenburg and the Kellogg Institute at the University of Notre Dame (Teorell et al., 2019).³ They have over 530 indicators that measure democracy and government quality based on official documents and perception assessments (Coppedge et al., 2016; Teorell et al., 2019). These indices are calculated specifically for comparability across nations (Coppedge et al., 2016). The executive corruption indicator measures corruption at the level of rulers and the cabinet, and the public sector corruption indicator concerns low- and mid-level public officials (Coppedge et al., 2019, p. 67). Executive corruption ranges from .011 to .978, with the lowest executive corruption in Sweden, and the highest executive corruption in Chad. The variable for public sector corruption ranges from .004 to .979, with the lowest public

³ See also the Varieties of Democracy Project at the Kellogg Institute: kellogg.nd.edu/research/major-research-initiatives/varieties-democracy-project.

sector corruption in Singapore and the highest public sector corruption in Chad. Both indicators are calculated from expert surveys by the Varieties of Democracy (Coppedge et al., 2016).

Executive sector corruption is calculated using a Bayesian item response theory measurement model from the responses to the following ordinal questions: “How routinely do members of the executive (the head of state, the head of government, and cabinet ministers), or their agents, grant favors in exchange for bribes, kickbacks, or other material inducements?”; and “How often do members of the executive (the head of state, the head of government, and cabinet ministers), or their agents, steal, embezzle, or misappropriate public funds or other state resources for personal or family use?” (Coppedge et al., 2019, p. 119). Public sector corruption is calculated from the following questions: “How routinely do public sector employees grant favors in exchange for bribes, kickbacks, or other material inducements?”; and “How often do public sector employees steal, embezzle, or misappropriate public funds or other state resources for personal or family use?” (Coppedge et al., 2019, p. 120). Each answer ranges from 0 to 4 where 0 means corruption is routine and expected and 4 means never or hardly ever. As mentioned, the ordinal responses are converted to interval by the measurement model employed by Varieties of Democracy (Coppedge et al., 2016).⁴

3.3. Other variables and controls

Following previous studies, we control for GDP per capita, urban population, manufacturing as a percentage of GDP (Jorgenson, 2007, 2009; Jorgenson et al., 2010), foreign direct investment stocks as a percentage of GDP (Shandra et al., 2004), and access to electricity (Prasad & Munch, 2012). We considered including the percentage of population aged 15 to 64, trade as a percentage of GDP, and political rights, but removed them from the analysis for both theoretical (i.e., these were not found to be important factors determining CO₂; population aged 15–64, trade as a percentage of GDP, and political rights) and model specification purposes (i.e., the inclusion of these variables led to issues with over-specification and multicollinearity; population aged 15–64 and political rights).

4. Findings

Table 2 contains the two-way fixed effects regression estimates of renewable energy consumption and corruption on CO₂ emissions per capita. In the first two, Models 1 and 2, we include only the additive effects of renewable energy consumption and executive and public sector corruption, respectively. In Model 3

4 More information on these data sets can be found at www.v-dem.net/en/data/archive/previous-data/data-version-9/ and www.gu.se/en/quality-government/qog-data/data-downloads/basic-dataset.

we include the interaction terms between renewable energy consumption and executive corruption, and in Model 4 we include the interaction term between renewable energy consumption and public sector corruption. The interaction terms are calculated by multiplying renewable energy consumption by each of the two corruption measures. The first number presented is the unstandardized coefficient, the second is the standardized coefficient, and the third number in parentheses is the robust standard error. In every model, we include renewable energy consumption, GDP per capita, manufacturing as a percentage of GDP, urban population, foreign direct investment stocks as a percentage of GDP, and access to electricity.

Table 2. Two-way fixed effects estimates for carbon dioxide per capita, 1990–2015

Independent Variables	Model 1	Model 2	Model 3	Model 4
Renewable energy consumption	-.005**	-.005**	-.008***	-.008**
	-.094	-.095	-.099	-.101
	(.002)	(.002)	(.002)	(.003)
Executive corruption	.053		-.208†	
	.009		-.008	
	(.084)		(.120)	
Public corruption		.141		-.089
		.024		-.009
		(.126)		(.167)
Renewable × executive			.006**	
			.032	
			(.002)	
Renewable × public				.005†
				.028
				(.003)
GDP per capita (natural log)	.578***	.583***	.564***	.567***
	.504	.508	.492	.495
	(.085)	(.085)	(.083)	(.083)
Manufacturing	.007*	.007*	.007*	.007*
	.032	.032	.033	.033
	(.003)	(.003)	(.003)	(.003)
Urban population	.014**	.014**	.015**	.015**
	.209	.207	.213	.217
	(.005)	(.005)	(.005)	(.005)
Foreign direct investment (natural log)	.005	.006	.004	.004
	.006	.006	.005	.004
	(.007)	(.007)	(.007)	(.007)

Independent Variables	Model 1	Model 2	Model 3	Model 4
Access to electricity	.011***	.011***	.011***	.011***
	.184	.184	.183	.182
	(.002)	(.002)	(.002)	(.002)
Within R-square	.443	.445	.451	.450
Number of observations	2,767	2,767	2,767	2,767
Number of countries	160	160	160	160

Note. The first number is the unstandardized coefficient, the second is the standardized beta, and the robust standard error is in parentheses.

† $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$ for a two-tailed test.

Source: Authors' findings.

In the first two models (additive) in Table 2, we find that the coefficients that represent renewable energy consumption reach levels of statistical significance. This suggests that higher levels of renewable energy consumption are associated with lower levels of CO₂ emissions. This aligns with previous research which suggests that renewables should be associated with lower levels of carbon dioxide emissions. To take a couple of concrete examples, in the United Kingdom, CO₂ emissions decreased from 9.71 metric tons per capita (1990) to 6.50 (2014), while renewable energy increased from 1.83% of total energy consumption (1990) to 19.26% (2014). Alternatively, Uganda saw an increase in CO₂ emissions from 0.04 metric tons per capita (1990) to 0.14 metric tons per capita (2014) while renewables decreased from 99.35% of total energy consumption (1990) to 31.36% (2014). While renewable energy consumption has a clear inverse relationship with CO₂, executive sector corruption and public sector corruption fail to reach levels of statistical significance in the additive models (Models 1 and 2). Additionally, we find several other factors are associated with CO₂ emissions. We find that the coefficient that represents GDP per capita is positive and significant in every model. As expected, this suggests that higher levels of GDP per capita correspond with more CO₂ emissions (Hargrove et al., 2019; Jorgenson, 2007, 2009; Jorgenson et al., 2010; Shandra et al., 2004; Sommer & Hargrove, 2020). Higher levels of GDP per capita indicates wealthier nations that likely have higher levels of consumption, therefore leading to increased CO₂ emissions. In line with past research, the coefficient that represents manufacturing is also positive and significant in every model. This too is unsurprising, as production requires energy use and is one of the largest consumers of energy (Jorgenson, 2007, 2009; Jorgenson et al., 2010; Sommer & Hargrove, 2020). We also find that the coefficients that represent urban population are associated with significantly higher levels of CO₂ emissions across all models. This finding confirms previous studies that find that an increase in urban populations corresponds with higher levels of CO₂ emissions (Jorgenson, 2007, 2009; Jorgenson et al., 2010). Additionally, we find that access to electricity is associated with higher levels of CO₂ emissions. Access to electricity should correlate with increased CO₂

emissions because a large portion of emissions comes from electricity generation (Prasad & Munch, 2012). These findings all correspond to previous literature on carbon emissions.

The models also include several non-significant findings. Among these, an unexpected finding is that the coefficients that represent foreign direct investment stocks as a percentage of GDP fail to reach levels of statistical significance. This is surprising, as it has been an important explanatory factor in previous research (Shandra et al., 2004).

Figure 1. Marginal effects of renewable energy on CO₂ emissions at different levels of executive corruption

Source: Authors' findings.

Figure 2. Marginal effects of renewable energy on CO₂ emissions at different levels of public corruption

Source: Authors' findings.

Moving to (interactive) Models 3 and 4, we find that the interaction terms between both executive and public sector corruption and renewable energy consumption reach levels of statistical significance. Figure 1 presents the graphed marginal effects of executive sector corruption and renewable energy consumption and Figure 2 contains the graphed marginal effects of public sector corruption and renewable energy consumption. The coefficients that represent the interaction terms are positive and statistically significant. The interaction terms reveal that corruption slows the beneficial effect of renewable energy consumption on CO₂ emissions. Renewable energy consumption reduces CO₂ emissions more in nations with lower levels of corruption than in those with higher levels of corruption. These findings provide substantial support for the idea that corruption can diminish the benefits of renewable energy consumption on CO₂ emissions. In countries with very low corruption, each 1% increase in renewable energy as a share of total energy is predicted to decrease CO₂ between 0.04 and 0.045 metric tons per capita. However, in nations with high levels of executive or public corruption, the impact of renewable energy as a proportion of total energy on CO₂ emissions per capita is more than halved, with each 1% increase only predicted to decrease CO₂ emissions by between 0.015 and 0.018 metric tons per capita. These interactions demonstrate that renewables significantly reduce CO₂ emissions within a nation. However, these beneficial effects are substantially diminished when nations have high levels of corruption. When nations can control corruption within their borders, the positive impact of renewable energy is more than doubled.

For an example of the interaction between corruption and renewables on CO₂ emissions we can look at Germany. In Germany, a nation with very low levels of executive and public corruption, there is a clear trend of decreasing CO₂ emissions per capita over time while the proportion of renewable energy sources increases. However, in China, a nation with higher levels of public and executive corruption, the increase in renewable energy sources did not lead to reductions in CO₂ emissions per capita. On the contrary, CO₂ emissions per capita nearly quadrupled in the time period observed. This is in large part due to the increase in GDP and manufacturing in China during this time period; however, we believe that the level of corruption in China prevented their corresponding increase in renewable energy sources from having the positive impact on emissions that we observe in other contexts. This suggests that simply increasing renewables in a nation is not an adequate solution to decreasing emissions. To take another example, Croatia has very high levels of corruption and had a relatively large increase in renewable energy over the time period (48.92% to 73.96%). However, CO₂ emissions per capita in Croatia remain fairly similar during this time period (3.59 metric tons per capita to 3.97). Cyprus, a nation with low to moderate corruption, has rising levels of CO₂ emissions per capita until the introduction of renewable energy sources in 2005, after which CO₂

emissions per capita began to steadily decline, beginning in 2009. These examples and the analysis results suggest that corruption may be a moderating factor when it comes to the effectiveness of renewable energy sources decreasing carbon emissions.

5. Conclusion

Reducing CO₂ emissions is key to managing the impacts of climate change. While renewable energies are seen as a positive way forward in controlling our CO₂ emissions, it is clear from the academic research and debate that various processes limit the success of renewable energy in decreasing CO₂ emissions (Thombs, 2017; York & McGee, 2017). As noted, creating more efficient energy can increase the consumption of energy, which can increase total emissions (York & McGee, 2016). Moreover, previous research suggests that renewable energy is not entirely displacing fossil fuel production, and thus fossil fuels will continue to be used unless there is some form of intervention. Building on this previous work concerning the displacement paradox (York, 2012), we argue that the failed transition from fossil fuel energy to renewable energy could in part be explained by a nation's level of corruption. This is because corruption may keep governments entrenched in the interests of fossil fuel companies, prevent the creation or enforcement of policies designed to usher in the transition from fossil fuel energies to renewable energies, and reduce or misdirect funding for environmental and technological expansion for renewable energies.

We test this hypothesis by using two-way fixed effects regression analysis from 1990 to 2015 for 160 nations. We find that executive and public sector corruption moderates the effect of renewable energy consumption (total energy consumption by renewable energy sources in a nation as a percentage of total energy consumption) on CO₂ emissions per capita. Renewable energy consumption reduces CO₂ emissions more in nations with lower levels of corruption, supporting the idea that corruption can diminish the benefits of renewable energy consumption on CO₂ emissions. Building on previous research, our results point to corruption as a potential factor facilitating the displacement paradox. Corruption seems to be one missing piece of the puzzle in explaining why nations are not fully committing to the transition to fully renewable energy consumption.

Of course, the focus of nations on economic growth is the other obvious limiting factor identified in previous research, as they may believe that a switch to renewable energy will hurt developmental progress (Fisher & Jorgenson, 2019). Previous research suggests that nations need some sort of policy intervention to facilitate the transition from fossil fuel energies to renewable energies so that renewable energy sectors grow and the fossil fuel energy sector shrinks. While a shift in political focus to seeing sustainable energies as an asset to development and growth would be ideal,

our findings in this article begin to suggest that shifting to renewable energy sources may lead to an ineffective transition if corruption is not also addressed. Thus, we argue that creating and enforcing policies to reduce corruption, especially in the energy sector, may help foster this shift, making renewable energy consumption more effective in reducing CO₂ emissions by counteracting the displacement paradox.

Although our analysis includes the full extent of data available, care should be taken when making claims beyond the time period and sample in our analysis. Future work may use updated data to strengthen or expand upon our analysis. For instance, previous research argues that level of income may alter the effectiveness of renewable energy for reducing CO₂ emissions (York & McGee, 2017). Thus, it is important for researchers to see whether internal state factors, such as corruption, have differential impacts on the effectiveness of renewable energy at reducing CO₂ emissions.

Despite these shortcomings, the present research defines the importance of internal state factors, namely executive and public sector corruption, as a factor that undermines renewable energy consumption's capacity to reduce CO₂ emissions. This research concerns the salience of investigating how such internal factors may shape sustainable energy transitions, and what can be done to improve this process. Going forward, we as researchers and practitioners should continue to consider how corruption factors into the effectiveness of various initiatives, tools, and policies to adapt to and mitigate climate change.

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Appendix 1. List of countries included in the analysis

Afghanistan, Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Costa Rica, Côte d'Ivoire, Croatia, Cyprus, Czech Republic, Democratic Republic of the Congo, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Fiji, Finland, France, Gabon, The Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyz Republic, Lao PDR, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, The Philippines, Poland, Portugal, Qatar, Republic of Congo, Republic of Korea, Romania, Russian Federation, Rwanda, Sao Tome and Principe, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, South Sudan, Spain, Sri Lanka, Sudan, Suriname, Sweden, Switzerland, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

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