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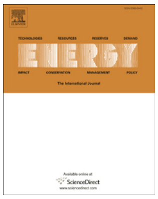

Do energy-pollution-resource-transport taxes yield double dividend for Nordic economies?

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ABSTRACT

With the policy performance of the Nordic countries especially from the aspects of energy security, energy equity, and environmental sustainability, this study provides more in-depth on the performance of the countries' disaggregated environmental taxes. To examine the greenhouse gas emission and energy intensity effects of energy tax, pollution tax, resource tax, and transport tax alongside controlling for the role of employment rate and gross domestic product over the period 1995–2020, empirical tools such as the method of moments quantile regression, short- and long-run cointegration, and Granger causality approaches were utilized. Importantly, there are series of interesting results from this investigation. Firstly, the result posits the feasibility of Green growth in the panel of Nordic countries while a significant and negative nexus between GDP and energy intensity was also established. Secondly, also from the panel result, we found that only energy tax significantly mitigates both emissions and energy intensity across the quantiles while pollution tax and resource tax exacerbate emissions and energy intensity. Thus, for the panel case, only energy tax could validate the double dividend hypothesis. Thirdly, the result revealed that double dividend hypothesis and by large extent co-benefit is achievable with pollution and resource tax policies in Finland but in the short-run. Similarly, pollution, resource, and transport tax policies in Sweden are all desirable for achieving both environmental and economic benefits in the short-run. However, there is no valid evidence to support the validity of double dividend hypothesis in Denmark and Norway. Lastly, we found a one-way Granger causality from GDP, energy tax, resource tax, and transport tax to greenhouse gas emission while a one-way Granger causality also exists from GDP, energy tax, and transport tax to energy intensity. Overall, compelling policy dimensions are inferred from the investigation.

1. Introduction

While advocating for green growth and a cost-effective pathway out of the climate change debacle, several leading economies are more practical at designing and implementing policy tools that internalises negative externalities [1–5]. Specifically, policy instruments such as the emissions trading systems (ETS) and carbon pricing are increasingly being considered effective at mitigating environmental-related and climate change challenges. For instance, following the proactive approach of Finland to introduce carbon tax in January 1990 as a result of the carbonized nature of conventional energy sources, several countries especially the European Union (EU) member states have since implemented the carbon-tax policy. Given the motivation to directly mitigate negative externalities associated with environmental emissions in a more holistic approach, the implementation of environmental tax policy is arguably geared to offer other socioeconomic benefits such as a shift in other tax burden. Thus, according to Pearce [6]; environmental tax arguably offers double divided i.e environmental quality as a benefit (Green dividend) alongside offering a shift in consumption pattern through alternative investment and innovations,

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incentives for efficiency gains, and creating other growth-related pathways (as Blue dividend). In the case of the EU for instance, EUR 299.9 billion in environmental tax revenue was collected, which is 2.2% of the bloc's Gross Domestic Product (GDP) and 5.4% of the bloc's taxes and social contributions (TSC) in 2020 [7]. Moreover, according to report of the European Commission [7]; energy tax has the highest share of environmental tax followed by transport tax, while the pollution and resource taxes are of smaller proportions.

Considering that each component of the environmental tax, such as in the Nordic economies has distinct contributory roles (see Fig. 1), this study prefers to explore these tax components in the framework of double dividend hypothesis. Importantly, the case of the Nordic countries is found compelling because of the countries' performance in term of energy security, energy equity, and environmental sustainability as informed by the latest ranking of the World Energy Council [8]. In a clear objective term, this study offers to examine the role of energy tax, pollution tax, resource tax, and transport tax in the greenhouse gas (GHG) emission mitigation drive of each of Denmark, Finland, Norway, and Sweden. Additionally, the investigation's objective also entails the examination of the specific role of each of the disaggregated tax policy as regard energy intensity. Considering these two frontlines i.e the double dividend implication, both the environmental benefit (green dividend) and the economic benefit (blue dividend) given the output cost implication from the energy intensification are investigated. In novelty, this study offers country-specific revelation by employing all the environmental tax components as against the panel comparison of the Nordic and G-7 countries with the use of only energy tax by He et al. [9]. The implication is that the result of this approach offers direct implementation or adjustment of existing sector-wide policy based on the specificity of energy tax, pollution tax, resource tax, and transport tax. Specifically, performances of each of the tax policies could easily be assessed and improved upon through policy target in the transportation, manufacturing, industrial, and household sectors. Moreover, the recently developed method of moments quantile regression (MMQR) by Machado and Silva [10] further provides a significant novelty since the relationships among the aforementioned variables are now interpreted along the quantiles as opposed to a selected or centralized value. In essence, the results from this investigation is expected to translate to policy instrument and guidance for not only the Nordic countries, but for the EU member states and other similar economies across the globe.

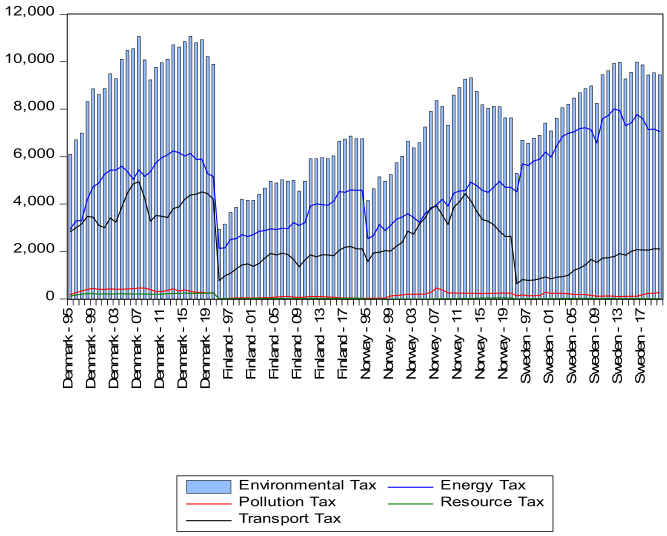

Fig. 1. The series trend for (dis)aggregated tax in the Nordic countries (Million Euros).

The study is carefully outlined in a specific order to provide a comprehensible reading pattern. We present the theoretical concept with the undelaying hypotheses in section 2 while the material and empirical methods employed are presented in section 3. The results of the investigation and the concluding statement are presented in sections 4 and 5 respectively.

2. Theoretical perspective and hypotheses

In one of the first queries of the implications of environmental-related tax, Pearce [6] motioned the advantages of carbon and/or environmental-related tax. The study inferred that environmental taxes correct distortion such as externalities unlike the distortion in incentives that is associated with most other taxes. Moreover, the study hinted about the potential of double dividend which is associated with environmental-related tax. Generally, the first part of the dividend or benefit (known as green dividend) is sort of a direct effect of environmental tax which is expected to suppress environmental emissions, thus yielding improved environmental quality or sustainable environment. Moreover, the second dividend (usually the blue dividend) arises from sort of indirect effect of the implemented environmental tax through a shift in tax burden, thus triggering economic growth or improved macroeconomic indicators. Thus, by implication, and especially in theoretical concept, it is noted that environmental-related tax is capable of delivering both green and blue dividend. While the study by Pearce [6] affirmed the green dividend in practice but failing to offer practical evidence for the validity of the blue dividend, succeeding studies have offered more compelling evidence of double dividend associated with the environmental-related tax [9,11].

Given the above reflection of the benefits vis-à-vis double dividend effects associated with environmental related tax, this study advanced the literature by examining the green and blue dividend evidence from the perspective of GHG emission determinants and energy intensity determinants respectively. While employing the disaggregated environmental-related taxes (energy tax, pollution tax, resource tax, and transportation tax), the impact of the tax categories alongside other socioeconomic factors (employment and economic growth) on (i) GHG emission offers an environmental (supposedly green dividend) inference, and (ii) energy intensity offers economic (supposedly blue dividend) inference from the perspective of cost of production or energy efficiency [12,13]. Thus, the hypotheses in consideration here are summed into the following:

H1. *Disaggregated environmental taxes correct environmental distortion by mitigating externalities thus improving environmental quality.*

H2. *Disaggregated environmental taxes promote economic productivity through improvement in energy efficiency or reduction in energy intensity.*

3. Data description and model

The dataset employed for this empirical investigation include the Greenhouse gas emission (measured as an index), economic variable (Gross Domestic Product, GDP measured in constant 2015 United States Dollars), employment rate (EMP, measured as a percentage of total population for people 20–64 years old), energy intensity (EIN, measured in Kilograms of oil equivalent (KGOE) per thousand euro) and the environmental-related taxes (energy tax (ENET), pollution tax (POLT), resource tax (REST), and transport tax

(TRAT), all measured in million euro). The European Commission database [14] is the source of the dataset except for that of the GDP that was retrieved from the World Development Indicator of the World Bank [15]. To get a balanced dataset, missing data were computed to ensure that the annual frequency time series span over 1995–2020 for all the examined Nordic countries (Denmark, Finland, Norway, and Sweden).

Additionally, Table 1 offers more information about the dataset, especially the statistical properties for the countries. With the highest mean of ~106.29, Norway has the highest GHG emission over the experimented period while the emission intensity is followed by Finland (~97.57), Denmark (~92.29), and lowest in Sweden (~89.62). Moreover, employment rate over the period is highest in Norway and followed by Sweden, Denmark, and lowest in Finland. For the environmental-related tax, except for the energy tax that is highest in Sweden, pollution, resource, and transport are heavily taxed in Denmark. However, except for the resource tax which is lowest in Norway, these taxes are lowest in Finland. In term of the distribution of the dataset, the skewness and kurtosis further provide additional statistical properties while the Jarque-Bera statistics shows that the variables are largely normally distributed.

3.1. Model and procedure

While employing the natural logarithmic of the variables (*l*), the models considered for the empirical investigation is presented as given that the drivers of greenhouse gas emission and energy intensity include the environmental-related revenues while employment and GDP are additional explanatory variables that control for other unobserved factors. For instance, previous studies have supported the argument that environmental tax/revenues and economic variables are potential drivers of GHG emission [16–18] and the intensity of energy utilization [19].

$$\text{Model 1: lghg} = f(\text{lgdp, lenet, lpolt, lrest, ltrat, emp}) \tag{1a}$$

$$\text{Model 2: leint} = f(\text{lgdp, lenet, lpolt, lrest, ltrat, emp}) \tag{1b}$$

To proceed to the estimation of the main models illustrated in equations (1a) and (1b) above, a flow chart (see Fig. 2) provides a guide and estimation route for the investigation. The first approach is to conduct series of preliminary tests such as the correlation,

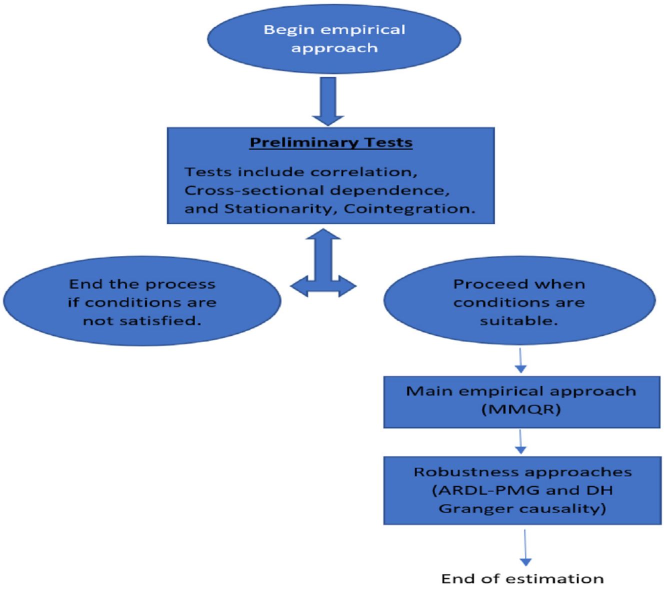

Fig. 2. The flow chart of the estimation procedure.

Table 1
Country-specific statistics.

Parameters	GHG	GDP	EMPY	ENET	EINT	POLT	REST	TRAT
Denmark								
Mean	92.29	2.83E+11	76.79	5232.31	85.44	361.33	214.44	3794.51
Median	95.15	2.86E+11	77.20	5395.41	86.07	388.97	214.32	3665.70
Std. Dev.	17.65	2.90E+10	1.54	897.46	15.54	75.22	27.66	613.53
Skewness	0.016	−0.07	−0.18	−1.28	0.40	−0.55	−1.68	0.24
Kurtosis	1.99	2.40	1.80	3.87	2.56	2.26	6.91	1.84
Jarque-Bera	1.09	0.42	1.69	7.95^{b}	0.92	1.89	28.82^{a}	1.71
Finland								
Mean	97.57	2.19E+11	72.54	3356.34	199.91	59.25	20.65	1680.59
Median	99.65	2.33E+11	73.05	3043.43	194.57	51.50	21.10	1800.07
Std. Dev.	13.02	2.99E+10	3.14	803.96	25.24	29.60	3.99	376.67
Skewness	−0.18	−0.87	−1.11	0.31	0.48	0.23	−0.16	−0.71
Kurtosis	1.87	2.60	3.84	1.74	1.95	1.83	1.99	2.82
Jarque-Bera	1.53	3.48	6.15^{b}	2.13	2.20	1.71	1.21	2.25
Norway								
Mean	106.29	3.43E+11	79.50	3936.38	93.60	208.08	14.55	3034.94
Median	106.85	3.53E+11	79.60	3945.02	96.14	235.55	10.03	3135.39
Std. Dev.	2.99	4.47E+10	1.00	745.19	7.62	99.84	16.74	787.49
Skewness	−0.90	−0.32	0.30	−0.27	−0.56	0.02	0.66	−0.08
Kurtosis	3.24	2.08	2.48	1.78	2.28	3.69	1.85	1.99
Jarque-Bera	3.60	1.37	0.68	1.93	1.95	0.52	3.32	1.13
Sweden								
Mean	89.62	4.31E+11	78.57	6843.04	149.79	171.73	16.65	1427.95
Median	92.35	4.41E+11	78.75	7092.12	138.86	161.82	15.92	1488.88
Std. Dev.	10.61	7.46E+10	2.50	851.79	28.39	55.69	5.83	519.76
Skewness	−0.12	−0.11	−0.50	−0.86	0.54	0.40	−0.27	−0.04
Kurtosis	1.64	1.91	2.39	3.28	2.16	1.79	4.51	1.41
Jarque-Bera	2.06	1.34	1.49	3.28	2.04	2.29	2.77	2.76

Note: The probability value < 0.01 and < 0.05 are respectively represented as ^{a} and ^{b}. The Std. Dev represent standard deviation.

cross-sectional dependence test, stationarity test, and cointegration test as required by either of the estimation techniques. In this study, the step-by-step estimation procedure with respective empirical illustrations are not provided here because of space constraint, however, these illustrations are well-documented in the literature. In the first route, the evidence of correlation between the dependent (lghg and leint) and the set of explanatory variables (lgdp, emp, lenet, polt, rest, and trat) variables are illustrated in appendix (see Table A). Additionally, the cross-sectionally robust unit root approach by Pesaran [20] shows that the variables are stationary at first difference (see Table 2). To check for the panel cointegrating properties of the variables which offers evidence of long-run relationships especially for the two models above, we employ the bootstrap version of the panel cointegration test of Westerlund and Edgerton [21] alongside the panel cointegration test of Kao [22]. With this approach, and controlling for cross-sectional dependence, there is a statistically significant evidence of cointegration in the models (see Table 3).

3.2. *Empirical method*

Before the more recent study of Machado and Silva [10]; previous studies dated to the foremost work of Koenker and Bassett [23] and Koenker [24] and later by Alexander et al. [25] have argued on the relevance and advantages of quantile econometric approach. The notion presented by these studies is that the traditional Ordinary Least Square (OLS) and many other empirical-related approaches only provide approximate conditional mean location which is based on a specific distribution. Thus, the argument largely concludes that most of these traditional approaches provide an incomplete information about the nexus between the explanatory variables and extreme values of the dependent variables. To address this inefficiency, a more complete information especially in respect to the extreme values of the dependent variables based on the quantiles in the conditional distribution, the quantile regression technique is found more suitable.

Hence, this more recently developed approach by Machado and Silva [10] which is better known as the MMQR, and as applied in the current context, assumes that the disaggregated environmental taxes alongside the economic and employment variables exert an impact on the distribution of greenhouse gas (GHG) emissions as illustrated through the following empirical expression.

$$Q\ lghg_{it}(\tau|X_{it}) = C_{it} + C_g lgdp_{it} + C_{em} emp_{it} + C_{en} lenet_{it} + C_p lpolt_{it} + C_r lrest_{it} + C_t ltrat_{it} + \varepsilon_{it} \tag{2}$$

where Q $lghg_{it}$ (τ I X_{it}) represents τ^{th} quantile function that is conditional on the set of explanatory variables X_{it}. The specific country and time are parameterized as i = (Denmark, Finland, Norway, and Sweden) and $t = 1995, 1996, 1997, \ldots, 2020$ while the white noise is the ε_{it}. Moreover, the C_g, C_{em}, C_{en}, C_r, and C_t are the respective coefficients of the explanatory variables while C_{it} is the panel constant value. Then, this expression is reparametrized within the framework of a location and scale function such that

$$Q\ lghg_{it}(\tau|X_{it}) = (C_i + \theta_i\, q(\tau)) + X\prime_{it}\beta + Z\prime_{it}\gamma q(\tau) \tag{3}$$

where the scalar parameter that represents the quantile-τ fixed effect for individual i is denoted by $\alpha_i(\tau) \equiv \alpha_i + \theta_i q(\tau)$, the k-vector of identified differentiable components of X denoted by$Z$ such that $Z_l = Z_l(X)$, where the element $l = 1, \ldots, k$. In this case, the intercept shifts are not represented by individual effects which is commonly obtainable for the least squares fixed effects. However, these time-independent parameters with heterogeneous impact varies across the quantiles of the conditional distribution of the dependent variable. Thus, the estimation of the MMQR approach offers solution to the following optimization problem:

$$min_q \sum_i \sum_t \rho_\tau(\widehat{R}_{it} - (\widehat{\delta}_i + Z'_{it}\widehat{\gamma})q) \tag{4}$$

such that the check function is presented as $\rho_\tau(\mu) = \mu(\tau - 1(\mu \leq 0) + (\mu > 0)$.

Moreover, considering that the MMQR estimation is performed on stationary values (levels), further computation is performed for referencing and comparison with the results from the preceding estimations. In this case, the differenced values of non-stationary variables in Table 1 are employed in a repeated mode (equations (1)–(3)). Yet, the result obtained failed to suggest or provide a significant contradiction to the preceding estimation (see further reading in Tables B and C).

Table 3
Panel cointegration with CS.

Westerlund cointegration	G_t	G_a	P_t	P_a
Model 1	-6.33^a	-3.18	-12.40^a	-4.71^a
	(0.00)	(0.60)	(0.00)	(0.00)
Model 2	-4.04^a	-2.77^a	-6.748^a	-2.31^a
	(0.00)	(0.00)	(0.00)	(0.00)
Kao cointegration		Statistic	P-value	
Model 1		-5.29^a	0.00	
Model 2		-7.43^a	0.00	

Note: ^{a} and () represents the probability value < 0.1 and robust p-value. The Kao cointegration adopt the Augmented Dickey-Fuller *t*-test by using the Newey-West lag selection (2), and kernel is Bartlett. CS is cross-sectional dependence.

Table 2
Pesaran panel unit root with CS.

Variables	Levels		First difference	
	T	$\not T$	T	___$\not T$
lghg	-3.57^a	-2.51^b	-4.13^a	-4.01^a
lgdp	-3.47^a	-1.18	-4.14^a	-4.01^a
emp	-1.28	-1.75	-3.04^b	-3.00^a
leint	-2.50	-2.68^a	-6.23^a	-6.06^a
lenet	-2.55	-2.68^a	-5.98^a	-5.13^a
lpolt	-2.38	-1.69	-4.98^a	-4.67^a
lrest	-4.45^a	-4.60^a	-5.40^a	-5.42^a
ltrat	-1.29	-1.24	-3.82^a	-3.81^a

Note: ^{a}, ^{b}, T, and $\not T$ represents the probability value < 0.01, probability value < 0.05, 'with trend' and 'without trend'. CS is the cross-sectional dependence.

3.2.1. *Robustness method*

To offer robustness evidence to the result from the MMQR approach, the Pesaran et al. [26] and Dumitrescu and Hurlin [27] approaches are further utilized. Through the Pooled Mean Group (PMG) of the autoregressive distributed lag (ARDL) by Pesaran et al. [26]; we are able to provide panel short- and long-run results for the aforementioned models. Additionally, the approach is advantageous because it offers country-specific short-run results. Given, the models of the above equations (1a) and (1b) with X = set of explanatory variables, the PMG-ARDL implements the panel long-run and short relationships with the following expressions.

$$\text{Model 1: } \mathrm{LGHG}_{i,t} = \mathrm{B}_i \mathrm{LGHG}_{i,t-1} - \mathrm{C}_i \mathrm{X}_{i,t} + \sum_{j=1}^{r-1} \mathrm{D}_{i,j} \mathrm{LGHG}_{i,\,t-j} + \sum_{j=0}^{s-1} \mathrm{E}_{i,j} \Delta \mathrm{X}_{i,\,t-j} + \varepsilon_{i,t} \tag{5a}$$

$$\text{Model 2: } \mathrm{LEINT}_{i,t} = \mathrm{B}_i \mathrm{EINT}_{i,t-1} - \mathrm{C}_i \mathrm{X}_{i,t} + \sum_{j=1}^{r-1} \mathrm{D}_{i,j} \mathrm{LEINT}_{i,\,t-j} + \sum_{j=0}^{s-1} \mathrm{E}_{i,j} \Delta \mathrm{X}_{i,\,t-j} + \varepsilon_{i,t} \tag{5b}$$

In this case, the expression on the first part of the right hand-side, i.e $B_i LGHG_{i,t-1} - C_i X_{i,t}$ (of both 5a and 5b) is employed in the estimation of the speed of convergence i.e ECM ($\mathrm{B_i}$) (from short-run to long-run) and the long-run coefficients (C_i). Additionally, the short-run estimates are computed from the second part of the right-hand side of the equations (5a) and (5b).

Moreover, the Granger causality inference through the Dumitrescu and Hurlin [27] approach is employed because of its suitability for heterogeneous panels. The empirical illustration of this Granger causality is extensively documented in the literature, thus, the detail is not covered here. However, the result is provided with relevant discussion and implication.

4. Results and discussion

In this section, the results of the investigation are presented in the order of the MMQR results and followed by the robustness result comprising of the short- and long-run panel, country-specific short-run results, and the Granger causality result.

4.1. MMQR panel result

The result showing the impact of economic growth, employment, energy tax, pollution tax, resource tax, and transport tax across the quantiles of (GHG) emission and energy intensity for the panel of Nordic countries is illustrated in Table 4 and Table 5 respectively.

4.1.1. Trend in GHG emission

The first point of discussion is about the impact economic growth (measured here as GDP) and other factors on GHG as illustrated in Table 4. Foremost, the impact of GDP clearly illustrates that the Nordic countries have succeeded in decarbonizing their economic prosperity i.e decoupling economic growth from GHG emission giving that the economy is growing with reduction in the greenhouse gas emissions as shown in the quantile panel result. The panel result shows that a 1% increase in the GDP is responsible for a statistically significant decline in GHG across the panel from ~100 (from 10th quantile) percent to ~70% (from 90th quantile). Although the studies of Stoknes and Rockström [28] and Tilsted et al. [29] both alluded to the evidence of potential green growth in the Nordic countries, Stoknes and Rockström [28] specifically affirmed the evidence of green growth in only Denmark, Finland, and Sweden while Tilsted et al. [29] observed potential variance in green growth evidence especially for sub-national case. The lack of consensus from their studies further justifies the need for more debate on genuine green growth (GGG). However, in the panel as well, the increase in the share of employed population (especially for people between 20 and 64 years) is responsible for about ~1% increase in GHG emissions across the quantiles.

For the environmental-related taxes, the result in Table 4 reflects a situation where both pollution and resource taxes have only triggered more GHG emissions across the quantiles. Specifically, a 1% increase in pollution and resource taxes respectively triggers GHG emission by ~7–9% (from 10th to 90th quantile) and ~7 to 5% (from 10th to 90th quantile) at 1% statistically significant level. On the other hand, energy tax shows a desirable effect on GHG emission in the panel. Notably, a larger reduction in emission of GHG is reported when energy-related taxation is increased. Indicatively, a reduction from about 14% at lowest quantile to about 21% at higher quantile is attainable when tax on energy-related good is increased by 1%. This is a very similar evidence to the study of He et al. [9] that revealed that a unit increase in energy tax is associated with about 4.8-unit reduction in carbon dioxide emission in the panel of Nordic countries. Similarly, this study reveals that transportation-related tax exhibit the potential mitigating GHG emission, however, the impact is not statistically significant.

4.1.2. Trend in energy intensity and DDH inference

Table 5 shows the response of energy intensity (Kilograms of oil equivalent per thousand euro) to the changes in the aforementioned factors. The result reveals that decoupling economic growth from the intensity of energy utilization is statistically significant

Table 4
Results of Machado and Silva [10] MMQR (Model 1).

Variables	Location Parameters	Scale Parameters	Quantiles								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
lgdp	−0.86	0.10	−1.06b	−0.96^{a}	−0.92^{a}	−0.88^{a}	−0.86^{a}	−0.82^{a}	−0.79^{a}	−0.75^{a}	−0.70^{b}
	(0.12)	(0.51)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
emp	0.01	−0.00	0.01^{c}	0.01^{b}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{b}
	(0.12)	(0.72)	(0.07)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
lenet	−0.14^{a}	−0.02	−0.14	−0.16^{b}	−0.17^{b}	−0.18^{a}	−0.18^{a}	−0.19^{a}	−0.20^{a}	−0.20^{a}	−0.21^{b}
	(0.00)	(0.62)	(0.23)	(0.04)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
lpolt	0.08	0.01	0.07^{c}	0.07^{a}	0.07^{a}	0.08^{a}	0.08^{a}	0.08^{a}	0.08^{a}	0.09^{a}	0.09^{a}
	(0.07)^{c}	(0.75)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lrest	0.06^{b}	−0.00	0.07^{b}	0.06^{a}	0.06^{a}	0.06^{a}	0.06^{a}	0.06^{a}	0.05^{a}	0.05^{a}	0.05^{b}
	(0.02)	(0.64)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
ltrat	−0.00	0.000	−0.00	−0.00	−0.00	−0.00	−0.00	0.00	0.00	0.00	0.00
	(0.99)	(0.94)	(0.98)	(0.98)	(0.97)	(0.99)	(1.00)	(1.00)	(0.99)	(0.98)	(0.98)

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively. The values in the parentheses are the probability values of the estimated parameters.

Table 5
Results of Machado and Silva [10] MMQR (Model 2).

Variables	Location Parameters	Scale Parameters	Quantiles								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
lgdp	−1.38^{a}	0.01	−1.40^{a}	−1.39^{a}	−1.39^{a}	−1.38^{a}	−1.38^{a}	−1.37^{a}	−1.37^{a}	−1.36^{a}	−1.35^{a}
	(0.01)	(0.79)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
emp	0.01	−0.00	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{b}	0.01
	(0.13)	(0.73)	(0.1	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.11)
lenet	−0.08^{b}	−0.01	−0.06^{c}	−0.07^{b}	−0.07^{a}	−0.07^{a}	−0.08^{a}	−0.08^{a}	−0.08^{a}	−0.08^{b}	−0.09^{b}
	(0.02)	(0.77)	(0.07)	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)
lpolt	0.07^{c}	−0.01	0.07^{a}	0.07^{a}	0.07^{a}	0.07^{a}	0.07^{a}	0.06^{a}	0.06^{a}	0.06^{a}	0.06^{b}
	(0.05)	(0.68)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
lrest	0.05^{b}	−0.01^{b}	0.05^{a}	0.05^{a}	0.05^{a}	0.05^{a}	0.05^{a}	0.04^{a}	0.04^{a}	0.04^{a}	0.04^{b}
	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)
ltrat	0.11	0.02	0.09	0.09^{b}	0.10^{a}	0.10^{a}	0.11^{a}	0.12^{a}	0.12^{a}	0.13^{b}	0.14^{b}
	(0.21)	(0.69)	(0.12)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively. The values in the parentheses are the probability values of the estimated parameters.

across the quantiles. This is an expected observation considering the progress of energy transition progress among the Nordic countries. Moreover, drawing a notion from the existing literature, the study of Irandoust [30] hinted that the Nordic countries are characterized with low energy intensity and high energy efficiency. Specifically, a more recent study of Mahmood and Ahmad [13] found that energy intensity and economic growth among European economies are inversely associated while an earlier study by Nilsson [12] also revealed an inverse relationship for 15 of the 31 industrial and developing economies. Similar to the result of the nexus between employment rate and greenhouse gas emission, this result further revealed that a unit increase in the share of employed population is responsible for about 0.01 unit increase in the intensity of energy utilization.

Similarly, to the trend in GHG emission in the Nordic region, an increase in energy tax by a million euro will reduce energy intensity from 0.06 Kilograms of oil equivalent per thousand-euro (in the lower quantile) to 0.09 Kilograms of oil equivalent per thousand-euro (in the upper quantile). Although there is a statistically significant evidence that pollution, resource, and transport taxes further increase the intensity of energy in the region, the desirable observation for the case of energy tax is not far from expectation considering the success of the energy transition policy of the Nordic states. Considering that only the energy tax among the examined components of environmental-related tax policies (energy, pollution, resource, and transport taxes) has a co-benefit of reduction of GHG emission (i.e climate mitigation) and reduction of energy intensity, it can be induced from the results that the double dividend hypothesis is not valid for all the categories of environmental-related tax but the energy tax. Thus, with energy tax, the double dividend hypothesis is an attainable dimension. Although there is sparse study in this direction, the study of Fang et al. [31] inferred that the application of carbon tax has the potential to reduce energy intensity while promoting economic growth in China.

4.2. Robustness and country-specific results

As a robustness measure, the result of the PMG-ARDL approach in Table 6 and Table 7 show that economic growth in the panel of examined countries exert a statistically significant and negative impact on both GHG emission and energy intensity. Similar to the result of the MMQR, a unit increase in energy tax account for ~0.86 unit decline in GHG emission in the long-run while an increase in emission by ~0.25 unit in the short-run is observed at a 10% statistically significant level. A similar and desirable effect is caused by the impact of energy tax on energy intensity in the panel countries especially in the long-run. However, against the evidence from the MMQR result, the PMG reflect that pollution tax offers a desirable impact on energy intensity by causing a reduction in the kilograms of oil equivalent per thousand euro. In general, the model has about 93% adjustment from disequilibrium annually at a 1% statistically significant level.

For the Granger causality evidence (see Table 9), by a large extent, there is a corroboration of the previous results. For instance, there is a statistically significant evidence of unidirectional Granger causality from GDP to both GHG and energy intensity while a unidirectional Granger causality evidence also holds from energy tax and transport tax to both GHG and energy intensity. The implication of this is that significant inference about GHG and energy intensity can be deduced from the historical information about the GDP and energy tax, and the reverse is also possible. Meanwhile, there is also a unidirectional Granger causality from resource tax to GHG, from GHG to pollution tax, and energy intensity to both pollution tax and resource tax.

4.2.1. Short-run country-specific results

As shown in Tables 6 and 7, in the short-run, there is no significance evidence to support decoupling economic growth from GHG emissions in Denmark and Finland (see Table 6) while economies of Norway and Sweden show a significant growth with GHG emissions. However, in Finland, economic growth is associated with decline in energy intensity at a 1% statistically significant level while the relationship is negative and insignificant in Denmark, Norway, and Sweden. Except in Denmark (where employment rate decreases with energy intensity), employment rate increases with increase in energy intensity in each of the Nordic countries while employment rate increases with decrease in energy intensity in each of the countries.

Concerning response to tax changes, tax policy regime related to energy, pollution, resource, and transport does not help to mitigate GHG emission in Denmark but energy intensity in the country could decline by ~8%, ~6%, and ~15% when there is a 1% increase in pollution tax, resource tax, and transport tax respectively. As revealed in Table 8, the environmental-related taxes in Denmark are not likely to be effective tool for driving a co-benefit policy that could validate the double dividend hypothesis.

In Finland, GHG emission further increase by ~35% and ~40 when there is a 1% increase in energy tax and transport tax respectively (see Table 6). These tax policy (in energy and transport) in Finland also account for a statistically significant increase in energy intensity while both pollution and resource taxes play a significant role in reducing both GHG emission and energy

Table 6
Results of PMG (Model 1).

Variables	ARDL (1,1,1,1,1,1,1), BIC					
	Panel Long-run	Panel Short-run	Denmark	Finland	Norway	Sweden
lgdp	−0.36	0.08a	1.48	0.31	0.61a	0.82a
	(0.22)	(0.00)	(0.55)	(0.57)	(0.00)	(0.00)
emp	0.01^{a}	−0.01^{b}	−0.02^{a}	−0.01^{a}	−0.00^{a}	−0.01
	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)	(0.11)
lenet	−0.86^{b}	0.25^{c}	0.05	0.35^{b}	0.03^{a}	0.59^{a}
	(0.02)	(0.06)	(0.31)	(0.01)	(0.00)	(0.00)
lpolt	0.06^{a}	−0.00	0.03	−0.03^{a}	0.02^{a}	−0.04^{a}
	(0.00)	(0.81)	(0.15)	(0.00)	(0.00)	(0.01)
lrest	0.25^{a}	−0.02	0.09	−0.14^{b}	0.01^{a}	−0.03^{a}
	(0.00)	(0.45)	(0.19)	(0.01)	(0.00)	(0.00)
ltrat	0.05	0.09	0.04	0.40^{a}	0.08^{a}	−0.18^{a}
	(0.64)	(0.72)	(0.27)	(0.00)	(0.00)	(0.00)
ECT (−1)		−0.33c	−0.19^{a}	−0.85^{a}	−0.02^{a}	−0.27^{a}
		(0.07)	(0.00)	(0.00)	(0.00)	(0.00)

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively. The values in the parentheses are the probability values of the estimated parameters.

Table 7
Results of PMG (Model 2).

Variables	ARDL (2,1,1,1,1,1,1), BIC					
	Panel Long-run	Panel Short-run	Denmark	Finland	Norway	Sweden
lgdp	−0.13	0.48	−0.49	−0.84a	−1.25	−0.31
	(0.42)	(0.45)	(0.63)	(0.00)	(0.40)	(0.18)
emp	−0.00^{c}	−0.00	−0.00^{a}	0.02^{a}	0.00^{a}	0.01^{a}
	(0.07)	(0.60)	(0.00)	(0.00)	(0.00)	(0.00)
lenet	−0.08	0.22^{c}	−0.04	0.24^{b}	0.23^{b}	0.57^{a}
	(0.13)	(0.05)	(0.11)	(0.00)	(0.01)	(0.00)
lpolt	−0.02^{c}	−0.02	−0.08^{a}	−0.07^{a}	−0.02^{a}	−0.05^{a}
	(0.06)	(0.20)	(0.00)	(0.00)	(0.00)	(0.00)
lrest	0.02	0.05	−0.06^{c}	−0.21^{a}	−0.04^{a}	−0.02^{a}
	(0.12)	(0.50)	(0.09)	(0.01)	(0.00)	(0.00)
ltrat	0.20^{a}	−0.07	0.15^{a}	0.17^{a}	−0.16^{a}	−0.31^{a}
	(0.00)	(0.38)	(0.00)	(0.00)	(0.00)	(0.00)
ECT		−0.93^{a}	−0.16^{c}	−1.28^{a}	−0.08^{a}	−0.15^{a}
(-1)		(0.00)	(0.07)	(0.00)	(0.00)	(0.00)

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively. The values in the parentheses are the probability values of the estimated parameters.

Table 8
Summary of the validity for ‘double dividend hypothesis.

Environmental Related Taxes	Double dividend hypothesis NORDIC countries	Country short-run inference			
		Double dividend hypothesis DENMARK	Double dividend hypothesis FINLAND	Double dividend hypothesis NORWAY	Double dividend hypothesis SWEDEN
Energy Tax	Yes, valid (long-run)	Not valid	Not valid	Not valid	Not valid
Pollution Tax	Potential validity	Not valid	Yes, valid	Not valid	Yes, valid
Resource Tax	Not valid	Not valid	Yes, valid	Not valid	Yes, valid
Transport Tax	Not valid	Not valid	Not valid	Not valid	Yes, valid

intensity (see Table 7). Thus, as shown in Table 8, only with the resource and transport taxes could the double dividend hypothesis be implied for Finland.

The situation is not so pleasant for the case of Norway. Specifically, the application of environmental-related taxes does not help in GHG emission mitigation drive because a 1% increase in energy tax, pollution tax, resource tax, and transport tax significantly increase GHG emission by ~3%, ~2%, ~1%, and ~8% respectively (see Table 6). Moreover, while energy tax in the country has not achieved the purpose of reducing energy intensity, pollution tax, resource tax, and transport tax are potent instruments toward reducing energy intensity. Evidently, as indicated in Table 8, no environmental-related tax policy is capable of driving the agenda of double dividend hypothesis in Norway.

Similarly, to the case of Finland, the result for Sweden reveals that there is a co-benefit of environmental-related tax especially for pollution and transport taxes. Although energy tax does not show a desirable effect on both GHG emission and energy intensity possibly alluding to the finding about Sweden by Cheng et al. [32]; the impacts of the other tax classifications on both GH emission and energy intensity are all desirable. For instance, as seen in Table 6, GHG emission is mitigated by ~4%, ~3%, and ~18% when there is 1% increase in pollution tax, resource tax, and transport tax respectively. Similarly, as seen in Table 7, a unit increase in pollution tax,

Table 9
Results of Granger causal relationship.

Relationship	W- Statistic	Zbar-Statistic	Probability
LGDP dnhc > LGHG	6.89[a]	6.90	5.00E-12
LGHG dnhc > LGDP	0.98	−0.15	0.88
EMP dnhc > LGHG	1.24	0.17	0.87
LGHG dnhc > EMP	1.03	−0.09	0.93
LEINT dnhc > LGHG	3.40[b]	2.73	0.01
LGHG dnhc > LEINT	0.79	−0.37	0.72
LENET dnhc > LGHG	8.47[a]	8.77	0.00
LGHG dnhc > LENET	0.47	−0.75	0.45
LPOLT dnhc > LGHG	1.60	0.60	0.55
LGHG dnhc > LPOLT	7.18[a]	7.24	5.00E-13
LREST dnhc > LGHG	5.16[a]	4.84	1.00E-06
LGHG dnhc > LREST	1.44	0.41	0.68
LTRAT dnhc > LGHG	6.23[a]	6.11	1.00E-09
LGHG dnhc > LTRAT	0.64	−0.55	0.5821
LEINT dnhc > LGDP	1.34	0.29	0.77
LGDP dnhc > LEINT	6.78[a]	6.76	1.00E-11
LENET dnhc > LEINT	3.53[a]	2.89	0.00
LEINT dnhc > LENET	0.89	−0.25	0.80
LPOLT dnhc > LEINT	0.80	−0.36	0.72
LEINT dnhc > LPOLT	6.37[a]	6.27	4.00E-10
LREST dnhc > LEINT	2.22	1.33	0.18
LEINT dnhc > LREST	4.47[a]	4.02	6.00E-05
LTRAT dnhc > LEINT	4.76[a]	4.36	1.00E-05
LEINT dnhc > LTRAT	2.26	1.38	0.17

Note: dnhc > implies ‘does not homogeneously cause’.

resource tax, and transport tax cut energy intensity by 0.05 unit, 0.02 unit, and 0.31 unit respectively. Then, the result (see Table 8) concludes that double dividend hypothesis is valid for Sweden only with pollution, resource, and transport taxes.

5. Conclusion and policy recommendation

Following the ongoing revelation and debate about the progress of the Nordic countries in the aspects of energy transition and environmental sustainability, this study offers a novel perspective from the reasoning of double dividend hypothesis. Along the objective of examining the co-benefit of environmental-related tax via the double dividend hypothesis, this study characteristically disaggregates the environmental-related tax into energy, pollution, resource, and transport taxes. Going by this approach, this study demonstrates the impact of energy tax, pollution tax, resource tax, transport tax, economic growth, and employment on (i) greenhouse gas emission and (ii) energy intensity by employing the MMQR as a main empirical tool alongside the PMG-ARDL and DH Granger causality approaches for a robustness check. The results from the investigations are unique interesting, thus implied in the following layout.

- Green growth is a reality in the Nordic region because the result revealed that there is a statistically significant decoupling of economic growth from GHG emission across the quantiles while also revealing a significant and negative nexus between GDP and energy intensity. However, the reverse is the case for regarding the impact of employment on GHG emission and energy intensity.
- For the MMQR and PMG-ARDL results, for the panel (regional) case, an increase in energy tax is associated with decline in both the GHG emissions and energy intensity across the quantiles. Although transport tax shows evidence of GHG emission mitigation effect, the impact is not statistically significant.
- In the case of pollution tax and resource tax, a policy that support an increase in these categories of taxation exacerbate GHG emissions and increase energy intensity.
- In the panel case, only energy tax, and not all the environmental-related taxes could validate the double dividend hypothesis.
- However, for short-run country-specific inference, double dividend hypothesis and by large extent co-benefit is achievable only with pollution and resource tax policies in Finland. For Sweden, these desirable characteristics are also achievable with pollution, resource, and transport tax policies. However, there is no valid evidence to support the validity of double dividend hypothesis in Denmark and Norway.

Although the case of interest in this study is that of the Nordic countries, it is recommended that a replication of the investigation could be implemented for the EU which has remained the leading bloc of sustainable energy and environment. Moreover, it this empirical framework could be re-investigated in the future by also employing the disaggregated GDP (i.e share of sector-wide value-added in the total GDP) and/or the growth rate of the GDP.

With these observations, it is glaring that policymakers in these countries should be more inclined to focus on the specific aspects the environmental-related tax because a direct impact could be more realistic, thus yielding a desirable and result-oriented outcome. Given the lack of statistical evidence to that pollution, resource, and transport tax policies helps to mitigate GHG emission and energy intensity, a combine approach of cost-effective policies that motivate consumer attitude and preference toward an environmentally friendly behaviour could yield more desirable result. More importantly, especially for Denmark and Norway, the countries would have to focus on how to draw from the potential benefit of aspects of the environment-related tax.

In term of implication for management, the implementation of high energy, pollution, resource, and transport tax rate will unavoidably imply higher cost of productivity. However, this potential cost burden could be alleviated by government-oriented incentive or subsidy especially that promotes environmental-related innovations. Similarly, in order to prevent passing the tax burden to the household or avoiding the worst-case scenario arising from environmental tax regime, citizens could soon learn to adjust to socially and environmentally responsible behaviours when there are effective awareness programs and incentives for adopting innovation pathways.

Credit author statement

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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.

Appendix

Table A
Correlation between the dependent and explanatory variables

Variables	LGHG	LEIN
LGDP	−0.35^{a}	−0.41^{a}
EMP	−0.12	−0.61^{a}
LENET	−0.59^{a}	−0.33^{a}
LPOLT	−0.05	−0.69^{a}
LREST	−0.32^{a}	−0.29^{a}
LTRAT	−0.13	−0.83^{a}_

Note: The probability value < 0.01 is represented as ^{a}.

Table B
Results of [10] MMQR (Model 1)

Variables	Location Parameters	Scale Parameters	Quantiles								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
lgdp	−0.41	0.14	−0.63^{a}	−0.55^{a}	−0.51^{a}	−0.46^{a}	−0.42^{a}	−0.34^{a}	−0.29^{c}	−0.24	−0.20
	(0.33)	(0.09)^{c}	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.07)	(0.18)	(0.36)
emp	−0.00	0.00	−0.00	−0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	(0.55)	(0.85)	(0.64)	(0.57)	(0.53)	(0.49)	(0.49)	(0.56)	(0.65)	(0.72)	(0.77)
lenet	−0.32	−0.12	−0.14	−0.21	−0.24^{c}	−0.28^{a}	−0.31^{a}	−0.38^{a}	−0.42^{a}	−0.46^{a}	−0.50^{a}
	(0.14)	(0.29)	(0.48)	(0.16)	(0.08)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
lpolt	0.00	−0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
	(0.21)	(0.18)	(0.30)	(0.22)	(0.20)	(0.17)	(0.20)	(0.33)	(0.50)	(0.61)	(0.72)
lrest	0.06^{b}	−0.01	0.00^{b}	0.06^{a}	0.06^{a}	0.06^{a}	0.06^{a}	0.06^{a}	0.05^{a}	0.05^{a}	0.05^{b}
	(0.02)	(0.58)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
ltrat	0.00	−0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.17)	(0.67)	(0.45)	(0.36)	(0.32)	(0.30)	(0.30)	(0.08)	(0.51)	(0.60)	(0.68)

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively. The values in the parentheses are the probability values of the estimated parameters.

Table C
Results of Machado and Silva [10] MMQR (Model 2)

Variables	Location Parameters	Scale Parameters	Quantiles								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
lgdp	−0.89^{a}	0.05	−0.98^{a}	−0.95^{a}	−0.93^{a}	−0.92^{a}	−0.89^{a}	−0.87^{a}	−0.86^{a}	−0.83^{a}	−0.81^{a}
	(0.01)	(0.38)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
emp	−0.01	−0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
	(0.76)	(0.73)	(0.89)	(0.87)	(0.82)	(0.81)	(0.77)	(0.76)	(0.77)	(0.83)	(0.86)
lenet	−0.12^{b}	−0.10^{a}	0.04	−0.01	−0.07	−0.08	−0.13	−0.17^{a}	−0.19^{a}	−0.25^{a}	−0.29^{a}
	(0.28)	(0.00)	(0.84)	(0.93)	(0.54)	(0.43)	(0.12)	(0.04)	(0.03)	(0.03)	(0.04)
lpolt	0.00	−0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.92)	(0.20)	(0.52)	(0.56)	(0.67)	(0.72)	(0.97)	(0.78)	(0.69)	(0.51)	(0.46)
lrest	0.04^{b}	−0.00	0.04	0.04^{c}	0.04^{a}	0.04^{a}	0.04^{a}	0.04^{a}	0.04^{a}	0.04^{a}	0.04^{c}
	(0.04)	(0.91)	(0.12)	(0.05)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.05)
ltrat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.15)	(0.27)	(0.92)	(0.84)	(0.70)	(0.66)	(0.50)	(0.43)	(0.42)	(0.46)	(0.50)

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively. The values in the parentheses are the probability values of the estimated parameters.

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