Trade and the government underfunding of environmental innovation

Muzhou Zhang[1]

[1]Department of Government, University of Essex.

Abstract

How does trade affect the making and implementation of environmental policies? I extend our understanding about this broad research question with an understudied case: government support for environmental innovation. As the foremost channel wherein cross-border technology transfer occurs, trade materializes the positive externality of technology investment. With this in mind, countries may tend to strategically underfund environmental technologies—particularly when their trade partners enlarge that spending—to have more money to use otherwise and to avoid politically awkward innovation failures. To substantiate this crowding-out argument, I perform spatial regression with data from 32 OECD countries, 1982–2017, and find that government spending on environmental R&D in one country is negatively correlated with that of the country's trade partners in environmental goods. My research contributes to the literature by adding new to our understanding about the international trade-environmental policy nexus, depicting a new scenario wherein states underprovide global public goods, and showing the strategic calculus underlying the use of technology-push strategy in addressing climate change.

Keywords: Trade, Environmental innovation, Crowding-out, Interdependence, Green transition, Environmental policy

Introduction

With the ever growing globalization, international trade increasingly affects the making and implementation of each country's environmental policies. The race-to-the-bottom theory, for example, suggests that countries leverage lax environmental regulations one after another to increase their export competitiveness (Cao and Prakash, 2010, 2012; Porter, 1999; Woods, 2006). By contrast, a growing body of literature lends support to the "California effect" (Vogel, 1995, 1997), with higher regulatory standards diffusing from a few first movers to the rest of the world through trade networks (Prakash and Potoski, 2006; Saikawa, 2013). Meanwhile, some studies within this vein of research particularly underscore the role of trade agreements in the aforesaid green policy diffusion (Bastiaens and Postnikov, 2017; Brandi et al., 2020; Jinnah and Lindsay, 2016; Lechner and Spilker, 2022; Prakash and Potoski, 2017).

In this article, I extend our understanding about trade's implications on environmental policies by focusing on the relationship between trade network and the differing extents of government support for environmental innovation in different countries. Despite being fundamental in addressing climate change, the development and deployment of environmental innovation is lagging behind that growing threat. For instance, the renewable share in the world's total primary energy consumption only increased from 6 to 11 percent in the past five decades (BP p.l.c., 2020), whereas the annual carbon dioxide emission rocketed from 11 to 37 billion tonnes during the same period (Friedlingstein et al., 2022). It was estimated that until 2050 ensuring a global green transition needs an additional $27-trillion investment—a 30 percent increase compared to the current trajectory—in low-carbon technologies (IRENA, 2018).[1] Nevertheless, the private sector cannot fill such funding gap due to market failure. For example, "low-emission infrastructures investment [remained] less than 1 percent of the total portfolios of institutional investors" (OECD, 2018, p. 23). In the meantime, government support is proven irreplaceable to environmental innovation (Acemoglu et al., 2012, 2016; Fischer et al., 2017). To deliver the Paris Agreement target, government research funding for environmental technologies worldwide has to grow at least twofold (Dechezleprêtre et al., 2019).

However, in this article I argue that trade could undermine the willingness of governments to fund environmental innovation. As the foremost channel wherein cross-border technology transfer occurs (e.g., Keller, 2004), trade materializes the positive externality of technology investment: one country invests, all others benefit. With that in mind, countries may tend to strategically underfund environmental technologies—particularly when their trading partners enlarge that spending—to have more money to use otherwise and to avoid politically awkward innovation failures happening on their own territory.

To substantiate that argument, I use data on government environmental R&D spending and bilateral trade in environmental goods from 32 OECD countries, 1982–2017. Spatial regression analysis—a typical empirical approach to test policy interdependence (Franzese and Hays, 2007, 2008)—corroborates my theoretical expectation: government spending on environmental R&D in one country is negatively correlated to that elsewhere, with this relationship being more pronounced between the countries with more environmental trade flows to each other. Such crowding-out effect still holds even if the trade data are inclusive of all goods, but it then becomes absent when trade partnership is replaced by geographic distance in regression. The

[1] See OECD, World Bank, and UN Environment (2018) for an overview on the financing gap in environmental innovation.

contrast of these two additional results shows robust and generalized evidence in support of my argument, while ruling out the alternative, confounding mechanisms that might underpin my finding.

This article contributes to the scholarship in environmental politics and beyond in various frontiers. First of all, I add new to the inconclusive, ongoing debate about international trade's implications on environmental policies with an understudied case: government support for environmental innovation. On one hand, the trade-driven underinvestment in environmental technologies I find is opposite to what the "California effect" implies. On the other hand, in spite of my finding demonstrating that trade undermines policy independence in a negative way, the underlying mechanism—free riding—is different from that seen in the race-to-the-bottom theory either. Additionally, the "California effect" is particularly relevant to the North-South trade, whereas the race-to-the-bottom theory is established upon the trade competition between the global South countries (Cao and Prakash, 2010, 2012; Porter, 1999; Woods, 2006; Vogel, 1995, 1997); yet by drawing conclusion based on the trade within the global North, my research echoes Lechner and Spilker (2022), among others, who reminded scholars of having more focus on the trade relationships that would otherwise draw less attention. Simply put, I show a new dynamic that enriches our understanding of the nexus between international trade and environmental policies and broaden the scope of the said literature.

When it comes to the transnationally contagious climate inaction, most previous studies emphasize on how some toothless international institutions, such as the United Nations Framework Convention on Climate Change (UNFCCC), fails to keep countries fully committed to climate mitigation (Aklin and Mildenberger, 2020; Bättig and Bernauer, 2009; Urpelainen, 2013). In contrast, I show in this article that trade could also exacerbate the underprovision of global public goods, with the trade-driven technology transfer materializing the positive externality of government spending on environmental innovation. Research in the future may further explores the cross-national connections that affect each country's willingness to address the growing threat of climate change.

Last, most of the research to date shows how governments employ regulatory instruments, such as renewable portfolio standards or feed-in tariff, to speed up the deployment of environmental technologies (e.g., Baldwin et al., 2019; Bayer and Urpelainen, 2016; Stokes, 2020). But beyond these demand-pull policy interventions, little is known about the equally important technology-push strategies in addressing environmental problems, i.e., how governments support the development of environmental technologies in the first place. This article fills this gap by showing the strategic calculus behind the government underfunding of environmental innovation. With that, I also shed light on the politics of innovation in general, which the existing literature primarily addresses through the lens of domestic dynamics such as institution and the relationship between government and business (e.g., Bayer and Urpelainen, 2016; McLean and Plaksina, 2019; Meckling and Nahm, 2018; Taylor, 2007, 2016). Focusing on the interplay between different countries instead, the present article expands the analytical scope of the relevant research.

Trade and underspending on environmental innovation

Before developing my argument that international trade undermines the willingness of governments to spend on environmental innovation, it is necessary to discuss why governments are reluctant to fully fund that business at all. First, government support for environmental innovation faces great technological and market uncertainties. In their investigation into the carbon capture and storage technologies in the United States, for instance, Abdulla et al. (2020) found that more than 80% investments ended up with failure in spite of generous funding from the federal government. A similar study concludes that these projects oftentimes overrun their budgets and are not cost-competitive without taxpayer bailouts, which leads the government to the sunk cost fallacy (Food & Water Watch, 2020; Stokes, 2020).

Second, funding environmental technologies enthusiastically could even bring political troubles for governments. For example, after the massive power outage in Texas, early 2021, the Republicans heavily criticized the incumbent's renewable energy subsidies to direct the public outrage over the unreliable power supply to the Democrats' support for environmental innovation (The New York Times, 2021). Among others, the collapse of Solyndra LLC might constitute one of the most high-profile cases that illustrate the potential political cost of funding environmental technologies. This famous energy start-up company received a $535-million federal grant from the Obama administration but then soon went into bankruptcy at the end of 2011, just a year ahead of the presidential election. Seeing Solyndra's failure as an electoral opportunity, Obama's opponents launched an 18-month investigation in Congress and spent $6 million on advertisements against the president's mishandling of the issue (Reuters, 2012; The Wall Street Journal, 2012).

However, the trade-driven technology transfer enables national governments to take advantage of the environmental innovation funding made by others and, thus, to prevent politically awkward innovation failures and to have more money to spend elsewhere. New technologies travel across borders with or without the notice of innovators themselves, because one can access the technological information embodied in the directly traded items by imitating or revere-engineering. Coe and Helpman (1995), Coe et al. (1997), among others, found that a nation's domestic R&D input significantly increases others' total factor productivity, an oft-used indicator for technology-empowered economic output. This relationship evidently shows the considerable impact that technology transfer has on innovation. A consensus among scholars, policymakers, and practitioners is that international trade in goods and services is the foremost channel wherein technology transfer occurs (Maskus, 2004). Wacziarg (2001) provided strong evidence in support of this claim by discovering a positive relationship between trade liberalization and technology transfer across different countries.[2]

From the late 1970s to the early 2000s, the global export rate of green inventions climbed from 10 to 30 percent with an accelerating trend (Dechezleprêtre et al., 2011). Drawing from the case studies on pollution mitigation measures and photovoltaics, de la Tour et al. (2011), Lanjouw and Mody (1996) concluded that it is trading on related

[2] See Keller (2004) for a review of the economics research on the trade-driven technology transfer.

products rather than domestic R&D that propels a nation's technological catch-up. Perkins and Neumayer (2009) showed that a country's carbon efficiency increases as a result of the deepening trade relationships with the carbon-efficient economies. This finding implies that through trade, environmental technologies elsewhere could serve as an alternative to a country's own innovation. Using the gravity model, Garsous and Worack (2021) directly demonstrated that international trade allows countries to acquire advanced renewable technologies that are otherwise challenging for them to develop.

Because of the trade-driven transfer of environmental technologies, the government funding of environmental R&D is providing a global public good, up to a point. In other words, it entails a positive externality, with all others benefiting from a single country's investment without bearing the fiscal cost and facing the technological and political risks (Gersbach et al., 2018; Jaakkola and van der Ploeg, 2019). Although state-funded environmental R&D is not completely non-excludable—so it is an impure public good, the impact of intellectual property rights on environmental-technology transfer in particular is in fact limited. As the UN Agenda 21 posited, many environmental technologies are in the public domain and off-patented, allowing them to travel across borders more easily at lower costs (Less and McMillan, 2005). Dechezleprêtre and Sato (2017) found the spillover of low-carbon technologies indeed faster than others. In addition, the trade-driven environmental-technology transfer is advocated by international trade regime. For instance, the WTO's 2001 Doha Declaration explicitly asked countries to reduce and even eliminate any tariff and non-tariff barriers on environmental goods and services (WTO, 2001). In their evaluations on the impact of the Eco-Patent Commons, a royalty-free patent pool of environmental technologies initiated by a dozen of giant multinationals, Contreras et al. (2018), Hall and Helmers (2013) ended up with null findings, implying that intellectual property's chilling effect on environmental-technology transfer is not as large as many may expect.

The positive externality of government spending on environmental innovation, and its materialization through international trade, incentivizes the cost-minimizing governments to strategically underfund environmental technologies. That is to say, the government spending on environmental innovation elsewhere crowd out one's very own spending, with trade bringing environmental technologies from overseas to home and thus weakening the government's justification for the R&D expense. We would therefore expect that countries reduce their government environmental R&D spending as a response to the increasing spending from their trade partners. Or put differently, government spending on environmental R&D in one country is negatively correlated with that in the country's trade partners.

Having said that, any budgetary decision—which is usually made on a yearly basis—takes time to materialize. So should a country wants to free ride off the environmental R&D investments made elsewhere, the reduction of its environmental R&D spending is unlikely to become effective instantly. Due to the concurrence of budgetary making across many different countries, in addition, it is more likely that policy makers do their strategic calculation according to each other's previous spending records. Thus, it is more reasonable to expect that the current government spending on environmental innovation in a country is, if any, influenced by that overseas in the preceding year. Also, since larger bilateral trade flows in general spread more environmental technologies, countries are more responsive, i.e., making more funding cuts, to the increasing environmental innovation spending of their larger trade partners, while remaining relatively insensitive to the expanding funding from the smaller trade partners.

Data and variables

Dependent variable

My sample is restricted to OECD countries, 1982–2017, because only the OECD provides high-quality, sector-specific, and cross-nationally comparable government research funding data with sufficient temporal coverage. Since developed countries are major investors and contributors in environmental innovation worldwide, the limited sample here only asserts a minimal impact on my research's substantive significance.[3] By focusing on OECD countries, I avoid introducing excessive cross-sectional heterogeneities by pooling categorically different countries together, which may confound my statistical results. I access the data for my dependent variable—government spending on environmental R&D—from the OECD's official statistics.[4] Among the 34 high-income OECD members as of 2017, I drop Chile and Switzerland from my sample since their data have a large number of missing values for undocumented reasons.[5] The raw distribution of my dependent variable is right-skewed, so I use natural logarithm to transform it.

Fig. 1 shows my dependent variable's considerable spatiotemporal variation. From the 1980s to 2010s, Germany and the United States always outspent the others in funding environmental R&D, notwithstanding their irresolute spending trajectory, while Japan soon joined the leading camp in the 2000s. By contrast, the expenditures made by the Nordic countries, which are generally viewed as green campaigners, actually almost stagnated in the past decades. The eastern European and Benelux countries also experienced a similar spending stagnation. Although the large economies expanded their environmental R&D expenditures over time, the trend of their funding expansions was wavering, indicating the probable hesitating and strategic spending decisions. My argument and the descriptive evidence shown in Fig. 1 imply that the countries in my sample would spend more on environmental R&D if there was no crowding-out effect in a counterfactual world. Therefore, I contend that my involuntary sample selection does not introduce a ceiling effect into the following empirical analysis.

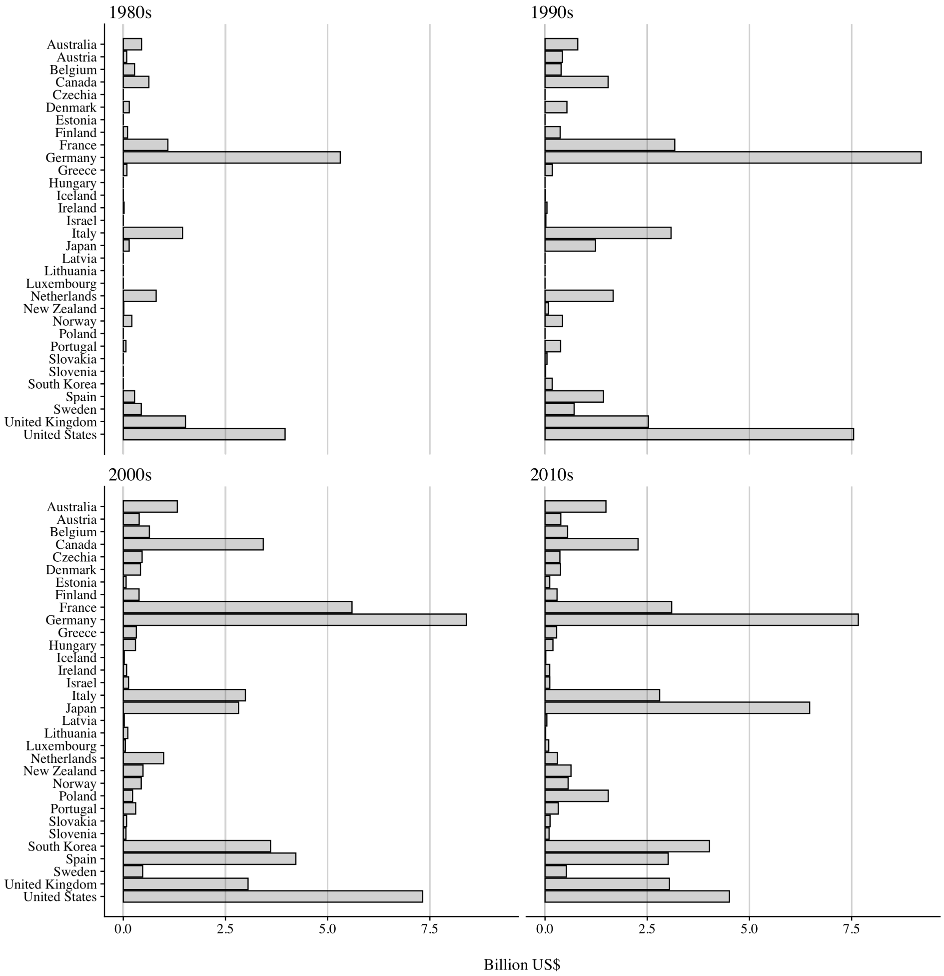
---

[3] Because China's environmental innovation is largely driven by its techno-nationalism and bid for global leadership (e.g., Kennedy, 2013), the country's government environmental R&D spending is theoretically irrelevant to the crowding-out argument made in this article. Thus, the exclusion of China from my empirical analysis should not bias my conclusion.

[4] This is done by using the `R` package `OECD: Search and Extract Data from the OECD` (Persson, 2019) with the query `GBARD_NABS2007`. But readers can also view and manually download the data from https://bit.ly/42upTw1 (last accessed October 26, 2021). By spending, the said data only capture direct budgetary allocations without considering implicit expenditures due to tax incentives.

[5] See Appendix Fig. A1 for missing values of other countries.

Fig. 1 Government environmental R&D expenditures of OECD countries, 1982–2017



Spatial lag

To substantiate my argument, I employ spatial regression model, wherein the explanatory variable is commonly known as spatial lag. For a single country, it is a weighted average of the government spending on environmental R&D elsewhere, and it thus can quantify how this country's spending is influenced by that of others. Taken together, spatial lag captures how different countries mutually influence each other. Dictated by my argument that the extent of such mutual influence is materialized by the international trade through which environmental technologies diffuse, I use the bilateral trade flows of environmental goods as the weights here. The colloquial term environmental goods, according to the OECD (1999), encompass three broad categories, namely pollution management, cleaner technologies and products, and resource management (including renewable energy). For the required data, I first access the fine-grained dyadic trade flows disaggregated by the Harmonized Commodity Description and Coding System (HS).[6] After that, the data filtering is done based upon the OECD's Combined List of Environmental Goods (see Sauvage, 2014). Some exemplary environmental goods in my data include filtering or purifying machinery, wind turbines, and photosensitive semiconductor devices.

Following the common practice in the policy interdependence literature, I temporally lag my explanatory variable, *Spatial lag by environmental trade flows*, by one year (Drolc et al., 2019; Wimpy et al., 2021; Beck et al., 2006). Noting my argument that the crowding-out effect of environmental R&D spending elsewhere is more likely to occur after some delay, this lagging exercise is foremost theoretically informed. Having said that, it also has something to do with the endogenous spatial weights, which may blur the causal direction in this research (Pinkse and Slade, 2010; Qu et al., 2021). Trade network influences a country's environmental R&D by technology transfer but, at the same time, environmental R&D also changes how a country trades with others. Yet a temporally lagged spatial lag is not subject to this simultaneity bias.

It is also worth noting that I do not row-standardize the spatial weights, otherwise I would make the homogeneous exposure assumption, which assumes all of my observations having identical overall trade volumes to all others (Neumayer and Plümper, 2016). This assumption not only discards the contemporaneous variation of trade volumes between different countries but also ignores the fact that most countries trade more over time as globalization deepens.

My regression equation takes the following form:

$$y_{i,t} = \rho \sum_{i \neq j}^{n} w_{i,j,t-1} \times y_{j,t-1} + X'_{i,t-1}\boldsymbol{\beta} + \epsilon_{i,t},$$

in which $y_{i,t}$ is country i's environmental R&D spending in year t, with $w_{i,j,t-1}$ denoting the environmental trade flows between this country i and its trade partner j in the preceding year $(t-1)$ and $y_{j,t-1}$ being the environmental R&D spending in country i's trade partner j in year $t-1$. In other words, $\sum_{i \neq j}^{n} w_{i,j,t-1} \times y_{j,t-1}$ is the time-lagged spatial lag presented in a scalar fashion and ρ is the coefficient of interest. $X'_{i,t-1}$ is a vector of control variables discussed below.

Control variables

Joining the spatial lag on the right-hand side of my regression equation is selected covariates that are correlated to my dependent variable according to some previous studies. The extent to which a country relies on fossil fuels reveals the degree of carbon lock-in and the political power that environment-unfriendly industries may have (e.g., Aklin and Urpelainen, 2013), which are likely to weaken the government's ability and willingness to fund environmental innovation. Conversely, a country's high reliance on fossil fuels could encourage the environmentally progressive government to expand its financial support for environmental innovation even faster. *Fossil fuel rents/GDP* in

[6]These data are originally provided by the United Nations International Trade Statistics Database (UN Comtrade). I download them through the API wrapper programmed by Vargas (2019). See Appendix Fig. A2 for missing data.

percentage is therefore included in light of these two possibilities. How do national governments spend on environmental R&D is naturally influenced by their very own ideological position on environmental issues. I thus use data from the Comparative Manifesto Project to control the government's environmental progressiveness (Volkens et al., 2020). Following Ward and Cao (2012)'s exercise, specifically, I aggregate the seat share-weighted environmental protection progressiveness of each party in every election and then use the aggregate value from one election until the next to proxy the government's environmental position during a certain period.

Compared to other countries, EU members have to meet their supernational, environmentally ambitious targets collectively, so their spending on environmental R&D are likely to converge. With that in mind, I control the binary *EU membership*, which equals 1 if a country in a given year is a member state of the EU. Next, I add the *KOF political globalization index* (Gygli et al., 2019), which measures to extent is a country engaged in multilateral institutions where norm cascade and policy learning usually take place (Cao, 2009; Finnemore and Sikkink, 1998; Holzinger and Knill, 2005). That is to say, I take the possibility that countries may follow one another to spend even more on environmental R&D—the competing theoretical expectation against my argument—into account directly.

A country's stage of development arguably determines its ability and willingness to innovate for the environment, and I therefore add *GDP per capita* on the right-hand side. Next, I also include *GDP growth* since governments are found less motivated to address environmental issues during economic downturns (Abou-Chadi and Kayser, 2017). I then take *Total population* into account to make countries of differing sizes, which are influential to the scale of R&D spending, more comparable to each other. The final control variable is *Total government R&D spending*, which quantifies the overall budget constraint that the government funding of environmental R&D faces. Since it is hard for data collectors to locate environmental R&D precisely and exclusively in all times, including this variable also alleviates the concern about measurement error in my dependent variable.[7] In consistency with the spatial lag, I temporally lag all of the aforementioned control variables too (Drolc et al., 2019).

Empirical analysis

Regression results

I include twoway fixed effects throughout the empirical analysis. The inclusion of country fixed effects absorbs time-invariant or sluggish heterogeneities between different countries, such as political institutions or geography. The inclusion of year fixed effects takes the common time trend or exogenous shocks, such as energy crises or international environmental movements, into account. Considering the incrementalism in the budget-making process, my estimation is made to allow autoregressive random errors. Last, the standard errors are "panel-corrected" such that they are robust to unobserved spatial interdependence (Beck and Katz, 1995).

[7]This variable is also from the OECD's official statistics and downloadable through Persson (2019). All other variables, unless specifically cited, are from the World Bank's World Development Indicators. See Appendix Table A1 for summary statistics.

Table 1 reports my main regression results. I regress my dependent variable to the stand alone spatial lag to present a baseline result in column (1). The purpose of doing so is to show that my subsequent results are not just the artifact of some particular covariates (Lenz and Sahn, 2020). Next, column (2) shows the full specification which incorporates all of the variables discussed so far. Across these two columns, the coefficient estimates of my explanatory variable, *Spatial lag by environmental trade flows*—are all negatively signed and is consistent with my theoretical expectation. The negative sign, specifically, indicates that a country reduces its own government environmental R&D spending following the increasing funding made by its trade partners in the preceding year. This "strategic-substitute" spending suggests that national governments indeed take advantage of one another when it comes to funding environmental innovation (Franzese and Hays, 2008). The statistical significance levels of these two spatial lag coefficients are both below the conventional 0.05 threshold, indicating there is sufficient statistical evidence in support of my argument.

Table 1 Government environmental R&D spending crowded out by that elsewhere, OECD Countries, 1982–2017

	(1) Baseline	(2) Full
Spatial lag by environmental trade flows	-0.154^{***}	-0.125^{***}
	(0.000)	(0.000)
Fossil fuel rents/GDP		-0.003
		(0.019)
Gov. environmental position		0.021
		(0.051)
EU membership		0.059
		(0.121)
KOF political globalization index		0.065
		(0.005)
GDP per capita		0.022
		(1.007)
GDP growth		0.013
		(0.015)
Total population		2.606^{**}
		(1.052)
Total gov. R&D spending		0.062
		(0.006)
Number of observations	905	888
Number of countries	32	32
Root-mean-square error	0.422	0.397

Twoway FEs included; SEs in parentheses; standardized coefficients; $^{*}p < 0.050$, $^{**}p < 0.010$, $^{***}p < 0.001$.

Substantive effects

The spatial lag coefficients shown in Table 1 quantify the negative correlation between a country's very own government funding of environmental R&D and that elsewhere in (weighted) sum. Yet it would be more substantively interesting to see how the increased government environmental R&D spending in a single country asserts a global impact. To this end I adopt the method advocated by LeSage and Pace (2009), Ward and Gleditsch (2008), Whitten et al. (2021), among others, to recover country-specific spillover effects.

At the first step, 1,000 simulated coefficients of *Spatial lag by environmental trade flows* are drawn parametrically from a multivariate normal distribution based upon the estimates from column (2), Table 1. I then use these simulated values with the spatial weights, bilateral trade on environmental goods, to calculate 1,000 "effect matrices," of which the off-diagonal entries correspond spillover effects from column countries to row countries.[8] So the sum of a column represents the global spillover effect a single country asserts. With simulation, there are 1,000 different global spillover effects from any single country, enabling the intuitive calculation of uncertainty estimates (King et al., 2000).[9]

Fig. 2 visualizes these spillover effects by each country in descending order of magnitude. Across all cases the upper bounds of the 95 % confidence interval fall below zero, indicating the estimated effects are all statistically significant here. The negative signs, again, suggest that the increased funding in environmental R&D in a country crowds out that in the country's trading partners. Unsurprisingly, such leading innovators in environmental technologies as Germany and the United States come with significantly more sizable crowding-out effects than others. For instance, a 10% increase in environmental R&D spending made by the German government would actually suppress the spending made by other governments by about 1.1%. This unintended crowding-out effect sharply contradicts the growing threat of climate change, which begs governments worldwide to generously invest in green technologies sooner rather than later.

Importantly, the spillover effect from, say, Germany includes a part that crowds out some environmental R&D expenditures in, for example, the United States, and vice versa. Hence my finding implies that not only latecomers or small countries take advantage of the environmental innovation made by first-movers and large countries—as expected by conventional wisdom, but also the crowding-out effect undermines the "willingness to innovate" of the leading countries in environmental technologies as well. In other words, these countries would contribute more to the development of environmental technologies without their strategic calculus on environmental R&D spending.

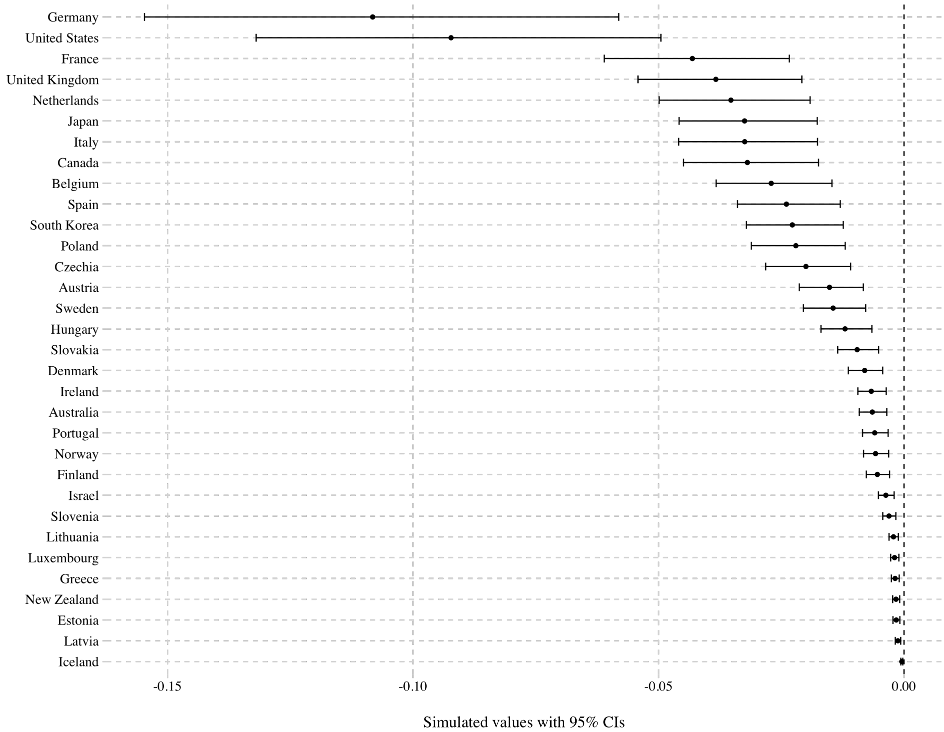
Robustness checks

Defining what goods are environment-related accurately and exclusively amid international trade is not easy. And beyond the narrowly defined environmental goods, environmental technologies may diffuse internationally through the trade on general commodities as well, since environmental innovation itself is an intersectoral process (Nemet, 2012). For these two reasons, I replicate Table 1 while using *Spatial lag by aggregate trade flows* instead. The updated spatial lag coefficients are both negative

[8] For the spatial weights I use the cross-section of 2017, the latest time point in my sample.

[9] Readers may consult panel data spatial econometrics textbooks, such as Elhorst (2014), LeSage and Pace (2009), for the detailed matrix algebra.

Fig. 2 Negative spillover (crowding-out) effects of each country's government environmental R&D spending



and statistically significant, providing robust and generalized evidence in support of my argument (see Appendix Table B1).

Bilateral trade is necessarily correlated with various dyadic attributes. Considering that, some may ask to what extent my empirical finding really involves the trade-driven technology transfer—the mechanism I argue—rather than some other cross-national connections. To address this concern, I use geographic distance between countries to replace trade as the placebo spatial weights to replicate my main regression model. The first law of geography claims that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). If my finding was an artifact of some confounding factors that are interrelated to trade, rerunning regression with *Spatial lag by geographic distance* would return a statistically significant spatial lag coefficient, whereas a statistical insignificance result from the said placebo replication could rule out alternative mechanisms. Appendix Table B2 lends support to the latter, as the placebo spatial lag's effect is not statistically distinguishable from 0 once control variables are taken into account.

Government spending in environmental R&D has some "memory." Compared to just allowing autoregressive errors in model estimation, I directly add the time-lagged dependent variable on the right-hand side in Appendix Table B3. While adding this term along with twoway fixed effects (as in my case) causes the Nickell bias by construction (Nickell, 1981) and may also render posttreatment bias (Morgan and Winship, 2014), ignoring this temporal dynamic when it is actually present is likely to give rise to spurious spatial interdependence (Drolc et al., 2019; Plümper and Neumayer, 2010), which would nullify the crowding-out effect I argue. In the absence of a solely "correct" answer, regression results when the time-lagged dependent variable is added anyway show that my finding is not model-dependent.

Finally, I demonstrate that my finding is insensitive to different functional forms with regards to the nexus between the stage of development and government spending on environmental R&D. Following the well-known environmental Kuznets curve, there might exist a U-shaped relationship between, say, *GDP per capita* and my dependent variable (Grossman and Krueger, 1995), not to mention the possible N-shaped relationship as discovered by Allard et al. (2018). I take these two possibilities into account by putting *GDP per capita* in quadratic polynomial and cubic polynomial, respectively, and replicate my main regression model. As shown in Appendix Table B4, there is empirical evidence in support of the N-shaped relationship, but importantly the conclusion regarding my central argument remains unchanged in either case. The triangular relationship involving innovation, economic development, and environmental quality (including climate mitigation) is of course more complicated. Though beyond my article's scope, future research could explore this research question that is of both strong theoretical potential and impactful policy relevance.

Concluding remarks

In its ambitious infrastructure proposal, the American Jobs Plan, the Biden-Harris administration called on Congress to make a $35-billion investment in environmental technologies, the largest ever federal funding increase on R&D outside defense.[10] According to the theories on the transnational diffusion of norms and policies, it would "rally the rest of the world to meet the threat of climate change,"[11] a key component of the Biden-Harris campaign. Specifically, the international socialization theory suggests that the United States' strong demonstration effect and leadership in international organizations would persuade other countries to conform to the norm that governments should fund environmental R&D generously (Finnemore and Sikkink, 1998). The policy learning theory and the "California effect" contend that countries with some similarities or close economic relationships with the United States would also follow its massive environmental innovation spending plan (Bennett, 1991; Rose, 1991; Vogel, 1995, 1997).

In this article, nonetheless, I argue that such progressive diffusion might not happen as the trade-driven technology transfer incentivizes national governments to underfund environmental innovation. Using data on government environmental R&D expenditures and bilateral trade flows from 32 OECD countries, 1982–2017, spatial econometric analysis corroborates the said crowding-out argument.

[10] https://bit.ly/3pBhs3u (last accessed May 18, 2021).
[11] https://bit.ly/456SEAL (last accessed May 18, 2021).

My finding presents a specific yet important case where the diffusion of progressive norm and policy ceases to exist and even goes to the opposite side. By drawing a different conclusion from the influential "California effect," I add new to the inconclusive and ongoing debate about international trade's implications on environmental policies. I also show a new context—international trade—under which countries take advantage of each other's climate action. Joining the conventional, institution-centric studies, my research adds new to the dynamics underlying the transnationally contagious climate inaction. Last, by focusing on government funding for environmental R&D, the present article contributes to our understanding of the use of technology-push policies, compared to demand-pull policies which are the focus of most of the research to date, in addressing the growing threat of climate change.

References

Abdulla, A., R. Hanna, K.R. Schell, O. Babacan, and D.G. Victor. 2020. Explaining successful and failed investments in U.S. carbon capture and storage using empirical and expert assessments. *Environmental Research Letters 16*(1): 014036. https://doi.org/10.1088/1748-9326/abd19e .

Abou-Chadi, T. and M.A. Kayser. 2017. It's not easy being green: why voters punish parties for environmental policies during economic downturns. *Electoral Studies* 45: 201–207. https://doi.org/10.1016/j.electstud.2016.10.009 .

Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous. 2012. The environment and directed technical change. *American Economic Review 102*(1): 131–66. https://doi.org/10.1257/aer.102.1.131 .

Acemoglu, D., U. Akcigit, D. Hanley, and W. Kerr. 2016. Transition to clean technology. *Journal of Political Economy 124*(1): 52–104. https://doi.org/10.1086/684511 .

Aklin, M. and M. Mildenberger. 2020. Prisoners of the wrong dilemma: why distributive conflict, not collective action, characterizes the politics of climate change. *Global Environmental Politics 20*(4): 4–27. https://doi.org/10.1162/glep_a_00578 .

Aklin, M. and J. Urpelainen. 2013. Political competition, path dependence, and the strategy of sustainable energy transitions. *American Journal of Political Science 57*(3): 643–658. https://doi.org/10.1111/ajps.12002. https://onlinelibrary.wiley.com/doi/pdf/10.1111/ajps.12002 .

Allard, A., J. Takman, G.S. Uddin, and A. Ahmed. 2018. The N-shaped environmental kuznets curve: an empirical evaluation using a panel quantile regression approach. *Environmental Science and Pollution Research* 25: 5848–5861. https://doi.org/10.1007/s11356-017-0907-0 .

Baldwin, E., S. Carley, and S. Nicholson-Crotty. 2019. Why do countries emulate each others' policies? a global study of renewable energy policy diffusion. *World*

Development 120: 29 – 45. https://doi.org/10.1016/j.worlddev.2019.03.012 .

Bastiaens, I. and E. Postnikov. 2017. Greening up: the effects of environmental standards in EU and US trade agreements. *Environmental Politics 26*(5): 847–869. https://doi.org/10.1080/09644016.2017.1338213 .

Bayer, P. and J. Urpelainen. 2016. It is all about political incentives: democracy and the renewable feed-in tariff. *The Journal of Politics 78*(2): 603–619. https://doi.org/10.1086/684791 .

Beck, N., K.S. Gleditsch, and K. Beardsley. 2006. Space is more than geography: using spatial econometrics in the study of political economy. *International Studies Quarterly 50*(1): 27–44. https://doi.org/10.1111/j.1468-2478.2006.00391.x .

Beck, N. and J.N. Katz. 1995. What to do (and not to do) with time-series cross-section data. *American Political Science Review 89*(3): 634–647. https://doi.org/10.2307/2082979 .

Bennett, C.J. 1991. What is policy convergence and what causes it? *British Journal of Political Science 21*(2): 215–233. https://doi.org/doi.org/10.1017/S0007123400006116 .

BP p.l.c. 2020. Statistical review of world energy. https://bit.ly/42L4DSo (accessed January 22, 2021).

Brandi, C., J. Schwab, A. Berger, and J.F. Morin. 2020. Do environmental provisions in trade agreements make exports from developing countries greener? *World Development* 129: 104899. https://doi.org/10.1016/j.worlddev.2020.104899 .

Bättig, M.B. and T. Bernauer. 2009. National institutions and global public goods: are democracies more cooperative in climate change policy? *International Organization 63*(2): 281–308. https://doi.org/10.1017/S0020818309090092 .

Cao, X. 2009. Networks of intergovernmental organizations and convergence in domestic economic policies. *International Studies Quarterly 53*(4): 1095–1130. https://doi.org/10.1111/j.1468-2478.2009.00570.x .

Cao, X. and A. Prakash. 2010. Trade competition and domestic pollution: A panel study, 1980–2003. *International Organization 64*(3): 481–503. https://doi.org/10.1017/S0020818310000123 .

Cao, X. and A. Prakash. 2012. Trade competition and environmental regulations: Domestic political constraints and issue visibility. *The Journal of Politics 74*(1): 66–82. https://doi.org/10.1017/S0022381611001228 .

Coe, D.T. and E. Helpman. 1995. International R&D spillovers. *European Economic Review 39*(5): 859–887. https://doi.org/10.1016/0014-2921(94)00100-E .

Coe, D.T., E. Helpman, and A.W. Hoffmaister. 1997. North-South R&D spillovers. *The Economic Journal 107*(440): 134–149. https://doi.org/doi.org/10.1111/1468-0297.00146 .

Contreras, J., B. Hall, and C. Helmers. 2018. Green technology diffusion: a post-mortem analysis of the Eco-Patent Commons. National Bureau of Economic Research Working Paper Series 25271.

de la Tour, A., M. Glachant, and Y. Ménière. 2011. Innovation and international technology transfer: the case of the Chinese photovoltaic industry. *Energy Policy 39*(2): 761–770. https://doi.org/10.1016/j.enpol.2010.10.050 .

Dechezleprêtre, A., M. Glachant, I. Haščič, N. Johnstone, and Y. Ménière. 2011. Invention and transfer of climate change–mitigation technologies: a global analysis. *Review of Environmental Economics and Policy 5*(1): 109–130. https://doi.org/10.1093/reep/req023 .

Dechezleprêtre, A., R. Martin, and S. Bassi. 2019. Climate change policy, innovation and growth, In *Handbook on Green Growth*, ed. Fouquet, R., 217–239. Cheltenham, England: Edward Elgar Publishing.

Dechezleprêtre, A. and M. Sato. 2017. The impacts of environmental regulations on competitiveness. *Review of Environmental Economics and Policy 11*(2): 183–206. https://doi.org/10.1093/reep/rex013 .

Drolc, C.A., C. Gandrud, and L.K. Williams. 2019. Taking time (and space) seriously: how scholars falsely infer policy diffusion from model misspecification. *Policy Studies Journal*. https://doi.org/10.1111/psj.12374 .

Elhorst, J.P. 2014. *Spatial Econometrics: From Cross-Sectional Data to Spatial Panels*. Heidelberg, Germany: Springer.

Finnemore, M. and K. Sikkink. 1998. International norm dynamics and political change. *International Organization*: 887–917. https://doi.org/10.1162/002081898550789 .

Fischer, C., L. Preonas, and R.G. Newell. 2017. Environmental and technology policy options in the electricity sector: are we deploying too many? *Journal of the Association of Environmental and Resource Economists 4*(4): 959–984. https://doi.org/10.1086/692507 .

Food & Water Watch. 2020. The case against carbon capture: false claims and new pollution. https://foodandwaterwatch.org/wp-content/uploads/2021/04/ib_2003_carboncapture-web.pdf (accessed September 27, 2021).

Franzese, R.J. and J.C. Hays. 2007. Spatial econometric models of cross-sectional interdependence in political science panel and time-series-cross-section data. *Political*

Analysis: 140–164. https://doi.org/10.1093/pan/mpm005 .

Franzese, R.J. and J.C. Hays. 2008. Interdependence in comparative politics: substance, theory, empirics, substance. *Comparative Political Studies 41*(4-5): 742–780. https://doi.org/10.1177/0010414007313122 .

Friedlingstein, P., M. O'Sullivan, M.W. Jones, R.M. Andrew, L. Gregor, J. Hauck, C. Le Quéré, I.T. Luijkx, A. Olsen, G.P. Peters, W. Peters, J. Pongratz, C. Schwingshackl, S. Sitch, J.G. Canadell, P. Ciais, R.B. Jackson, S.R. Alin, R. Alkama, A. Arneth, V.K. Arora, N.R. Bates, M. Becker, N. Bellouin, H.C. Bittig, L. Bopp, F. Chevallier, L.P. Chini, M. Cronin, W. Evans, S. Falk, R.A. Feely, T. Gasser, M. Gehlen, T. Gkritzalis, L. Gloege, G. Grassi, N. Gruber, O. Gürses, I. Harris, M. Hefner, R.A. Houghton, G.C. Hurtt, Y. Iida, T. Ilyina, A.K. Jain, A. Jersild, K. Kadono, E. Kato, D. Kennedy, K. Klein Goldewijk, J. Knauer, J.I. Korsbakken, P. Landschützer, N. Lefèvre, K. Lindsay, J. Liu, Z. Liu, G. Marland, N. Mayot, M.J. McGrath, N. Metzl, N.M. Monacci, D.R. Munro, S.I. Nakaoka, Y. Niwa, K. O'Brien, T. Ono, P.I. Palmer, N. Pan, D. Pierrot, K. Pocock, B. Poulter, L. Resplandy, E. Robertson, C. Rödenbeck, C. Rodriguez, T.M. Rosan, J. Schwinger, R. Séférian, J.D. Shutler, I. Skjelvan, T. Steinhoff, Q. Sun, A.J. Sutton, C. Sweeney, S. Takao, T. Tanhua, P.P. Tans, X. Tian, H. Tian, B. Tilbrook, H. Tsujino, F. Tubiello, G.R. van der Werf, A.P. Walker, R. Wanninkhof, C. Whitehead, A. Willstrand Wranne, R. Wright, W. Yuan, C. Yue, X. Yue, S. Zaehle, J. Zeng, and B. Zheng. 2022. Global carbon budget 2022. *Earth System Science Data 14*(11): 4811–4900. https://doi.org/10.5194/essd-14-4811-2022 .

Garsous, G. and S. Worack. 2021. Trade as a channel for environmental technologies diffusion: the case of the wind turbine manufacturing industry. OECD Trade and Environment Working Papers 2021/01.

Gersbach, H., Q. Oberpriller, and M. Scheffel. 2018. Double free-riding in innovation and abatement: a rules treaty solution. *Environmental and Resource Economics 73*(2): 449–483. https://doi.org/https://doi.org/10.1007/s10640-018-0270-8 .

Grossman, G.M. and A.B. Krueger. 1995. Economic growth and the environment. *The Quarterly Journal of Economics 110*(2): 353–377. https://doi.org/10.2307/2118443 .

Gygli, S., F. Haelg, N. Potrafke, and J.E. Sturm. 2019. The KOF globalisation index – revisited. *The Review of International Organizations 14*(3): 543–574. https://doi.org/10.1007/s11558-019-09344-2 .

Hall, B.H. and C. Helmers. 2013. Innovation and diffusion of clean/green technology: can patent commons help? *Journal of Environmental Economics and Management 66*(1): 33–51. https://doi.org/10.1016/j.jeem.2012.12.008 .

Holzinger, K. and C. Knill. 2005. Causes and conditions of cross-national policy convergence. *Journal of European Public Policy 12*(5): 775–796. https://doi.org/10.1080/13501760500161357 .

IRENA. 2018. Global energy transformation: a roadmap to 2050. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf (accessed January 22, 2021).

Jaakkola, N. and F. van der Ploeg. 2019. Non-cooperative and cooperative climate policies with anticipated breakthrough technology. *Journal of Environmental Economics and Management* 97: 42–66. https://doi.org/10.1016/j.jeem.2018.04.001 .

Jinnah, S. and A. Lindsay. 2016. Diffusion through issue linkage: environmental norms in US trade agreements. *Global Environmental Politics 16*(3): 41–61. https://doi.org/10.1162/GLEP_a_00365 .

Keller, W. 2004. International technology diffusion. *Journal of Economic Literature 42*(3): 752–782. https://doi.org/10.1257/0022051042177685 .

Kennedy, A.B. 2013. China's search for renewable energy: pragmatic techno-nationalism. *Asian Survey 53*(5): 909–930. https://doi.org/10.1525/as.2013.53.5.909 .

King, G., M. Tomz, and J. Wittenberg. 2000. Making the most of statistical analyses: improving interpretation and presentation. *American Journal of Political Science 44*(2): 347–361. https://doi.org/10.2307/2669316 .

Lanjouw, J.O. and A. Mody. 1996. Innovation and the international diffusion of environmentally responsive technology. *Research Policy 25*(4): 549–571. https://doi.org/10.1016/0048-7333(95)00853-5 .

Lechner, L. and G. Spilker. 2022. Taking it seriously: commitments to the environment in South-South preferential trade agreements. *Environmental Politics 31*(6): 1058–1080. https://doi.org/10.1080/09644016.2021.1975399 .

Lenz, G. and A. Sahn. 2020. Achieving statistical significance with control variables and without transparency. *Political Analysis 29*(3): 356–369. https://doi.org/10.1017/pan.2020.31 .

LeSage, J. and R.K. Pace. 2009. *Introduction to Spatial Econometrics*. Boca Raton, FL: Chapman & Hall/CRC.

Less, C.T. and S. McMillan. 2005. Achieving the successful transfer of environmentally sound technologies: trade-related aspects. OECD Trade and Environment Working Paper No. 2005-02.

Maskus, K.E. 2004. Encouraging international technology transfer. UNCTAD-ICTSD Project on IPRs and Sustainable Development Issue Paper No. 7.

McLean, E.V. and T. Plaksina. 2019. The political economy of carbon capture and storage technology adoption. *Global Environmental Politics 19*(2): 127–148. https://doi.org/10.1162/glep_a_00502 .

Meckling, J. and J. Nahm. 2018. When do states disrupt industries? electric cars and the politics of innovation. *Review of International Political Economy 25*(4): 505–529. https://doi.org/10.1080/09692290.2018.1434810 .

Morgan, S.L. and C. Winship. 2014. *Counterfactuals and causal inference: methods and principles for social research* (second ed.). Cambridge University Press.

Nemet, G.F. 2012. Inter-technology knowledge spillovers for energy technologies. *Energy Economics 34*(5): 1259–1270. https://doi.org/10.1016/j.eneco.2012.06.002 .

Neumayer, E. and T. Plümper. 2016. W. *Political Science Research and Methods 4*(1): 175–193. https://doi.org/10.1017/psrm.2014.40 .

Nickell, S. 1981. Biases in dynamic models with fixed effects. *Econometrica 49*(6): 1417–1426. https://doi.org/10.2307/1911408 .

OECD. 1999. The environmental goods & services industry: Manual for data collection and analysis. OECD Publishing. DOI: 10.1787/9789264173651-en.

OECD. 2018. Mobilising bond markets for a low-carbon transition. Green Finance and Investment Series. OECD Publishing. DOI: 10.1787/9789264308114-en.

OECD, World Bank, and UN Environment. 2018. Financing climate futures: rethinking infrastructure. OECD Publishing. DOI: 10.1787/9789264308114-en.

Perkins, R. and E. Neumayer. 2009. Transnational linkages and the spillover of environment-efficiency into developing countries. *Global Environmental Change 19*(3): 375–383. https://doi.org/10.1016/j.gloenvcha.2009.05.003 .

Persson, E. 2019. OECD: Search and extract data from the OECD. R Package, version 0.2.4. The Comprehensive R Archive Network (CRAN), https://CRAN.R-project.org/package=OECD.

Pinkse, J. and M.E. Slade. 2010. The future of spatial econometrics. *Journal of Regional Science 50*(1): 103–117. https://doi.org/10.1111/j.1467-9787.2009.00645.x .

Plümper, T. and E. Neumayer. 2010. Model specification in the analysis of spatial dependence. *European Journal of Political Research 49*(3): 418–442. https://doi.org/10.1111/j.1475-6765.2009.01900.x .

Porter, G. 1999. Trade competition and pollution standards: “race to the bottom” or “stuck at the bottom”. *The Journal of Environment & Development 8*(2): 133–151. https://doi.org/10.1177/107049659900800203 .

Prakash, A. and M. Potoski. 2006. Racing to the bottom? Trade, environmental governance, and ISO 14001. *American Journal of Political Science 50*(2): 350 – 364. https://doi.org/10.1111/j.1540-5907.2006.00188.x .

Prakash, A. and M. Potoski. 2017. The EU effect: does trade with the EU reduce CO_2 emissions in the developing world? *Environmental Politics 26*(1): 27–48. https://doi.org/10.1080/09644016.2016.1218630 .

Qu, X., L.f. Lee, and C. Yang. 2021. Estimation of a SAR model with endogenous spatial weights constructed by bilateral variables. *Journal of Econometrics 221*(1): 180–197. https://doi.org/10.1016/j.jeconom.2020.05.011 .

Reuters. 2012. Solyndra backers could reap big tax breaks; U.S. wants details. https://reut.rs/3vvaSJP (accessed May 19, 2021).

Rose, R. 1991. What is lesson-drawing? *Journal of Public Policy 11*(1): 3–30. https://doi.org/10.1017/S0143814X00004918 .

Saikawa, E. 2013. Policy diffusion of emission standards: is there a race to the top. *World Politics 65*(1): 1–33. https://doi.org/10.1017/S0043887112000238 .

Sauvage, J. 2014. The stringency of environmental regulations and trade in environmental goods. The OECD Trade and Environment Working Paper Series.

Stokes, L.C. 2020. *Short circuiting policy: interest groups and the battle over clean energy and climate policy in the American States.* Oxford University Press.

Taylor, M.Z. 2007. Political decentralization and technological innovation: testing the innovative advantages of decentralized states. *Review of Policy Research 24*(3): 231–257. https://doi.org/10.1111/j.1541-1338.2007.00279.x .

Taylor, M.Z. 2016. *The politics of innovation: why some countries are better than others at science and technology.* Oxford University Press.

The New York Times. 2021. The lessons of the Texas power disaster. https://www.nytimes.com/2021/02/19/opinion/texas-power-energy.html (accessed September 27, 2021).

The Wall Street Journal. 2012. Americans for prosperity to air ads slamming Obama’s ties to Solyndra. https://www.wsj.com/articles/BL-WB-33080 (accessed May 19, 2021).

Tobler, W.R. 1970. A computer movie simulating urban growth in the detroit region. *Economic Geography 46*(sup1): 234–240. https://doi.org/10.2307/143141 .

Urpelainen, J. 2013. Promoting international environmental cooperation through unilateral action: when can trade sanctions help? *Global Environmental Politics 13*(2): 26–45. https://doi.org/10.1162/GLEP_a_00165 .

Vargas, M. 2019. tradestatistics. R Package, version 0.2.5. GitHub, https://github.com/ropensci/tradestatistics.

Vogel, D. 1995. *Trading Up: Consumer and Environmental Regulation in a Global Economy.* Cambridge, MA: Harvard University Press.

Vogel, D. 1997. Trading up and governing across: Transnational governance and environmental protection. *Journal of European Public Policy 4*(4): 556–571. https://doi.org/10.1080/135017697344064 .

Volkens, A., T. Burst, W. Krause, P. Lehmann, T. Matthieß, N. Merz, S. Regel, B. Weßels, and L. Zehnter. 2020. The manifesto data collection. Manifesto Project (MRG/CMP/MARPOR), Version 2020b. Berlin: Wissenschaftszentrum Berlin für Sozialforschung (WZB). DOI: 10.25522/manifesto.mpds.2020b.

Wacziarg, R. 2001. Measuring the dynamic gains from trade. *The World Bank Economic Review 15*(3): 393–429. https://doi.org/10.1093/wber/15.3.393 .

Ward, H. and X. Cao. 2012. Domestic and international influences on green taxation. *Comparative Political Studies 45*(9): 1075–1103. https://doi.org/10.1177/0010414011434007 .

Ward, M.D. and K.S. Gleditsch. 2008. *Spatial regression models.* Thousand Oaks, CA: Sage Publications.

Whitten, G.D., L.K. Williams, and C. Wimpy. 2021. Interpretation: the final spatial frontier. *Political Science Research and Methods 9*(1): 140–156. https://doi.org/10.1017/psrm.2019.9 .

Wimpy, C., L.K. Williams, and G.D. Whitten. 2021. X marks the spot: unlocking the treasure of spatial-X models. *The Journal of Politics 81*(2). https://doi.org/10.1086/710089 .

Woods, N.D. 2006. Interstate competition and environmental regulation: a test of the race-to-the-bottom thesis. *Social Science Quarterly 87*(1): 174–189. https://doi.org/10.1111/j.0038-4941.2006.00375.x .

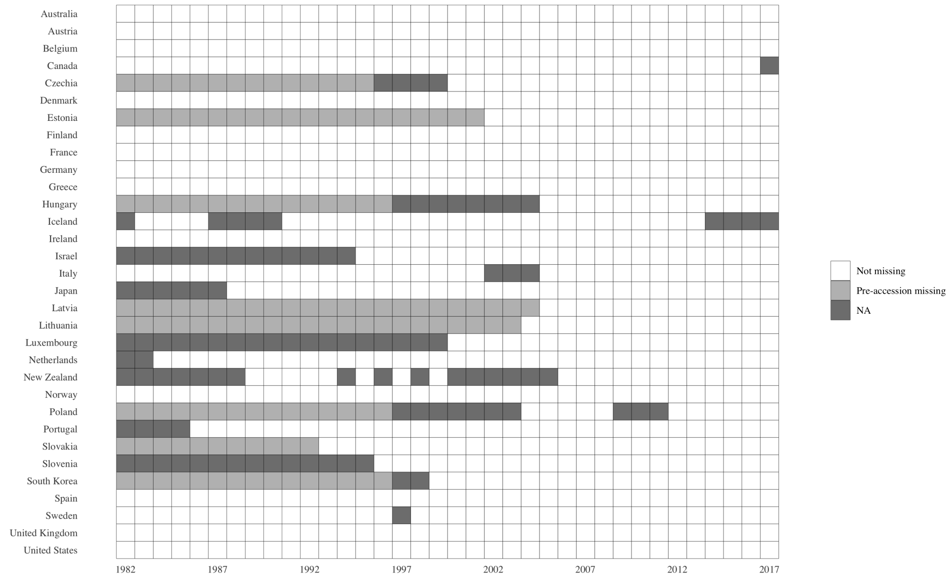
WTO. 2001. Doha WTO Ministerial 2001. https://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.htm (accessed September 27, 2021).

Appendix (supplementary materials)

Table A1 Summary statistics of the variables used in the main text

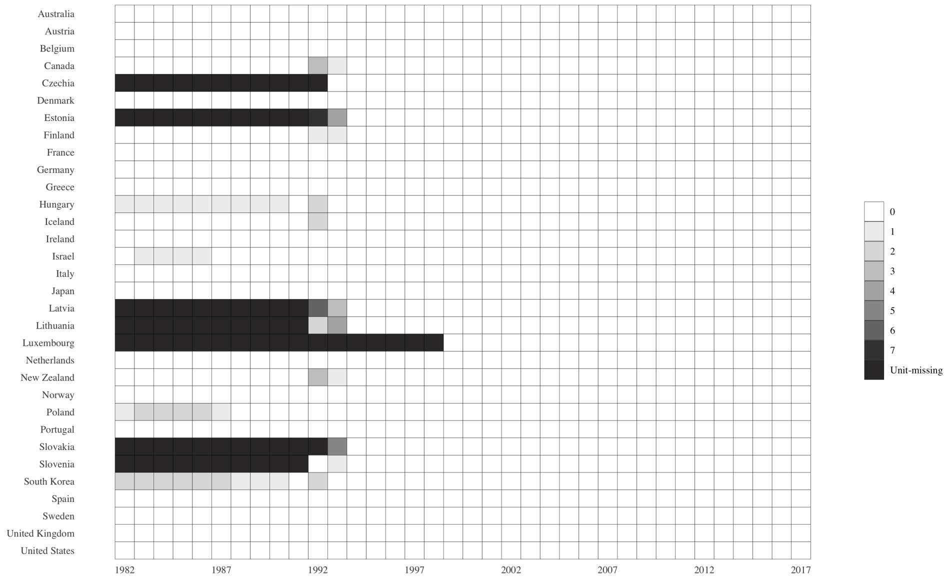
Variable	Min	Median	Max	Mean	SD	Obs
Government environmental R&D spending	3.37	10.82	14.17	10.85	1.78	906
Spatial lag	0.83	697.98	15,444.20	1,645.65	2,395.96	1,066
Fossil fuel rents/GDP	0.00	0.08	12.11	0.60	1.44	1,066
Government environmental position	0.00	0.59	3.67	0.78	0.62	1,042
EU membership	0.00	1.00	1.00	0.54	0.50	1,087
KOF globalization index	36.50	87.31	98.85	81.13	15.26	1,090
GDP per capita	1.36	3.47	4.72	3.36	0.59	1,064
GDP growth	−14.84	2.75	25.16	2.70	3.15	1,056
Total population	12.35	16.12	19.59	16.17	1.54	1,152
Government total R&D spending	0.02	2.27	150.50	9.81	21.81	935

Fig. A1 Missing values in government environmental R&D spending (dependent variable)



The vast majority of missing values in my dependent variable is caused by the later accessions to the OECD of South Korea and the eastern European members (labeled as "Pre-accession missing"). There is no convincing factor that may endogenize this data missing process, so I delete the relevant cases in a listwise way.

Fig. A2 Missing values in bilateral trade flows on environmental goods (spatial weights)



I omit the sparsely missing values in these data. Since my sample only consists of OECD countries with high state capacity and relatively low incentive of committing data fabrication, no unobserved endogenous factor is likely to govern the data missing process in a convincing way. In other words, the missing at random (MAR) assumption is very likely to hold. Given various covariates are included in my regression model along with twoway fixed effects, dropping the missing values here should have no effect on my point estimates. "Unit-missing" occurs when there is no data for a country at all in a given year, and it almost only applies to the eastern European countries before 1991.

Table B1 Additional regression results, with aggregate trade flows used for spatial weights

	(1) Baseline	(2) Full
Spatial lag by aggregated trade flows	−0.149***	−0.121***
	(0.000)	(0.000)
Fossil fuel rents/GDP		−0.001
		(0.019)
Gov. environmental position		0.021
		(0.051)
EU membership		0.057
		(0.120)
KOF political globalization index		0.064
		(0.005)
GDP per capita		0.022
		(1.027)
GDP growth		0.013
		(0.015)
Total population		2.657**
		(1.073)
Total gov. R&D spending		0.059
		(0.007)
Number of observations	904	887
Number of countries	32	32
Root-mean-square error	0.423	0.397

Twoway FEs included; SEs in parentheses; standardized coefficients; $^{*}p < 0.050$, $^{**}p < 0.010$, $^{***}p < 0.001$.

Table B2 Additional regression results, with geographic distance used for spatial weights

	(1) Baseline	(2) Full
Spatial lag by geographic distance	−0.098**	−0.020
	(0.001)	(0.001)
Fossil fuel rents/GDP		0.004
		(0.018)
Gov. environmental position		0.025
		(0.051)
EU membership		0.075*
		(0.117)
KOF political globalization index		0.077*
		(0.005)
GDP per capita		0.047
		(0.994)
GDP growth		0.013
		(0.015)
Total population		2.785**
		(1.142)
Total gov. R&D spending		−0.005
		(0.007)
Number of observations	897	879
Number of countries	32	32
Root-mean-square error	0.425	0.401

Twoway FEs included; SEs in parentheses; standardized coefficients; $^{*}p < 0.050$, $^{**}p < 0.010$, $^{***}p < 0.001$.

Table B3 Additional regression results, with time-lagged dependent variable included

	(1) Baseline	(2) Full
Spatial lag by environmental trade flows	−0.047*	−0.051**
	(0.000)	(0.000)
Time-lagged dependent variable	0.716***	0.696***
	(0.046)	(0.048)
Fossil fuel rents/GDP		−0.003
		(0.013)
Gov. environmental position		0.013
		(0.030)
EU membership		0.025
		(0.096)
KOF political globalization index		0.023
		(0.003)
GDP per capita		−0.082
		(0.572)
GDP growth		0.025
		(0.015)
Total population		0.805
		(0.503)
Total gov. R&D spending		0.069
		(0.004)
Number of observations	882	882
Number of countries	32	32
Root-mean-square error	0.385	0.382

Twoway FEs included; SEs in parentheses; standardized coefficients; $^{*}p < 0.050$, $^{**}p < 0.010$, $^{***}p < 0.001$.

Table B4 Additional regression results, with environmental Kuznets curve modeled

	(1) *U*-shaped Kuznets curve	(2) *N*-shaped Kuznets curve
Spatial lag by environmental trade flows	−0.134***	−0.124***
	(0.000)	(0.000)
Fossil fuel rents/GDP	0.005	0.013
	(0.018)	(0.017)
Gov. environmental position	0.021	0.018
	(0.051)	(0.051)
EU membership	0.059	0.046
	(0.110)	(0.115)
KOF political globalization index	0.064	0.044
	(0.005)	(0.005)
GDP per capita	−0.137	0.841
	(0.057)	(0.074)
GDP per capita, squared	−0.057	−1.910
	(0.000)	(0.001)
GDP per capita, cubed		1.021*
		(0.000)
Total population	2.893***	3.075***
	(0.947)	(0.885)
Total gov. R&D spending	0.069	0.071
	(0.006)	(0.006)
GDP growth	0.018	
	(0.015)	
Number of observations	888	888
Number of countries	32	32
Root-mean-square error	0.397	0.397

Twoway FEs included; SEs in parentheses; standardized coefficients; $^{*}p < 0.050$, $^{**}p < 0.010$, $^{***}p < 0.001$.