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RESEARCH ARTICLE

Environmental taxes and environmental quality in Canada

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Abstract

This paper aims to capture the effect of environmentally related taxes on environmental quality in Canada while controlling economic growth, financial development, and energy consumption over the period of 1990Q1 to 2020Q4. The present study employs novel econometric approaches, namely, the nonlinear autoregressive distributed lag (N-ARDL) test and the gradual shift causality (GS-C) test. The outcomes of the study reveal that (i) there is long-run cointegration equation between environmental taxes (E-TAX), carbon dioxide emissions (CO_2E), economic growth (ECG), financial development (FD), and primary energy consumption (PREC); (ii) E-TAX causes to decrease in environmental degradation in Canada; (iii) PREC and ECG increase (and cause) environmental degradation in Canada; and (iv) financial development also positively affect the environmental sustainability. This effort may also be of great importance for policymakers and decision-makers to better understand the factors of environmental degradation for developing effective tax policies that will alleviate human impacts and contribute to reducing environmental degradation.

Keywords Environmental taxes · Environmental quality · Canada · N-ARDL, Gradual shift causality

Abbreviations

CO_2E	Carbon dioxide emissions
ECG	Economic growth
EIA	Energy Information Administration
E-TAX	Environmental taxes
EU-ETS	European Union Emissions Trading System
FD	Financial development
GS-C	Gradual shift causality
GHG	Greenhouse gasses
GDP	Gross domestic product
N-ARDL	Nonlinear autoregressive distributed lag
OECD	Organisation for Economic Co-operation and Development
PREC	Primary energy consumption
SDG	Sustainable Development Goal
TY	Toda and Yamamoto

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Introduction

In the world, climate change, carbon dioxide emissions, and improving energy accountability are urgent policy issues that need to be addressed (Adedoyin et al., 2022; Agboola et al., 2022; Wu et al., 2022; Kartal et al., 2023b). It is widely accepted that pollution is primarily caused by carbon dioxide emissions. Globally, environmental practitioners and policymakers are coming to a consensus about the need to set new rules and regulations to tackle climate change's environmental effects. To the best of my knowledge, despite multiple studies on the effect of taxes on the quality of the environment, there is no research conducted to capture the effect of environmental taxes on the quality of the environment in Canada. Moreover, the present study uses some novel and newly developed approaches, the N-ARDL test and the GS-C test, to capture this linkage for the case of Canada. Finally, the present study aims to provide some suggestions for the governors in Canada based on the empirical outcome of the study.

In the graph, the carbon pricing scenario begins at 727.8 million tonnes of greenhouse gas emissions in 2018, falling to 680.9 million tonnes in 2022. As of 2022, Canada is estimated to emit 770.5 million tonnes of greenhouse gasses without carbon pricing, which is marked by a blue dot. Figure 1 clearly illustrates that carbon pricing leads to a reduction of 90–80 million tonnes of greenhouse gas emissions.

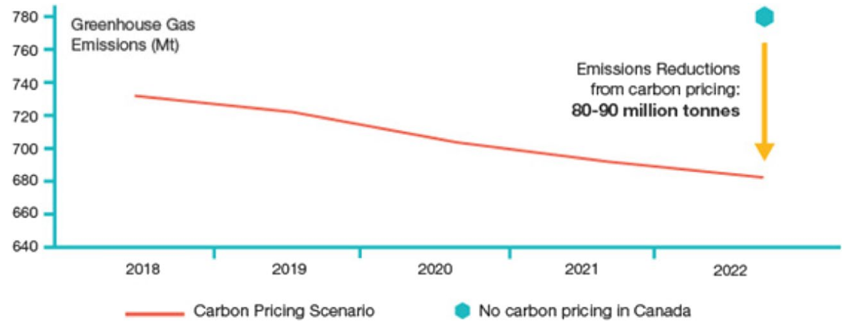

Fig. 1 Projected greenhouse gas emissions in Canada with and without carbon pricing. Source: Canada.ca

As part of the 2016 Pan-Canadian Framework on Climate Change, Canada implemented a federal carbon price; it continues to negotiate with provinces over its implementation, including legal challenges (Green, 2021). Canada produced 565 million metric tonnes of CO_2 in 2018, making it the tenth-largest economy in the world. Carbon capture and storage readiness ranks Canada the highest in the world. A significant part of Canada's emissions is generated by the transportation sector, which accounted for over 25% of emissions in 2018. A clean fuel standard was developed by the government of Canada to reduce the emissions intensity of transportation fuels in order to meet the government's Paris Agreement pledge of zero emissions by 2050. The federal government also pledged a CA$170 per tonne CO_2 price in 2030. However, no information has been released about the economic impacts other than the claim that there will be no effect on gross domestic product, despite the fact that the organization claims to have done a comprehensive macroeconomic analysis. A targeted reduction of emissions intensity is particularly appropriate for diesel because its emissions intensity is higher than gasoline's. As global energy markets shift to more sustainable solutions, Canada will benefit from the domestic production of next-generation low-emission diesel. As reported by the study of McKitrick and Aliakbari (2021), the federal carbon tax will, however, result in a 1.8% drop in gross domestic product (GDP) (as seen in Figure 2) and the loss of upwards of 184,000 jobs nationwide. As argued by the federal government, Canadians will "most likely" find themselves better off as a result of the carbon-tax policy since the government will rebate most of the revenues from the tax. Most of the new tax revenues will be offset by the shrinking tax base caused by the increased carbon tax. Government deficits will increase by about $22 billion annually if 90% of carbon tax revenues are rebated to households, and the remainder is spent while other tax rates remain the same (McKitrick and Aliakbari, 2021).

Several researchers have identified four mitigation pathways that policies can target to address freight greenhouse gasses (GHG) emissions: enhance the technological capabilities of vehicles, reduce fuel-related GHGs, decline freight traffic, and promote less emission-intensive modes of transportation (Hammond et al., 2020). However, the impact of environmental taxes on the environment still has not been discussed comprehensively using country-based analysis.

Carbon taxes can encourage conservation, substitution, and innovation to reduce carbon emissions. Australians, Swedes, and Albertans have proposed or implemented this measure around the world. It appears, however, that a carbon tax may harm the growth of the economy. Thus, a carbon tax should be systematically studied to determine an effective and economically feasible strategy for reducing GHG emissions (Bhat and Mishran, 2020; Liu et al., 2018; Vera and Sauma, 2015).

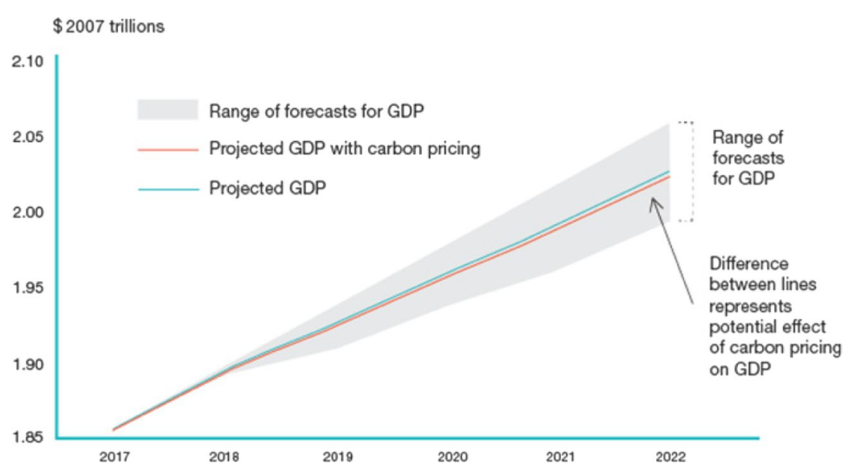

Fig. 2 Projected real GDP in Canada with and without carbon pricing. Source: Canada.ca

According to Haites et al. (2018), carbon pricing policies perform well in terms of emissions reductions, cost-effectiveness, and economic efficiency. The authors examine whether and how tax rates have changed over time and how taxes and emissions trading systems have reduced emissions. The study provides useful information on the effectiveness of carbon pricing schemes and the impact of various policies on carbon emissions (or their lack thereof). The authors note, however, that carbon pricing cannot be separated from other climate mitigation policies (Haites, 2018). Based on emissions reductions and cost-effectiveness, Haites (2018) reviews carbon pricing policies. Carbon taxes in European nations have led to small reductions, up to 6.5% over the past few years, according to Haites (2018). Yet countries that are also part of the EU-ETS (European Union Emissions Trading System) whose emissions are not taxed reduced emissions more quickly than those whose emissions are taxed. Non-ETS emissions may have been reduced more by other policies than carbon taxes, according to a study by Haites (2018).

The cross-sectional dataset of effective energy tax rates of Organisation for Economic Co-operation and Development (OECD) countries is used by Sen and Vollebergh (2018) to estimate the long-run impact of a broad-based carbon tax on energy consumption. The outcomes of Sen and Vollebergh (2018) reveal that higher energy taxes decline environmental pollution in OECD countries. Hassan et al. (2020) also focus on the case of OECD countries and conclude that taxes related to the environment could promote economic growth if GDP per capita is high. Loganathan et al. (2020) aim to capture the impact of productivity and green taxation on the quality of the environment in Malaysia. They conclude that green taxation contributes to environmental sustainability positively. Ghazouani et al. (2021) argued that promoting cleaner energy sources and environmental taxes can be effective ways to reduce pollution. Moreover, as underlined by Ghazouani et al. (2021), economists and environmental scientists recommend the use of environmental-related taxes and carbon and energy taxes to achieve zero carbon emissions.

As far as I observed in the existing literature, no study has examined the effect of environmental taxes on environmental degradation in Canada by using single-country data and the asymmetric and Fourier-based approach. Therefore, the study fills a literature gap. Accordingly, analyzing the effect of environmental taxes on the quality of the environment may reduce omitted variable bias in the econometric model. Finally, it is also important that policymakers and decision-makers understand environmental degradation factors to develop effective tax policies that will reduce human impacts and contribute to reducing environmental degradation while maintaining economic growth and alleviating human impacts.

Data and methodology

This section describes the variables used in the estimated models and explains how the models were constructed. Based on the main aim of this present study, the BDS test, ADF unit root test, N-ARDL test, and GS-C test are employed. As advised by Liu et al. (2023b), Cheng et al. (2021), and Shahbaz et al. (2019), a quadratic match-sum approach is used in this study to simulate an annual-to-quarter-frequency transformation of time series variables in order to prevent potential problems arising from a small sample size. Moreover, for the N-ARDL and GS-C tests, the E-TAX, CO_2E, ECG, FD, and PREC can be either stationary at the level or stationary at the first difference. Therefore, the integration of the order of the time series is not problematic as long as they do not have I(2) behavior. For the main aim of the present study, Eq. 1 is estimated in this study.

$$\mathrm{CO2E} = f(\mathrm{E-TAX}, \mathrm{ECG}, \mathrm{PREC}, \mathrm{FD}) \tag{1}$$

Equation (1) highlights that CO_2 emissions are determined by a combination of variables such as E-TAX, ECG, FD, and PREC. This model is converted into their regression form for empirical analysis, as follows:

$$\mathrm{LCO2E}_t = \beta_1 \mathrm{E-TAX}_t + \beta_2 \mathrm{LECG}_t + \beta_3 \mathrm{LPREC}_t + \beta_4 \mathrm{LFD}_t + \varepsilon_t \tag{2}$$

where CO_2E, E-TAX, ECG, FD, and PREC stand for production-based CO_2 emissions, environmentally related taxes % of GDP, economic growth, financial development, and primary energy consumption, respectively. It is worth mentioning that all variables, except E-TAX, are in log form in this study. Figure 3 illustrates the analysis flow of the present study, while Figure 4 shows the box plots of the LCO_2E, E-TAX, LECG, LPREC, and LFD variables. In addition, the descriptive statistics of the variables are reported in Table 1. Based on the Kurtosis test, as reported in Table 1, the study determined whether the variable was light-tailed or heavy-tailed. All of the indicators are platykurtic since they have values less than 3. Skewedness statistics in Table 1 show that LCO_2E, LECG, LPREC, and LFD distributions are slightly right-skewed, whereas E-TAX distributions are left-skewed. The findings from the Jarque–Bera show that only LPREC is normally distributed within all variables. Figure 4 also reports the box plot of the time series variables.

After calculating the main descriptive statistics of the time series variables (as reported in Table 1), the present study employed the BDS test of Broock et al. (1996) to check the nonlinearity attributes of LCO_2E, E-TAX, LECG, LPREC, and LFD variables. As a next step, the order of the integration of the time series variables is captured by the ADF unit root test with a breakpoint. In addition to the ADF unit root test, this study used Enders and Lee's (2012)

Fig. 3 Research design

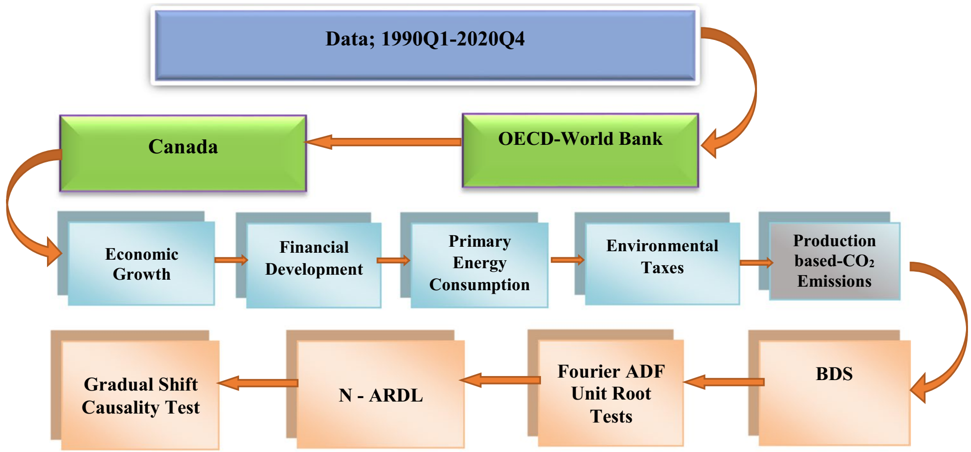

Fig. 4 Box plot of the time series variables

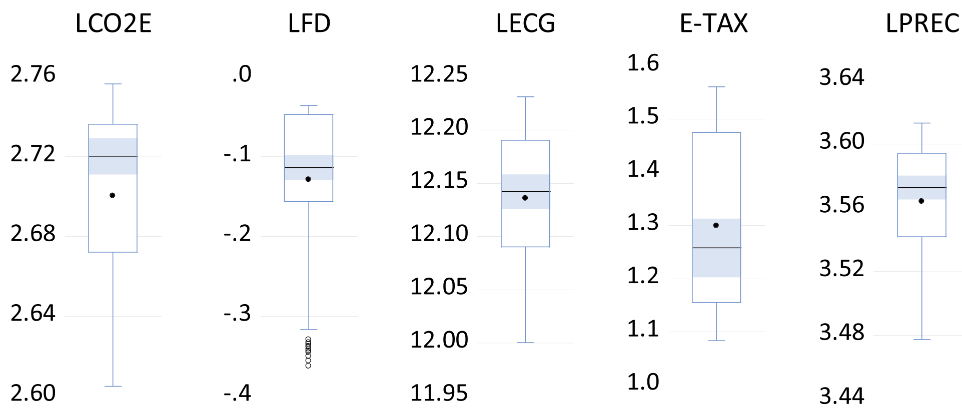

Table 1 Descriptive statistics

Code	LCO_2E	E-TAX	LECG	LPREC	LFD
Variable	Environmental quality	Environmental taxes	Economic growth	Primary energy consumption	Financial development
Measure	Production-based CO_2 emissions	Environmentally related taxes % of GDP	GDP (constant 2015 US$)	Terawatt-hours	Index
Source	Global Carbon Project	OECD	World Bank	EIA	World Bank
Mean	2.716471	1.257222	12.11172	3.573780	–0.095610
Median	2.722496	1.193750	12.12714	3.574864	–0.092512
Max.	2.750068	1.551875	12.19184	3.604473	–0.038265
Min.	2.665740	1.083438	12.00039	3.535624	–0.171059
Std. Dev.	0.022388	0.136759	0.052235	0.019173	0.044736
Skewness	–0.712817	0.832356	–0.507678	–0.263808	–0.080697
Kurtosis	2.482242	2.559575	2.284219	2.223844	1.365286
J-B	6.901524	8.895721	4.629873	2.642393	8.095014
Prob.	0.031721	0.011704	0.098772	0.266816	0.017466

ADF unit root test. Since the Fourier ADF unit root test uses a limited number of parameters, it avoids the problem of losing power that occurs when using too many dummy variables (Ozgur, Yilanci, & Kongkuah, 2022; Pata et al., 2022; Kirikkaleli et al., 2023a; Kirikkaleli et al., 2023b; Kartal et al., 2023a).

As a main estimator, the present study employs the N-ARDL approach of Shin et al. (2014) in order to identify the long-term and asymmetric impact of E-TAX on LCO_2E while taking into account LECG, LPREC, and LFD variables over the period of 1990–2020 for the case of Canada. It is widely accepted that obtaining nonlinearity behavior and mix integration order for the time series variables is likely to increase the possibility of biased estimation results with linear models. Therefore, the present study used the N-ARDL approach developed by Shin et al. (2014). As with the ARDL model, the NARDL model is flexible since all variables do not have to have the same order of integration (Liu et al., 2023a; Meng et al., 2023; Abosedra et al., 2023). Therefore, the test provides superior outcomes relative to the traditional linear ARDL estimator (Lau et al., 2023). The N-ARDL approach allows the present study to detect the long-run effects of both negative and positive shocks in E-TAX, LECG, LPREC, and LFD to the LCO_2E variable.

The traditional Toda and Yamamoto (TY) causality test was developed by Toda and Yamamoto (1995) in order to capture causal linkage among the time series variable. The test could be applied without detecting the integration order of the time series variables. More recently, the TY causality test was improved by Nazlioglu et al. (2016) by taking into account the Fourier function. The developed version of the TY causality test is called "gradual shift causality" since the test allows gradual shifts in the estimated model. As mentioned by Nazlioglu et al. (2016), "this approach is capable of capturing gradual or smooth shifts and does not require prior knowledge regarding the number, dates, and form of structural breaks."

Table 2 BDS test

Dimension	BDS statistic	Std. error	*z*-Statistic	Prob.
LCO_2E				
2	0.204941	0.006371	32.16796	0.0000
3	0.348891	0.010172	34.29778	0.0000
4	0.448630	0.012168	36.87029	0.0000
5	0.517372	0.012738	40.61536	0.0000
6	0.564695	0.012338	45.76748	0.0000
E-TAX				
2	0.199479	0.006241	31.96065	0.0000
3	0.338067	0.009966	33.92092	0.0000
4	0.433173	0.011920	36.33958	0.0000
5	0.497575	0.012477	39.87854	0.0000
6	0.541039	0.012083	44.77507	0.0000
LECG				
2	0.205505	0.005452	37.69079	0.0000
3	0.349393	0.008714	40.09374	0.0000
4	0.449734	0.010432	43.11308	0.0000
5	0.520173	0.010928	47.60140	0.0000
6	0.569679	0.010591	53.78973	0.0000
LPREC				
2	0.203634	0.006480	31.42412	0.0000
3	0.345775	0.010327	33.48132	0.0000
4	0.443486	0.012330	35.96725	0.0000
5	0.509954	0.012885	39.57846	0.0000
6	0.554662	0.012457	44.52565	0.0000
LFD				
2	0.206828	0.008093	25.55545	0.0000
3	0.352262	0.012947	27.20830	0.0000
4	0.454268	0.015520	29.26916	0.0000
5	0.525114	0.016286	32.24343	0.0000
6	0.574228	0.015813	36.31423	0.0000

Empirical findings

This empirical research examines the long-run and causal effect of the E-TAX variable on LCO_2E in Canada while controlling some important determinates of LCO_2E, namely, LECG, LPREC, and LFD variables in Canada for 1990–2020. To achieve the stated objectives, as an initial test, the BDS test is performed to capture whether the time series variables have nonlinear behavior over the selected time period for the case of Canada. The outcome of the BDS test is reported in Table 2, which clearly reveals the validity of the nonlinear characteristics of the LCO_2E, E-TAX, LECG, LPREC, and LFD variables, implying that performing linear and traditional approaches might create biased outcomes. Therefore, the present study used N-ARDL and GS-C tests in order to capture the long-run and causal effect of the E-TAX variable on LCO_2E in Canada.

As a next step, the integration of the order of the time series variables is captured using the Fourier ADF unit root test and ADF unit root test with breakpoint. The outcomes are reported in Table 3. As clearly seen, the *F*-stats of the time series variables are not significant at a 5% significance level. Therefore, the decisions are made using the ADF unit root test with a breakpoint to identify the integration of order of the LCO_2E, E-TAX, LECG, LPREC, and LFD variables. The outcome of the unit root test exposes that while LCO_2E, E-TAX, and LPREC seem stationary at the first difference, LECG and LFD appear stationary at the level, implying that the integration of order of the LCO_2E, E-TAX, and LPREC variables are one (I-1), whereas LECG and LFD have an I-0 behavior. Since the variables are mixed ordered and have nonlinear behavior over the selected time period for the case of Canada, the present study performed N-ARDL and GS-C tests.

Table 4 reports both N-ARDL bounds and N-ARDL long-run results. As clearly seen in Table 5, the outcomes

Table 3 ADF unit root test with break point

Variable	ADF unit root test		Fourier ADF unit root test		
	Test statistic	Break point	Frequency	*F*-stat	F-ADF test
LCO_2E	−3.244	1993Q2	2	2.612012	1.086234
LECG	−4.605**	1997Q4	5	3.362549	0.145959
LPREC	−3.920	1991Q3	5	2.304192	0.043106
LFD	−5.486***	1992Q2	3	3.693845	0.142913
E-TAX	−3.209	1998Q1	4	1.273548	−1.052091
$DLCO_2E$	−4.452**	1993Q1			
DLECG					
DLPREC	−4.445**	1993Q3			
DLFD					
DE-TAX	−5.979	2008Q1			

ADF unit root test		Fourier ADF unit root test			
Test critical values			Critical values		
1% level	−4.949133	Frequency	1% level	5% level	10% level
5% level	−4.443649	1	−4.95	−4.35	−4.05
10% level	−4.193627	2	−5.68	−5.08	−4.78
		3	−6.33	−5.73	−5.42
		4	−6.94	−6.31	−6.00
		5	−7.52	−6.86	−6.54

*, **, and *** denote statistically significant at the 10%, 5%, and 1% levels, respectively

Table 4 N-ARDL bounds and long-run results

Nonlinear-ARDL bounds results				
		Critical values		
F-statistics	3.4862	Significance	I(0)	I(1)
K	8	10%	1.85	2.85
		5%	2.11	3.15
		2.5%	2.33	3.42
		1%	2.62	3.77
N-ARDL long-run results				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
LECG_POS	0.407913	0.064919	6.283434	0.0000
LECG_NEG	1.413540	0.153649	9.199813	0.0000
E-TAX_POS	−0.185349	0.024859	−7.456031	0.0000
E-TAX_NEG	−0.048887	0.012310	−3.971216	0.0002
LPREC_POS	0.165247	0.098470	1.678135	0.0978
LPREC_NEG	−0.254374	0.173060	−1.469862	0.1461
LFD_POS	−0.048743	0.026744	−1.822556	0.0727
LFD_NEG	−0.420465	0.057776	−7.277539	0.0000
B-P-G heteroskedasticity approach				
F-statistic	1.262844	Prob.	0.2299	
Ramsey reset approach				
F-statistic	1.380768	Prob.	0.2440	

of N-ARDL show that the null hypothesis that there was no cointegration equation between LCO_2E, E-TAX, LECG, LPREC, and LFD can be rejected for the case of Canada. The result shows that there is a long-run linkage between

Table 5 Gradual shift causality test

		T-stat	*p* value
Ho_1	LECG does not cause LCO_2E	9.107840	0.058460
Ho_2	ETAX does not cause LCO_2E	10.87117	0.028051
Ho_3	LFD does not cause LCO_2E	7.933176	0.094057
Ho_4	LPREC does not cause LCO_2E	1.192286	0.879367

The present study used four as an optimal lag for the model, and VAR($p + d$) is VAR(4 + 1). p and d denote lags and integration numbers, respectively. In the model, as a default setting, the number of Fourier is selected as three

environmental taxes and environmental quality while controlling the main determinants of LCO_2E in Canada. In addition to this, Table 5 also reports that positive and negative shocks in E-TAX decline the environmental degradation in Canada. In the long run, green growth, as a result of rising environmentally related taxes, tends to degrade pollution by reducing environmental degradation in Canada. E-TAX plays a vital role in executing sustainable development. Therefore, it can manage the development of economics and sustainability of the environment. It is therefore important for environmentally friendly countries to achieve these objectives through green growth. This outcome supports the environmentally friendly taxes–led–environmental sustainability hypothesis and also can be supportive evidence for the early empirical outcome of Chien et al. (2021) and Zahan and Chuanmin (2021). Actually, it is interesting to have a finding that negative shocks in E-TAX also decrease environmental degradation in Canada.

This finding supports that paying environmentally related taxes indicates obtaining greener technology, and this situation leads to a better environment in Canada. This outcome also reveals that serious environmental tax legislation in Canada will allow firms to switch to cleaner production techniques. Additionally, the study argues that investing tax funds in initiatives promoting sustainable technologies will aid countries in meeting SDG-7 and SDG-13. For ecological stability, environmental taxes must be based on the polluter-pays principle. It is also important to fund renewable technology development in Canada with tax revenue from environmental taxes.

The outcomes of N-ARDL also reveal that positive and negative shocks in ECG cause an increase in CO_2E, whereas positive and negative shocks in FD contribute to environmental sustainability positively. Finally, as expected, positive shocks in PREC increase CO_2E. The stability of the N-ARDL estimators is confirmed by B-P-G heteroskedasticity approach (reported in Table 5), Ramsey reset approach (reported in Table 5), Cusum and Cusumsq (as illustrated in Figs. 5 and 6, respectively).

As a final step, the present study employed the GS causality test to capture the possible causal effect of E-TAX, LECG, LPREC, and LFD on LCO_2E in Canada. The outcome of the GS-C test is shown in Table 5. As expected, changes in E-TAX significantly lead to changes in LCO_2E in Canada, implying that environmentally related taxes are an important factor in predicting production-based CO_2 emissions. In addition, at a 10% significance level, LFD and LECG cause LCO_2E, showing how economic growth and financial development are important in order to estimate production-based CO_2 emissions in Canada.

Conclusion

To combat the environmental effects of climate change, environmental practitioners and policymakers around the world have come to a consensus about the need to set new rules and regulations. Based on the author's knowledge, despite numerous studies examining the effect of taxes on the environment, no research has been conducted to examine the effect of environmental taxes in Canada. Therefore, the paper fills this gap in the literature. Based on this aim, this paper captures the long-run and causal impact of environmentally related taxes on environmental quality in Canada while controlling economic growth, financial development, and energy consumption over the period of 1990Q1 to 2020Q4. The present study employs novel econometric approaches, namely, N-ARDL and GS-C tests.

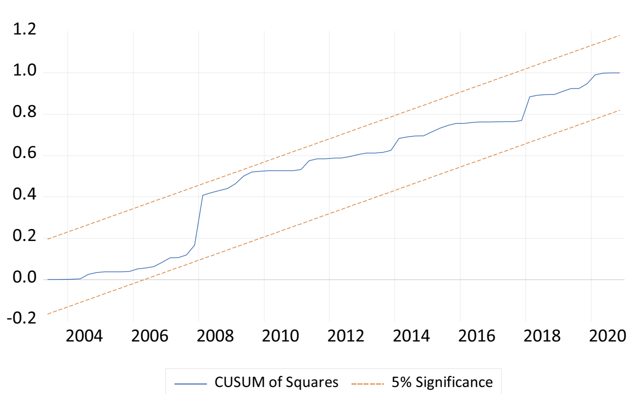

Fig. 5 Cusum of squares

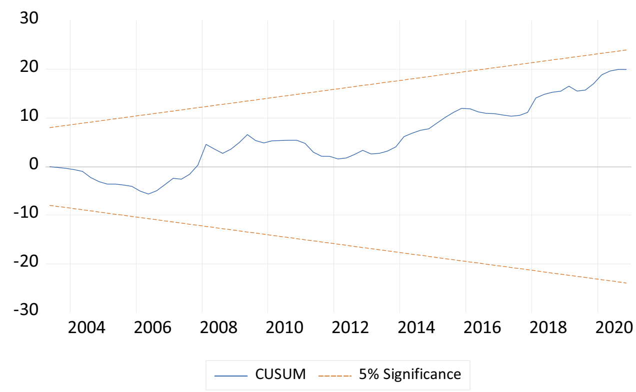

Fig. 6 Cusum

The outcome of novel econometric approaches reveal that (i) E-TAX, CO_2E, ECG, FD, and PREC are cointegrated in Canada over a selected time period; (ii) Canadian environmental degradation decreases due to rising environmentally related taxes; (iii) PREC and ECG increase (and cause) CO_2E in Canada; (iv) the development of the financial sector also has a positive effect on the sustainability of the environment.

Due to strict environmental tax laws in Canada, businesses will be able to shift production to cleaner methods based on the empirical findings of this study. The paper concludes that redistributing tax revenue to sustainable technology programs would enable nations to achieve the United Nations Sustainable Development Goals 7 and 13. Polluter-pay principles must be adhered to when it comes to environmental taxes so that ecological sustainability can be ensured in Canada. Furthermore, tax revenues received from environmental taxes in Canada should support research and development of renewable technologies. It is imperative that environmental taxes be based on the polluter-pays principle in order to maintain ecological stability. Green growth tends to degrade pollution in the long run by reducing environmental degradation in Canada due to rising taxes related to the environment. In addition, environmental taxes should be used to fund the development of renewable technologies in Canada. As a result, in the case of Canada, sustainable development relies heavily on E-TAX.

Author contribution The manuscript is written by DK.

Data availability The data that support the findings of this study are available from the OECD, EIA, Global Carbon Project, and World Bank.

Declarations

Ethics approval and consent to participate I confirmed that this manuscript has not been published elsewhere and is not under consideration by another journal. Ethical approval and informed consent are not applicable for this study.

Consent for publication Not applicable.

Competing interests The author declares no competing interests.

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