



Research paper

Renewable-energy consumption and international trade[☆]Nneamaka Ilechukwu^{a,1}, Sajal Lahiri^{b,*}^a Division of Social & Behavioral Science, Snow College, Ephraim, UT, USA^b School of Analytics, Finance and Economics, Southern Illinois University Carbondale, Carbondale, IL 62901, USA

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ABSTRACT

This paper investigates the implications for international trade of a country's dependence on renewable energy consumption in total energy use. We use data for 152 countries over the period 1990–2014. We estimate a gravity equation of bilateral trade to assess the role of renewable energy consumption on international trade. We find, *inter alia*, that a 1% increase in the use of renewable energy as a proportion of total energy leads to, on an average, a 1.026% decrease in exports, and a 0.39% increase in imports, suggesting that renewable energy use makes trade less competitive. This outcome is due in part to cost implications of using renewable energy sources. However, we also find some heterogeneity in this respect. Whereas Organization for Economic Co-operation and Development (OECD) countries export more with increased use of renewable energy, for non-OECD countries renewable energy use reduces exports.

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1. Introduction

In this paper, we examine the implications for international trade of increasing the share of renewable energy consumption in total energy use. It is a well-known fact that non-renewable energy sources like natural gas, petroleum and other liquids, and fossil fuels are bad for the environment, given their contributions to atmospheric pollution.

Renewable energy refers to energy produced from sources that do not deplete or sources that can be replenished in a person's lifetime. Compared with fossil fuel energy systems, renewable energy systems generate lower greenhouse emissions, making them better for the environment. Greenhouse emissions are the main contributor to global climate change. The United States Energy Information Administration categorizes renewable energy into five classes: biomass, geothermal, hydropower, wind, and solar.

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These energy sources are naturally replenishing. However, not all renewable energy is clean energy; some renewable sources of energy do release significant pollution into the environment. Fuel wood which is renewable biomass, for example, releases greenhouse emissions when burnt for cooking and other purposes. It can also lead to deforestation, which creates other environmental issues.

The literature, discussed in the next section, identifies many factors for the poor adoption of renewable sources of energy. Given these costs associated with the adoption of renewable sources of energy, we examine how the composition of renewable energy in a country affects international trade in terms of its exports and imports. If the effect turns out to be negative, then there is even a bigger reason to look into policies aimed at encouraging the use of environmentally friendly sources of energy. Can such policies do both things simultaneously: (i) encourage the use of renewable sources of energy, and (ii) increase the competitiveness of the country in international trade?

This paper expands on the work done by Nesta et al. (2014) by estimating the impact of renewable energy consumption on imports and exports by a country. We estimate a gravity model using data for 152 countries from 1990–2014. We find that whereas Organization for Economic Co-operation and Development (OECD) countries export more with increased use of renewable energy, for non-OECD countries, renewable energy use reduces exports. This is possible because the OECD countries have been able to adapt new technologies effectively and mitigate

the adverse effects of renewable energy use on competitiveness. Thus, we find both yes and no to our research question. The positive result for the OECD countries suggests that a negative effect of using renewable resources on exports is not inevitable, and even the non-OECD countries should be able to overcome the trade-off with appropriate policies.

In explaining international trade flows, it is now quite common to use the gravity model, which was first introduced by Tinbergen to predict market integration or bilateral trade in terms of economic sizes and bilateral distances (Tinbergen, 1962). Following the recent developments in the literature, we include pairwise fixed effects to capture all bilateral trade costs and exporter-time and importer-time fixed effects, which deal with multilateral resistances in international trade. These fixed effects make the estimates consistent with general equilibrium estimates based on economic theory and include all the direct and indirect impacts on international trade. Moreover, the presence of the fixed effects eliminates to a large extent the possibility of the existence of endogeneity or spurious correlation because of observable and unobservable omitted variables.

The remainder of the paper is organized as follows: Section 2 provides a discussion on the relevant literature, Section 3 describes the data and lays down the empirical strategy, and Section 4 presents the empirical results. Section 5 then makes some concluding remarks and policy implications of our study.

To summarize, our contributions in this paper are:

- Using annual bilateral trade data for 152 countries over the period 1990–2014, we estimate the magnitude of the effect of increasing renewable energy consumption in total energy consumption on imports and exports by a country.
- We do so using up-to-date developments in the application of gravity models, which include the use of pairwise fixed effects, importer-time fixed effects, and exporter-time fixed effects.
- We find, on average, that a 1% increase in the use of renewable energy as a proportion of total energy leads to, on average, a 1.026% decrease in exports and a 0.39% increase in imports.
- However, we find heterogeneity in the effects across country groups.
- In particular, the negative impact on trade mentioned above occurs only for poorer countries (non-members of the Organization of Economic Co-operation and Development).
- For richer countries, more dependence on renewable energy, in fact, increases exports and decreases imports.

2. Literature review

The relevant literature for this study has two parts. One part is about the positive effect of using renewable energy on the environment. The second part is about estimating possible costs of using renewable energy using a statistical methodology of gravity analysis.

The problems associated with fossil energy use are the main driving force behind environmental activism, and the creation of a global climate regime represented by the Kyoto Protocol and other climate treaties, including the Paris Treaty signed in 2016 and the Glasgow Agreement of 2021 (COP26), to manage greenhouse gas emissions (Chakravorty et al., 2006).

Advocates for the use of renewable energy argue that an increasing substitution of dirty energy by carbon-free energy sources accelerates the transition to a green economy and that this substitution could not be coming at a better time, given the challenges posed by atmospheric pollutants which leave catastrophic damages in its wake (Parikh and Parikh, 1977; Amigues and Moreaux, 2019).

The literature identifies many factors for the poor adoption of renewable energy sources, despite its macroeconomic gains (Nesta et al., 2014), including the high cost of capital, low demand, and small-scale production, all of which raise the unit cost of producing renewable energy. Researchers who studied the move to a carbon-free economy note that the efficiency gains from using renewable energy sources do not come without costs.² However, given the catastrophic damages caused by pollution-induced climate change, empirical evidence suggests a strong need for countries to embrace technologies that use renewable energy (Bento et al., 2018; Amigues and Moreaux, 2019). Parikh et al. (2002) highlights the vulnerability of developing countries to changes in the climate and the need for economic policies that include environmental sustainability in these countries. They also note that the significant trade-offs usually associated with switching to cleaner energy sources can be outweighed by the level of economic development, reduced vulnerability to climate change, and the ability to adapt to or mitigate the adverse effects of climate change. Considerations for how climate change impacts development are crucial to building cost-effective strategies for responding to climate change in developing countries.

Turning to the literature on gravity analysis, given the availability of large panel datasets, many methodological improvements have been introduced in gravity models in recent years (Campbell, 2010; Yotov et al., 2016). These innovations include the inclusion of time-invariant pairwise fixed effects, which take care of factors such as distance, colonial links, landlockedness, language similarities, and importer-time and exporter-time fixed effects, which cover country-specific variables that change with time, like GDP, population, etc. Furthermore, pairwise fixed effects capture all bilateral trade costs (Agnosteva et al., 2014; Egger et al., 2022), and exporter-time and importer-time fixed effects, which account for multilateral resistances in international trade (Anderson and van Wincoop, 2003). By including all these fixed effects, we obtain general equilibrium estimates as they account for all the direct and indirect impacts on international trade (Baldwin and Taglioni, 2006; Yotov et al., 2016). Including these fixed effects also reduces the possibility of spurious correlation arising because of omitted variables significantly (Baier and Bergstrand, 2007; Wooldridge, 2002). One issue with a large country panel dataset is that many trade flows between pairs of countries take zero values, making the estimation of log-linear gravity models with Ordinary least Squares methods challenging. Following the literature, this paper will use the latest advancement in the Poisson Pseudo-Maximum Likelihood (PPML) method, which can deal with zero trade flows (Kitenge and Lahiri, 2022).

3. Data and empirical strategy

3.1. Data and variables

Before going into the empirical exercise in detail, we shall describe our data, give their source, and define the variables. This is done in Table 1.³ Summary statistics for the variables we provided in Table 2. We use the information on various variables for 152 countries from 1990–2014. Data for renewable energy

² Analyzing India's ambitions for economic growth and the after-effects of energy growth and carbon dioxide (CO₂) emissions, Parikh and Parikh (2011) find that the potential to reduce CO₂ emissions comes with additional costs; a reduction in the demand for energy and an increase in usage of efficient energy in production and consumption, remaining the best options.

³ Any researcher should be able to access these data from the websites mentioned in Table 1. However, if requested, we shall be happy to share the data and the codes for running the regressions in an Excel file.

Table 1
Data.

Variable	Description	Data Source
Renergy _{it}	Share of Renewable energy consumption in total energy use	United States Energy Information Administration
Fenergy _{it}	Ratio of fossil fuel consumption to total energy consumption	United States Energy Information Administration
X _{ijt}	Trade flow between country <i>i</i> (the exporter) and country <i>j</i> (the importer) at time <i>t</i>	Center d'tudes prospectives et d'Informations International (CEPII)
Fta_hmr _{ijt}	Represents membership of a free trade agreement constructed by Head et al. (2010), takes the value 1 if a member, and 0 otherwise	Center d'tudes prospectives et d'Informations International (CEPII)
GDPPC (in US\$)	Gross Domestic Product (GDP) Per Capita (its square, and cube)	Center d'tudes prospectives et d'Informations International (CEPII)
CO2te	Carbon dioxide emissions to total energy consumption	United States Energy Information Administration

Table 2
Summary statistics.

Variable	Obs	Mean	Std. Dev	Min	Max
GDP	3,800	2.51e+11	1.12e+12	8824746	1.74e+13
GDPPC	3,800	9287.969	14922.61	64.81015	100818.5
Renergy	3,800	13.15824	17.4711	0	89.5
Fenergy	3,800	84.89645	19.42855	0	100
Co2te	3,800	59.07583	21.96891	0.0125	200
X _{ijt}	565,772	1.65e+08	2.35e+09	0	2.84e+11
Fta_hmr _{ijt}	565,772	0.291107	0.1681169	0	1
Renergy _{ijt}	565,772	35.92326	31.98953	0	89.5

use, fossil fuel use, per-capita gross domestic production, and carbon dioxide emission are available from the sources mentioned in Table 1 up to 2019. However, data for bilateral trade flows, our dependent variable, is only available up to 2014. This is an unfortunate constraint for, and limitation of, the present study.

3.2. Empirical strategy

In this paper we estimate a gravity equation (Anderson and van Wincoop, 2003; Bergstrand et al., 2015) to calculate the impact of the share of renewable energy consumption in total energy use on bilateral trade.

The theoretical basis for the gravity equation is as follows (Anderson and van Wincoop, 2003):

$$X_{ijt} = \left(\frac{E_j * Y_i}{Y_t} \right) \cdot \left(\frac{C_{ij}}{N_j * \varphi_i} \right)^{1-\sigma} \quad \sigma > 1, \tag{1}$$

where X_{ijt} is the trade flow from exporter *i* to importer *j* at time *t*, E_j is the total expenditure of country *j*, Y_i is goods sold by county *i* at the destination price, and Y_t is global output. The parameters N_j and ϕ_i represent inward and outward multilateral resistance, C_{ij} is trade costs for trade flows from country *i* to country *j*, and σ is the elasticity of substitution between traded goods. We assume that σ is greater than 1. It is called the gravity model as it is derived from the Newton's law of universal gravitation which, in its original form, states that every particle draws every other particle in the universe with a force that is directly proportionate to the product of their masses and inversely proportionate to the square of the distance between their centers. Mathematically, the law is written thus:

$$F = G \cdot \frac{m_1 m_2}{d^2} \tag{2}$$

where *F* is the gravitational force between two objects, *m*₁ and *m*₂ are the masses of the objects, *d* is the distance between the centers of the two masses, and *G* is the gravitational constant

(see https://en.wikipedia.org/wiki/Newton%27s_law_of_universal_gravitation).

For our gravity analysis, we follow a two-step approach as suggested by Anderson and Yotov (2016). In the first-stage, we estimate the following equation

$$X_{ijt} = \exp [\beta_0 + \beta_1 \text{FTA_hmr}_{ijt} + \nu_{ijt}] + \varepsilon_{ijt}, \tag{3}$$

where

$$\nu_{ijt} = \eta_{it} + \theta_{jt} + \delta_{ij}. \tag{4}$$

The dependent variable X_{ijt} is the exports of country *i* to country *j* at time *t* and FTA_hmr_{ijt} is a binary variable which takes the value 1 if both countries *i* and *j* are member of the same trade agreement at time *t*, and 0 otherwise. This variable is used extensively in gravity analysis and has been shown to be very important (Anderson and Yotov, 2016; Head et al., 2010). Following the literature, we use a number of fixed effects: η_{it} is the exporter-time fixed effect, θ_{jt} is the importer-time fixed effect, δ_{ij} is the time-invariant exporter–importer fixed effects, also known as pairwise fixed effects. Between these three fixed effects, they take care of numerous observable and unobservable variables that affect trade flows. Therefore endogeneity arising due to spurious correlation because of omitted variables is very unlikely to occur. The importer-time and exporter-time fixed effects are often called the multilateral resistance terms. The expression ε_{ijt} is the idiosyncratic error term.

We employ the Poisson Pseudo Maximum Likelihood (PPML) method to estimate Eq. (3), which is known to take care of zero trade flows that are omitted when an Ordinary Least Squares (OLS) method is used to estimate a log-linearized gravity model. It can also deal with heteroscedastic error terms created by the log transformation of the gravity model. We also carry out a number of robustness checks. For example, we use 2-period and 3-period interval data. The use of interval data is necessary since trade flow adjustments in response to changes in other variables happen over time (Cheng and Wall, 2005; Anderson and Yotov, 2016).

From the estimation of Eq. (3), we take the estimated values of the exporter-time fixed effects (η̂_{it}) and the importer-time fixed effects (θ̂_{jt}); we denote these by EXTFE_{it} and IMTFE_{jt} respectively. We then run the following OLS regressions:

$$\text{EXTFE}_{it} = \alpha_0 + \alpha_1 \text{Renergy}_{it} + \alpha_2 \text{GDPPC}_{it} + \zeta_t^e + \nu_i^e + \varepsilon_{it}^e, \tag{5}$$

$$\text{IMTFE}_{jt} = \beta_0 + \beta_1 \text{Renergy}_{it} + \beta_2 \text{GDPPC}_{it} + \zeta_t^m + \nu_i^m + \varepsilon_{it}^m, \tag{6}$$

where ε^k_{it} is an idiosyncratic error term, and ζ^k_t and ν^k_i are time fixed effect and country fixed effect respectively (*k* = *e*, *m*).

Table 3
Renewable Energy consumption on bilateral trade.

	Linear Regressions									
	EXTFE as dependent variable					IMTFE as dependent variable				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Renergy	−45.46** (0.042)	−51.97** (0.017)	−77.33** (0.039)	−102.60** (0.052)	−195.13*** (0.000)	40.68*** (0.000)	42.62*** (0.000)	39.00*** (0.000)	39.03*** (0.000)	1.265*** (0.003)
GDP		2.60e−08*** (0.000)	2.57e−08*** (0.000)	2.57e−08*** (0.000)	2.57e−08*** (0.000)		4.02e−08*** (0.000)	3.91e−08*** (0.000)	3.89e−08*** (0.000)	2.62e−08*** (0.000)
GDPPC			0.153** (0.019)	0.149** (0.041)	0.111* (0.109)			0.098*** (0.028)	0.097*** (0.028)	0.112*** (0.001)
Co2te				−54.30*** (0.000)	−50.78*** (0.000)				0.261* (0.075)	0.358*** (0.016)
RenergyOECD					1229.30*** (0.000)					0.261*** (0.041)
R ²	0.8461	0.8766	0.8768	0.8770	0.8778	0.9987	0.9988	0.9988	0.9988	0.9983

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

The number of observations is 3,800, and country and time fixed effects are applied in all regressions.

4. Empirical results

4.1. Trade and energy use

We shall now examine the effect of renewable energy use and fossil fuel energy use on exports and imports. As mentioned before, we do this in two stages. In the first stage we estimate a gravity model (Eq. (3)) using PPML method. We then take the estimated exporter-time and importer-time fixed effects from that regression and then in the second stage we estimate Eqs. (5) and (6). We use the software Stata, version 16. The estimated Eq. (3) is as follows:

$$X_{ijt} = \exp[22.75*** + 0.0214*** \text{FTA}_{hmr_{ijt}}], \quad (7)$$

(0.000) (0.009)

where the number of observations (N) is 475,298 and the value of R-squared is 0.991. The figures in the parenthesis are the p-values. As we can see, the coefficients are significant at 1% level.

The second-stage regression results for (5) and (6) are given in Table 3. The main explanatory variable of interest is Renergy (share of renewable energy consumption). We also control for GDP, GDP per capita, and CO₂ emission (to control for the fact that some renewable energy like fuel wood can emit CO₂ gases).

We do the same exercise after replacing Renergy as an explanatory variable in Eqs. (5) and (6) with Fenergy (share of fossil fuel consumption). The results for that are presented in Table 3. It is to be noted that these two energy sources do not exhaust all sources as quite a few countries use significant levels of nuclear energy.

We find that as the share of renewable energy use (as a proportion of total energy) increases, export falls and imports rises. A 1% increase in the share of renewable energy use as a proportion of total energy consumption, causes a 1.026% decrease in exports, and a 0.39% increase in imports. And with a 1% increase in the share of fossil fuel energy consumption in total energy use, exports increase by 2.231% and imports fall 0.21%. The results can be explained in terms of the unit costs and therefore the unit price of renewable energy *vis-à-vis* that of fossil fuel. The higher prices of renewable energy (relative to fossil fuel) as an intermediate input reduce the international competitiveness of the country, and therefore, its exports when the country relies more on renewable energy source. For the same reasons, it increases imports.

We also examine if there is any heterogeneity in the average results we just presented. In particular, we test if the results

are qualitatively different between Organization for Economic Cooperation and Development (OECD) countries and non-OECD countries. We do so by defining a dummy variable that takes the value 1 if the country is an OECD country, and 0 otherwise, and then interacting this dummy variable with Renergy. We call this variable RenergyOECD. The coefficients for the dummy variable on its own cannot be identified as it is absorbed by the country fixed effects. The results are presented in columns 5 in the two panels of Table 3. As we see, for the OECD countries both exports and imports increase with more use of renewable energy, but for the non-OECD countries exports decrease, but imports increase, with more use of renewable energy. The OECD countries, apart from receiving price incentives from their governments, are possibly also able to adapt their technologies so that increased use of renewable energy do not increase their unit cost of production. They use their economies of scale in adopting renewable energy to gain comparative advantage which affects their exports positively. This is not the case for non-OECD countries.

In Table 4 we present the results when we replace our main explanatory variable Renergy by Fenergy which is the share of fossil fuel energy in total energy consumption. The results are, as one would expect, qualitatively just the opposite of those in Table 3. Here we use two dummy variables: one for oil-producing countries and one for OECD countries, and interact them with Fenergy. The variable Fdummy represents the interaction between oil-producing dummy and Fenergy, and FenergyOECD is the interaction between Fenergy and OECD dummy.

4.2. Robustness checks

We carry out two robustness checks. First, to address any doubt on the possibility of two-way causality, we run the regressions in Eqs. (5) and (6) by considering a one-year lag of the main explanatory variable Renergy. The results are presented in Table 5. As we can see from Table 5, the qualitative results still hold: more dependence on renewable energy reduces exports and increases imports. The magnitude of the effects are however quite a bit larger in the present case.

Finally, given that the adjustments to trade as a result of changes in some of the explanatory variables takes time, Cheng and Wall (2005) and Olivero and Yotov (2012) suggested using intervals data instead of continuous panel data. We therefore consider 2 and 3 year interval data to see if our results are robust. The results are presented in Table 6. Here we once again find that the qualitative nature of the results still hold, but the magnitudes once again are different: the effect on exports is bigger but that on imports are lower.

Table 4
Fossil Energy consumption on bilateral trade.

	Linear Regressions											
	EXTFE as dependent variable						IMTFE as dependent variable					
	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
Fenergy	10.82** (0.058)	8.16** (0.077)	32.47** (0.043)	56.67* (0.093)	223.1*** (0.000)	293.94*** (0.000)	-3.16** (0.019)	-20.88*** (0.001)	-20.42*** (0.001)	-20.60*** (0.001)	-21.16*** (0.001)	-1.34*** (0.009)
GDP		2.60e-08*** (0.000)	2.57e-08*** (0.000)	2.57e-09*** (0.000)	2.55e-08*** (0.000)	2.56e-08*** (0.000)		4.18e-08*** (0.000)	4.04e-08*** (0.000)	4.03e-08*** (0.000)	4.04e-08*** (0.000)	2.61e-08*** (0.000)
GDPPC			0.18** (0.043)	0.14** (0.048)	0.15** (0.034)	0.110* (0.104)			0.12*** (0.008)	0.12** (0.008)	0.12*** (0.008)	0.11*** (0.001)
Co2te				-51.40*** (0.000)	-52.30*** (0.001)	-47.71*** (0.000)				0.23* (0.062)	0.24** (0.048)	0.36*** (0.017)
Fdummy					-559.3*** (0.000)	-421.22*** (0.004)					-0.79 (0.173)	0.29** (0.028)
FenergyOECD						-1337.8*** (0.000)						0.004* (0.097)
R ²	0.8577	0.8766	0.8768	0.8769	0.8773	0.8783	0.9987	0.9988	0.9988	0.9988	0.9988	0.9983

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

The number of observations is 3,800, and country and time fixed effects are applied in all regressions.

Table 5
Renewable Energy consumption on bilateral trade with one-year lag.

	EXTFE as dependent variable		IMTFE as dependent variable	
Renergy_1	-97.45* (0.083)		0.822*** (0.008)	
GDP	2.57e-08*** (0.000)		1.34e-08*** (0.007)	
GDPPC	0.142** (0.048)		0.001*** (0.000)	
Co2te	-55.49*** (0.000)		0.335** (0.027)	
Country FE	Yes		Yes	
Year FE	Yes		Yes	
Obs	3,799		3,799	
R ²	0.8772		0.9982	

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

Table 6
Renewable Energy consumption on bilateral trade (2-yearly, 3-yearly data).

	EXTFE as dependent variable		IMTFE as dependent variable	
	2-year interval	3-year interval	2-year interval	3-year interval
	Renergy	-152.92** (0.045)	-96.99** (0.050)	1.925*** (0.004)
GDP	2.59e-08*** (0.000)	2.61e-08*** (0.001)	2.50e-08*** (0.005)	2.22e-11** (0.018)
GDPPC	0.141* (0.102)	0.138 (0.233)	0.003*** (0.000)	0.002*** (0.000)
Co2te	-63.21*** (0.001)	-73.41*** (0.004)	0.617** (0.017)	0.443 (0.118)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	1,976	1,368	1,976	1,368
R ²	0.8739	0.8672	0.9977	0.9982

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

5. Conclusion

This paper examined the implications of using more environmentally friendly energy sources for bilateral trade between nations. We carry out the main exercise, namely the effect of using more environmentally friendly energy on bilateral international trade, by taking advantage of recent innovations in the gravity model of international trade. We have used a dataset covering 152 countries from 1990–2014. Our robust finding is that more dependence on renewable resources, on average, would reduce exports and increase imports. However, the Organization for Economic Cooperation and Development (OECD) countries managed to avoid the trade-off between export performance and renewable energy use.

In other words, we find that despite the environmental and health gains associated with using cleaner energy, renewable energy use makes bilateral trade less competitive as exports decline and imports increase in the international market for non-OECD countries. This outcome is due in part to the high-cost implication of using renewable energy sources. However, due to the invaluable gains associated with using renewable energy, several policy measures have been suggested that would bring down the unit price of renewable energy and thus a country's competitiveness in the international market after adopting more renewable energy sources. These policies include pricing policies, the introduction of subsidies, better innovations, research and development, among others. The finding that the OECD countries have managed to increase exports while using more renewable energy gives hope that other countries should also be able to do so with appropriate policies.

According to Parikh (2012), improving energy use efficiency on the demand side and encouraging renewables, which reduces greenhouse gas emissions on the supply side, is necessary for sustainable development, given the threats of climate change. Indeed, demand management can lead to large-scale renewables production, thus reducing unit costs via economies of scale. This, in turn, would reduce the negative impact of the use of renewables on exports. The OECD countries seem to have managed to do so.

This study has several shortcomings, which, in turn, give us agenda for future research. First, our study is limited by the lack of availability of bilateral trade data beyond 2014. Hopefully, this database will be updated in the future and allow us to reestimate our model with more up-to-date data. Second, we do not analyze the effect of policies on the relationship between the reliance on renewable resources and international trade performances, except to the extent that exporter-time and importer-time fixed effects include policy measures taken by countries and how those have changed over time. Further studies in this area would be to separate the policy variables from the fixed effects, i.e., to estimate the impact of pricing policies and the introduction of subsidies in the use of renewable energy and its impact on production and subsequently on bilateral trade. In particular, we would like to look closely at policy measures adopted by OECD countries and examine their feasibility in non-OECD countries.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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