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Research article

Analysing the co-benefit of environmental tax amidst clean energy development in Europe's largest agrarian economies

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ABSTRACT

The increasing human activities amidst competition for resources across the globe has made environmental challenges an ongoing classic problem, thus prompting policymakers to continually seek effective solution while ensuring sustainable development. With the wide coverage of the relevance of the double dividend hypothesis in explaining the co-benefit of environmental tax, there is a dearth of evidence in the literature to suggest that environmental tax offers green dividends for both the environment and agricultural practice in the European countries. As such, this study employed the more recent Method of Moments Quantile Regression (MMQR) alongside other approaches for Europe's largest agrarian economies (France, Germany, Italy, and Spain) over the annual period 1995–2020. The investigation affirms the validity of the co-benefit of environmental tax as far as environmental sustainability and value-added to agriculture are concerned in this panel of 'Big Four' economies, thus motivating the countries to relentlessly pursue the carbon-neutral 2050 target. Moreover, the study aligns with the expectation that renewable energy utilization and population density are desirable factors for achieving a carbon-neutral target. Lastly, the findings suggest that environmental quality is attainable in the panel, especially as increasing income surpasses a certain threshold, thus validating the environmental Kuznets curve hypothesis. Above all, the findings provide timely policy insight that accommodates both the environmental sustainability and food security framework of the European Union. The policy options relevant in light of the study's conclusions include that the decision makers in the selected agrarian economies should ramp up energy transition opportunities through a resilient environmental tax system that incentives availability of credit and investment financing in the agriculture sector.

1. Introduction

The increasing human activities amidst competition for resources across the globe has made environmental challenges an age-long classic problem, thus prompting policymakers to continually seek effective ways to combat the challenge while ensuring sustainable development. Increasing levels of environmental pollution have triggered an enormous amount of scientific inquiry. Several reports from environmental and climate-related agencies have warned about the consequences of the increased level of greenhouse gases (GHG) in the atmosphere (IPCC, 2014). To this end, environmental-related taxes (ET) is increasingly gaining attention as a viable economic tool for incentivizing cleaner production and consumption practices (Freire-González, 2018). The term "environmentally related tax" is frequently used to refer to taxes that promote environmental and natural resource protection rather than fiscal interests (Kosonen and Nicodeme, 2009; Inkábová et al., 2021). It is regarded as a relatively cost-effective and efficient economic tool for combating climate change (Baranzini et al., 2016). Concerns that climate change mitigation objectives alone may not be enough to mobilize public support for more aggressive GHG emission reduction

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initiatives have sparked interest in research into the co-benefits of climate change mitigation (Bollen et al., 2009; Deng et al., 2017). Proponents of environmental-related tax emphasize the co-benefit of a cleaner environment, using the tax payments to pay for tax cuts already in place in different sectors, thus yielding a "double dividend" (DD) hypothesis. The DD hypothesis infers that the revenue generated by imposing a pollution tax is used to fund tax reductions in other areas of the economy while playing a critical role in regulating environmental degradation (Pearce, 1991; McKitrick, 1997; Orlov and Grethe, 2012; Fraser and Waschik, 2013; Pereira et al., 2016).

As a result of concerns about the increasing GHG levels in recent years, one of Europe's most important objectives is environmental protection, including environmental sustainability. To reduce GHG emissions in member states, the European Union has directly prescribed implementing environmental-related taxation measures as reported in extant studies (Jaeger, 2013; Freire-González and Ho, 2019). It is expected that the economic benefits of a sustainable taxation system are channeled to economic growth, for which agricultural businesses and their stability and survival play a significant role. The agricultural sector's functions span three aspects (environmental, social, and economic), all of which are intertwined with the concept of sustainable development (Muoneke et al., 2022; Alola and Alola, 2018; Agboola and Bekun, 2019; Alola et al., 2019; Freire-González, 2018). Protecting biodiversity and natural resources, combating pollution, and combating climate change are all critical parts of the environmental dimension of the taxation system (Inkábová et al., 2021). Although the EU has continued to experience a downward trend in the volume of agricultural labour in recent times, the sector comprises a more significant proportion of non-salaried labour (of over 6 million full-time workers) against salaried labour (of over 2 million full-time workers) in 2020 (European Environmental Agency, 2022).

Considering that the implementation of environmental tax has the potential of yielding co-benefits, this study opts to examine this perspective in a novel approach. In this case, the novelty is that the environmental tax's co-benefit is deduced from both environmental and agricultural aspects, especially in the case of the four largest European agricultural economies, i.e., France, Germany, Italy, and Spain. Evidently, France, Germany, Italy, and Spain, with the respective agricultural output value of EUR 76.3 billion, EUR 57.6 billion, EUR 56.9 billion, and EUR 52.3 billion, contributed 58.7% to the EU's total output value of the agricultural industry in 2020 (European Environmental Agency, 2022). Although several studies have documented the role of taxation, financial benefits, green technology, environmental taxes on agriculture, energy-related green gases, environmental technology, and globalization in supporting sustainability transitions (European Environmental Agency, 2022; Inkábová et al., 2021; Alola and Nwulu, 2022; Sadiq et al., 2022; Qing et al., 2022a, 2022b; Bashir et al., 2020), this is a rare study that potentially offers an in-depth analysis of the co-benefit of environmental tax alongside the development of clean energy especially for Europe's leading agrarian economies. By carrying out the investigation under the DD hypothesis's conceptual approach, the study's objectives are not far-fetched. Specifically, the study attempts to answer whether environmental tax drives carbon neutrality and increased agricultural output in the panel of the EU's largest agrarian economies. While also looking at carbon neutrality and increased agricultural output drive, another attempt is made to determine the role of population density alongside testing the validity of the environmental Kuznets curve (EKC) in the panel. The relevant hypothesis of the study includes; the environmental tax has no significant effect on both carbon neutrality and increased agricultural output in the panel of the EU's largest agrarian economies. Also, population density has no significant impact on carbon neutrality, and EKC is not valid in the panel of countries. Also, population density has no significant impact on carbon neutrality, and EKC is not valid in the panel of countries. With this approach and the empirical pathway adopted, the extant literature on DD hypothesis stands to benefit from this significant contribution.

This study has a specific structure layout. Several related studies are reviewed in section 2 while the description of the dataset with illustrative statistics are presented in section 3. The empirical approach with the discussion of the results is carried out in section 4 while concluding with policy remark in section 5.

2. Literature review

2.1. Nexus of ET and GHG emission

Environmental Tax Reforms (ETR) have been implemented in national legislation by EU countries over the previous two decades. This entails a tax shift from producers to polluters, described as a shift from economic 'goods' to environmental 'bads' (Meng, 2015; Kotnik et al., 2014). A large and growing body of literature has established the connection between environmental taxes and air pollution caused by GHG and other pollutants. Ghazouani et al. (2021) examined the role of environmental regulations alongside cleaner energy in mitigating GHG emissions among the high-emitting European economies. Using econometric tools for the investigation, the study revealed that environmental taxes and the promotion of cleaner energy sources could effectively reduce overall pollution in the case of leading European emitter countries. In the case of BRICS countries, Ulucak, et al. (2020) investigated the non-linear effects of the environmental-related tax on carbon dioxide emissions by controlling environmental technologies, patents, and economic growth. The authors relied on the panel smooth transition regression approach as its sole econometric technique while the data was sourced from online databases. Findings show that at lower levels of globalisation, environmental-related technologies and taxes increase CO_2 emissions. On the other hand, at higher levels of globalisation, environmental-related technologies, patents, and taxes decrease CO_2 emissions in the case of BRICS countries.

In the case of the United States, Chien et al. (2021) examined the extent of the association between green growth and carbon emission while controlling for innovation in the ecosystem, environmental taxes, and green energy. The authors adopted the Quantile Autoregressive Distributed lag method in light of its merits, not limited to depicting the causality patterns based on different quantiles for different variables. The findings from the QARDL estimation show that green growth and square of green growth alongside other indicators significantly reduced haze pollution in the long-run. López et al. (2011) accounted for GHG and other emissions when measuring the environmental impact of fiscal spending patterns. They discovered that reallocating government expenditure on social and public goods, such as climate change mitigation, considerably lowered the environmental burden.

Berker et al.(2001) examined the role of internal European Union (EU) policies and initiatives in achieving the Kyoto Protocol's greenhouse gas reduction target. They argued that environmental taxes are more effective in lowering carbon emissions when EU policy directives are used with national policies. Land Rivera et al. (2016)simulated the impact of suggested and expected energy policies on the environment and the Mexican economy over the medium and long term. A Multisector Macroeconomic Model for the Evaluation of Environmental and Energy Policy (Three-ME) was used to perform the research. According to the authors, if no compensation is provided to households, the taxing strategy will reduce CO_2 emissions by much more than 75% by 2050 compared to Business as Usual (BAU), but at a substantial economic cost. Meng et al. (2013) used a computable GEM (general equilibrium model) with an enhanced social accounting matrix for the environment to further support the double dividend hypothesis. According to the simulated results, a carbon tax can effectively reduce emissions while also causing a slight economic contraction, implying that ET has a minimal effect on GHG emissions. There are a large number of studies supporting the double dividend (DD) hypothesis in different countries by several authors (Jorgenson et al., 2013; Chen et al., 2017; Orlov et al., 2013; Allan et al., 2014; Jiang and Shao, 2014; Sajeewani et al., 2015;

Chisari and Miller, 2015; Chen et al., 2017).

Conversely, other studies have failed to support the DD hypothesis with convincing evidence. Bovenberg and de Moojj (1994) employed a static CGEM and discovered that DD is only conceivable if the labour supply function in a static CGEmodel is backward-bending. Although the empirical data on labour supply behaviour does not support this functional form, Freire-González (2018) argues that a static model is inadequate to deal with investment and capital issues. Wesseh and Lin (2019) created a static CGEM model for Liberia to analyze both a uniform and a partial carbon tax policy. An economic dividend was discovered for energy, employment, and welfare under the uniform policy enacted to assure mitigation in the range of 20–50 per cent. Energy usage grew by 5–15.5 per cent in particular. Surprisingly, when tax policy exemption is applied to the economically strategic sectors, no economic benefit is discovered for all three variables. According to the researchers, a uniform environmental tax policy is a more viable alternative for Liberia. It generates economic benefits for employment and welfare and encourages Liberia's adoption of renewable energy technologies. In the same vein, the DD hypothesis was tested by Goulder (2013), Meng et al. (2013), Zhang et al. (2016), Pereira et al. (2016), and Othman (2017); still, no evidence was found to support the DD hypothesis for an environmental-related tax. Generally, the idea of a double dividend is still widely debated among economists.

2.2. Nexus of ET and agricultural aspects

As Bonnet et al. (2018) pointed out, agriculture has the most significant environmental impact after the energy sector. Agriculture, forestry, and other land-use emissions accounted for 24% of total GHG emissions in 2010, while energy emissions accounted for 35% and industry emissions accounted for 21%. (Pereira et al., 2016). Bonnet et al. (2018) investigated whether a CO_2 equivalent (CO_2-eq) tax policy in France can alter household behaviour regarding purchasing animal products and their environmental impact. To examine the problem, two levels of CO_2-eq taxes were used (€56 and €200 per tonne of CO_2-eq) on all animal products, exclusively ruminant foods, or only beef consumption. They show that a high tax rate would only result in a 6% reduction in GHG emissions by 2020, preventing the target of a 20% reduction by 2020 from being met. The authors suggest the most efficient situation would be to tax beef consumption only at a high rate despite the tax's minimal effect. Similarly, Säll and Gren (2015) investigated the environmental consequences of imposing a meat and dairy consumption tax in Sweden. Their study looked at beef, pork, and poultry (as meat products), milk, fermented products, cream, and cheese (as dairy products) alongside GHG, nitrogen, ammonia, and phosphorus (as environmental indicators). Then, the study utilized per capita consumption in the econometric analysis with the almost ideal demand system (AIDS) for meat and dairy products to calculate consumer response to the tax. All meat items had moderately inelastic own-price and high-income elasticities, while dairy products had slightly lower elasticities. It was noted that the simultaneous implementation of a levy on all seven products reduced GHG, nitrogen, ammonia, and phosphorus emissions from the livestock sector by up to 12%. Hedenus et al. (2014) argues that meeting global climate targets without dietary changes will be difficult.

Furthermore, while using the life-cycle analysis (LCA) approach, Gemechu, et al. (2012) applied the environmentally extended input-output analysis (EIO) to determine the emission intensities on which tax is based. The study examined the impact of tax prices and the policy implications of including a non- CO_2 or GHG emission model. The results revealed that the environmental tax rate based on LCA was higher than the EIO techniques in the case study on pulp production, although they were of the same magnitude. The scholars recommended EIO as a more realistic strategy for applying an economy-wide environmental tax, even though LCA is more product specific and gives a more extensive review. They further proposed that if an environmental tax were imposed on non- CO_2/GHG emissions instead of CO_2, it would significantly impact agriculture, coal mining, peat extraction, and food industries.

Similarly, Meng (2015) investigated the impact of carbon taxes on Australia's agriculture industry. The study's findings revealed that tax costs are transmitted to other sectors of the economy via the price mechanism, thus lowering production, employment, and benefits despite significant reductions in emissions. Using the CGEM model, Bourne et al. (2012) investigated potential environmental policies for reducing CO_2 emissions in the Spanish agriculture sector. Their findings revealed a drop in GDP and employment, as well as a decline in agricultural production and a rise in the price level of farming items, lowering farmer income. Additionally, the imposition of a tax on CO_2 emissions produced by the agriculture sector was studied by Mardones and Lipski (2020). A CGE simulation with sensitivity analysis was employed to evaluate tax rates ranging from \$5 to \$131/ton CO_2. It was discovered that a tax on agricultural emissions merely makes agriculture less competitive and, as a result, diminishes productivity. As a result, real GDP fell from 0.00–0.01% to 0.12–0.40%, while total emissions fell from 0.07 to 0.10% to 1.79–2.25 per cent. They concluded that simply taxing agriculture had no meaningful effect on emissions. An argument for uniformly administering the tax while subsidizing forests was made and shown to be more efficient. In summary, little is known about the interrelationships between ET and agricultural-related business in the four largest agrarian European Union economies.

Following the review of the above related studies, this study has a potential contribution to environmental sustainability literature through the theory of double dividend vis-à-vis co-benefit hypothesis as motioned in the work of Pearce (1991). Specifically, the role of environmental-related tax which is the primary indicator in the study is examined in the context of environmental quality and agricultural productivity. Thus, as a rare contribution, the study among other queries hypothesizes whether there is (i) green benefit i. e environmental sustainability benefit arising from the deployment of environmental tax and (ii) blue benefit i. e welfare benefit such as agricultural productivity arising from the deployment of environmental tax for the case of agrarian economies. Moreover, this study is an important contribution given the rare case of the agrarian EU economies that is being examined.

3. Material and empirical model

The dataset from 1995 to 2020 was employed for the largest agrarian European Union member countries, i.e., France, Germany, Italy, and Spain. With the carbon emission represented as CE, economic performance/growth as Y, population density as PD, renewable energy consumption as RE, agricultural value added as AG, environmental tax revenue as ET, and crop production index as CP, the description of the dataset is further presented in Table 1.

Table 1
Dataset and description.

Variables	Description	Sources
CE	Carbon emission is measured in million tonnes of carbon dioxide	BP
Y	The Gross Domestic Product is measured in Euro	WDI
PD	The population of people per square km of land area	WDI
RE	The amount of renewable energy measured in exajoules (input-equivalent)	BP
AG	Agricultural value added is the share of Gross Domestic Product in Euro	WDI
ET	Environmental-related tax is measured in euro	EUROSTAT
CP	Crop production index is the production of agricultural product relative to 2014–2016	

Note: WDI is the World Development Indicators (2021) of the World Bank, BP is the British Petroleum (2021), EUROSTAT is the European Union Statistics (2022). Sadiq et al. (2022)

3.1. *Empirical model and tests*

Given that we employed the logarithmic values of dataset, the conceptual models from the environmental Kuznets curve (EKC) and subsequently the double dividend hypotheses are respectively presented as follows

$$CE_{i,t} = p_0 + p_1 Y_{i,t} + p_2 \mathrm{Y}2_{i,t} + p_3 PD_{i,t} + p_4 RE_{i,t} + p_5 ET_{i,t} + \epsilon 1_{i,t} \tag{1}$$

$$AG_{i,t} = q_0 + q_1 Y_{i,t} + q_2\ PD_{i,t} + q_3 CP_{i,t} + q_4 ET_{i,t} + \epsilon 2_{i,t} \tag{2}$$

Where $p_1 \ldots\ldots\ldots p_5$ and $q_1 \ldots\ldots\ldots\ldots q_4$ are the estimated coefficients and$\epsilon 1_{i,t}$ and $\epsilon 2_{i,t}$ are the stochastic error term in the models. In equation 1, If $\mathrm{p}_1 = 0$, and $\mathrm{p}_2 = 0$ there is no significant relationship between GDP per capita and GHG emission. If $\mathrm{p}_1 > 0$, and $\mathrm{p}_2 > 0$ there is linearly increasing relationship. $\mathrm{p}_1 <$ and $\mathrm{p}_2 < 0$ there is linearly decreasing relationship. If $\mathrm{p}_1 > 0$ and $\mathrm{p}_2 < 0$, there is presence of an inverted U-shape relationship. If $\mathrm{p}_1 < 0$ and $\mathrm{p}_2 > 0$, there is presence of U-shape relationship. p_3 in equation (1) & q_2 *in equation* 2 are expected to be negative or positive and that will indicate the level human activities on GHG emission and agricultural growth. p_4 *is expected to have negative impact on GHG emission which indicates transitio* n to cleaner production.p_5 is expected to be negative in equation (1) and positive in equation (2), imply the presence of double dividend hypothesis. q_3 is expected to have a positive impact on agricultural growth.

3.1.1. *Preliminary tests*

A series of initial tests are performed, including standard statistical distribution for each country under investigation, stationarity test of the variables, and cointegration test of the examined models. Moreover, the empirical pathway of the investigation is illustrated for clarity in Fig. 1.

Table 2 show the preliminary tests that include the descriptive statistics of the variables of interest. The descriptive statistics show that ET occupies the highest value, whereas GDP per capita has the lowest value. The data series shows evidence of normality, making it a candidate for scholarship investigation.

We used the Levin et al. (2002) (**LLC**) and Im et al. (2003) (IPS) **unit root tests** as presented in Table 3. Our results in the data series confirm that all variables were stationary at I (0) and I (1). As a result of the findings, it was determined that variables are integrated of mix orders.

4. Main estimation

This employed Pedroni co-integration, MMQR, FMOLS, and D-H causality tests to investigate the relationship between the use of taxation as an instrument for environmental policy and GHG emissions in the largest agrarian European Union member countries. In the first instance, Pedroni co-integration, as proposed by Pedroni (1999) and Pedroni (2004), depicts an augmented version of the Engle-Granger two-step residual-based co-integration test. Pedroni (1999) and Pedroni (2004) propose several tests for co-integration compatible with the inclusion of heterogeneous intercepts and trend coefficients across cross-sections distinct from the conventional co-integration test.

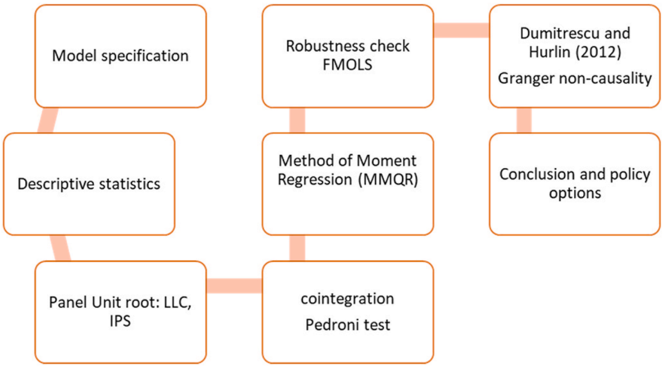

Fig. 1. Schematic methodological view.

In the second instance, MMQR (Method of Moments Quantile Regression) is implemented to achieve the objective of this study. The method embedded with fixed effects was proposed by Machado and Silva et al. (2019), poised to capture the distributional heterogeneity of independent variables at different conditional quantile distributions of carbon emission by incorporating fixed effects, erroneously missing in conventional mean regressions. Reasons for the superiority of the MMQR econometric technique over simple quantile regression and linearized FMOLS and DOLS are stated; thus, a) linear estimation techniques do not condition the distribution of data; instead, they address only averages. b) the ordinary quantile regression is deficient in non-crossing estimates when calculating estimators for multiple percentiles prompting an invalid distribution for the response. c) inability to account for unobserved heterogeneity across panel cross-sections.

The conditional quantiles of the following location-scale model are specified as thus:

$Y_{it} = \alpha_i + X_{it}^{'}\beta + (\delta_i + Z_{it}^{'}\gamma)U_{it}$ (3) In the above equation, $(\alpha, \beta^{'}, \delta, \gamma^{'})^{'}$ are estimated parameters, Z is known as k-vector of known components of X, and Pr $(\delta_i + Z_{it}^{'}\gamma) > 0) = 1$. U_{it} is stochastic error term, and U_{it} and $X_{it}^{'}$ explanatory variables. To account for the moment conditions, U_{it} is normalized: $E(U) = 0$ and $E(/U/) = 1$.

Equation 3 s how the following

$$Q_Y(\tau \upharpoonleft X_{it}) = (\alpha_i + \delta_i q(\tau)) + X_{it}^{'}\beta + Z_{it}^{'}\gamma q(\tau)$$

Where $\alpha_i(\tau) \equiv \alpha_i + \delta_i q(\tau)$ is the distributional effect at quantile (τ)

4.1. *Results and discussion*

Table 4 shows evidence of cointegration in data series with the statistically significant Modified Phillips-Perron, Phillips-Perron, and Augmented Dickey-Fuller in model specifications 1 & 2, respectively (see Table 4). In Tables 5 and 6, the distributional effects of environmental taxes and Crop production index on agricultural growth and GHG emission in the EU were estimated using the moment panel quantile regression with fixed effects (MM-QR) approach. For the 5th, 10th, … 90th percentiles of the conditional environmental policy and GHG emission, the 5th to 30th percentiles are employed to examine the effects of CE, economic performance/growth as Y, population density as PD, renewable energy consumption as RE, agricultural value-added as AG, environmental tax revenue as ET, and crop production index as CP on low conditional agricultural growth and GHG emission; 10th to 30th quantiles are used to specify the effect of low agricultural growth and GHG emission, from 40th to 60th percentiles are employed to specify the effects in medium agricultural growth and GHG emission and from 70th to 95th quantiles are used for the effects in high agricultural growth and GHG emission emitters.

In Table 5, the results show that Y positively impacts carbon emissions. All the estimations across the quantile, for instance, from the 10th to 90th quantile, are statistically significant and increase across the quantiles, showing that economic growth has a stronger impact on carbon emission at the lower quantile, middle and upper countries, respectively. The square of per capita Y has a negative coefficient and follows the similar distributional effects of environmental taxes across the 10th through 90th quantiles. Intuitively, the inverted EKC hypothesis (U-shaped inverted curve) is thus validated across the entire quantile distribution. The coefficient of PD and RE suggests that population density and renewable energy consumption negatively impact carbon emission, with statistical significance achieved across all quantiles in the agrarian European Union member countries. Put in another form, the impact of these two variables has a mitigating effect on carbon emission across the quantiles with a statistically significant effect across all

Table 2
Country-specific statistics.

Statistics	AG	CE	CP	ET	PD	RE	Y
France							
Mean	3.17 E+10	350.223	98.817	39,485.73	116.538	0.113	2.02 E+12
Median	3.13 E+10	360.760	99.160	36,035.50	117.240	0.103	2.07 E+12
Maximum	3.53 E+10	389.771	106.010	56,531.20	123.077	0.190	2.36 E+12
Minimum	2.69 E+10	251.083	89.800	30,634.19	108.739	0.059	1.60 E+12
Std. Dev.	2.32 E+09	36.865	4.521	8084.379	4.858	0.036	2.15 E+11
Skewness	−0.243	−0.880	−0.324	0.908	−0.223	0.860	−0.50
Kurtosis	2.392	2.998	2.188	2.496	1.640	2.843	2.28
Jarque-Bera	0.656	3.359	1.171	3.845	2.220	3.232	1.637
Probability	0.720	0.186	0.557	0.146	0.330	0.199	0.441
Germany							
	AG	CE	CP	ET	PD	RE	Y
Mean	2.06 E+10	805.487	93.451	54,115.18	235.120	0.867	2.77 E+12
Median	2.04 E+10	810.218	93.625	55,857.50	235.560	0.789	2.75 E+12
Maximum	2.54 E+10	914.845	107.610	61,112.71	238.252	2.205	3.24 E+12
Minimum	1.71 E+10	604.876	81.790	41,499.66	230.305	0.036	2.33 E+12
Std. Dev.	2.21 E+09	70.899	7.015	6141.813	2.053	0.718	2.74 E+11
Skewness	0.716	−0.818	0.064	−1.148	−0.985	0.445	0.148
Kurtosis	2.794	3.683	2.240	2.913	3.350	1.863	1.933
Jarque-Bera	2.268	3.403	0.644	5.724	4.335	2.258	1.328
Probability	0.322	0.182	0.725	0.057	0.114	0.323	0.515
Italy							
	AG	CE	CP	ET	RE	PD	Y
Mean	3.29 E+10	396.373	107.880	46,110.21	0.303	198.959	1.67 E+12
Median	3.29 E+10	410.489	108.650	43,819.50	0.168	199.335	1.69 E+12
Maximum	3.47 E+10	470.197	124.070	59,481.00	0.672	206.667	1.80 E+12
Minimum	3.07 E+10	287.157	95.400	31,015.51	0.037	193.276	1.50 E+12
Std. Dev.	1.11 E+09	53.845	7.734	8777.651	0.256	4.752	7.78 E+10
Skewness	−0.351	−0.358	0.190	0.234	0.429	0.210	−0.638
Kurtosis	2.504717	1.895	2.254	1.723	1.407	1.674	2.669
Jarque-Bera	0.798917	1.877	0.760	2.004	3.549	2.096	1.884
Probability	0.670683	0.391	0.684	0.367	0.170	0.351	0.390
Spain							
	AG	CE	CP	ET	PD	RE	Y
Mean	2.66 E+10	303.635	96.063	16,924.54	88.396	0.380	9.97 E+11
Median	2.61 E+10	299.472	94.835	17,477.50	91.372	0.340	1.04 E+12
Maximum	3.25 E+10	380.538	118.140	22,075.00	94.778	0.766	1.19 E+12
Minimum	1.83 E+10	220.404	59.030	9976.010	79.537	0.013	7.16 E+11
Std. Dev.	3.18 E+09	41.819	12.760	3556.318	5.686	0.285	1.37 E+11
Skewness	−0.191	0.198	−0.428	−0.442	−0.436	0.013	−0.722
Kurtosis	3.397	2.408	4.370	2.244	1.472	1.327	2.405
Jarque-Bera	0.330	0.549	2.827	1.470	3.354	3.032	2.639
Probability	0.848	0.760	0.243	0.480	0.187	0.220	0.267

Table 3
Panel unit root results.

	LLC		IPS	
	Constant	with trend	Constant	with trend
CE	4.301	2.292	4.437	2.966
AG	-3.018^{a}	-5.159^{a}	-3.264^{a}	-5368^{a}
Y	-3.417^{a}	1.200	-1.642^{c}	1.210
PD	-3.866^{a}	−0.802	-2.131^{b}	0.178
CP	-3.924^{a}	-7.607^{a}	-3.249^{a}	-6.340^{a}
RE	-6.269^{a}	0.181	-3.404^{a}	1.620
ET	-2.249^{b}	-2.102^{b}	−0.594	-1.402^{c}
Δ				
ΔCE	-1.375^{c}	-1.533^{c}	-3.706^{a}	-4.250^{a}
ΔAG	-8.778^{a}	-6.755^{a}	-9.130^{a}	-7.386^{a}
ΔY	1.265	1.466	-1.705^{b}	-1.654^{b}
ΔPD	−0.439	-1.660^{b}	−0.932	−0.521
ΔCP	-6.467^{a}	-5.315^{a}	-8.785^{a}	-7.944^{a}
ΔRE	-1.745^{b}	-4.916^{a}	-2.814^{a}	-7.737^{a}
ΔET	-2.857^{a}	-1.421^{c}	-4.301^{a}	-3.830^{a}

Note: Δ represents the first difference. The LLC and IPS are respectively the Levin et al. (2002) and Im et al. (2003) panel unit root approaches.

Table 4
Evidence of cointegration by Pedroni test.

	Model 1		Model 2	
	Statistic	p-value	Statistic	p-value
Modified Phillips-Perron t	1.915^{b}	0.028	0.994	0.160
Phillips-Perron t	1.866^{b}	0.031	-1.375^{c}	0.085
Augmented Dickey-Fuller t	2.836^{a}	0.002	-1.710^{b}	0.044

Note: The panel estimation employs Kernel with Bartlett and Augmented lags as 1.

quantile in the agrarian EU member countries. ET has a negative impact on CO_2 emissions. However, the magnitude of the effects of the independent variables on CO_2 emissions varies according to the quantiles. However, the estimates from the 10th to 20th quantile are statistically insignificant. This suggests that ET does not explain CO_2 emissions in the lower quantile countries. From the 30th to the 90th quantiles, the coefficient of ET is negative and statistically significant but decreases across the quantiles. This shows that ET substantially reduces environmental issues in countries at the lower quantile than at the upper quantiles, indicating that a unit increase in ET decreases CO_2 emissions in the EU countries by −0.212% to - 0.209%, ceteris paribus. By intuition, the revenue generated by imposing a pollution tax is used to fund tax reductions in other areas of the economy, which could be the reason for the reduced impact of ET on CO_2 emissions. These findings are contrary to the submission by Meng et al. (2013) on the insignificant effect of ET on GHG emissions.

Moreover, in Table 6, the coefficients of Y and PD are positive and statistically insignificant across the quantiles. The insignificant effects of economic performance/growth and population density on agricultural growth could be explained by the fact that there is a dynamic paradigm

Table 5
Results of Machado and Silva et al. (2019) 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
Y	56.428^{a}	3.233^{c}	51.549^{a}	52.979^{a}	53.965^{a}	55.963^{a}	57.099^{a}	58.266^{a}	59.019^{a}	59.941^{a}	61.003^{a}
	(0.000)	(0.088)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Y^{2}	-0.983^{a}	-0.057^{a}	-0.898^{a}	-0.923^{a}	-0.940^{a}	-0.975^{a}	-0.995^{a}	-1.016^{a}	-1.029^{a}	-1.045^{a}	-1.064^{a}
	(0.000)	(0.000)	(0.07)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
PD	-2.705^{a}	0.082	-2.828^{a}	-2.792^{a}	-2.767^{a}	-2.716^{a}	-2.688^{a}	-2.658^{a}	-2.639^{a}	-2.616^{a}	-2.588^{a}
	(0.000)	(0.493)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RE	-0.048^{a}	0.003	-0.052^{b}	-0.051^{a}	-0.049^{a}	-0.048^{a}	-0.047^{a}	-0.046^{a}	-0.045^{a}	-0.045^{a}	-0.048^{b}
	(0.009)	(0.024)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.006)	(0.023)
ET	-0.211^{b}	0.001	-0.213	-0.212	-0.212^{c}	-0.211^{b}	-0.211^{b}	-0.210^{b}	-0.211^{c}	-0.209^{c}	-0.209
	(0.126)	(0.965)	(0.234)	(0.143)	(0.088)	(0.026)	(0.021)	(0.035)	(0.056)	(0.098)	(0.162)

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 6
Results of Machado and Silva et al. (2019) 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
Y	0.057	-0.072	0.178	0.145	0.104	0.069	0.041	0.026	-0.002	-0.018	-0.044
	(0.594)	(0.363)	(0.409)	(0.407)	(0.427)	(0.510)	(0.673)	(0.793)	(0.989)	(0.889)	(0.778)
PD	0.089	-0.095	0.249	0.206	0.151	0.105	0.068	0.048	0.012	-0.010	-0.444
	(0.694)	(0.339)	(0.655)	(0.650)	(0.655)	(0.697)	(0.786)	(0.851)	(0.969)	(0.976)	(0.912)
CP	0.006^{a}	0.001	0.005^{a}	0.005^{a}	0.006^{a}	0.006^{a}	0.006^{a}	0.007^{a}	0.007^{a}	0.007^{a}	0.007^{a}
	(0.003)	(0.265)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ET	0.191^{c}	0.058	0.093	0.119^{a}	0.153^{b}	0.181^{a}	0.204^{a}	0.216^{a}	0.238^{a}	0.251^{a}	0.273^{a}
	(0.053)	(0.245)	(0.349)	(0.135)	(0.011)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

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.

shift from high agricultural emitting activities to cleaner production activity. There is a strong significant positive association between CP and agricultural growth across the MM-QR (10th −90th). When the size of the coefficient estimates across the entire quantile distribution is considered, it is clear that the crop production index (Cp) has a more significant impact on CO_2 emissions in countries in the upper quantiles. For instance, a unit increase in crop production index increases agricultural growth by 0.005.007% at the 10th quantile through to the 90th quantile, affirming that the crop production index, in these countries, remains a key determining factor that drives agricultural growth.

Interestingly, from lower to higher quantiles, the effect of the crop production index on agricultural growth is improving. ET is positively linked with agricultural growth, but estimates in the 10th and 20th quantiles are statistically insignificant. From 30th and 90th quantiles, the magnitude of the effects of the independent variables on agricultural growth varies according to the quantiles, and the effects of ET become more statistically significant, confirming the presence of the double dividend hypothesis at the upper and middle quantiles in the agrarian European Union member countries. When the size of the coefficient estimates across the 30th and 90th quantile distribution is considered, it is clear that the ET has a greater impact on agricultural growth in countries in the middle and upper quantiles. For instance, a unit increase in ET increases agricultural growth by 0.153% at the 30th quantile and by 0.273% at the 90th quantile. This shows the benefit of ET on welfare and a boost to the economy. At the same emphasis, the economic benefits of a sustainable taxation system are channeled to economic growth, for which agricultural businesses and their stability and survival play a significant role.

The location showed mixed findings indicating that all the independent variables strongly affect the CO_2 emissions and agricultural growth except ET and PD in Tables 5 and 6, respectively. Similarly, the scale effect coefficients in Table 5 and all the estimates in Table 6 are statistically insignificant in influencing CO_2 emissions and agricultural growth.

4.1.1. *Robustness evidence*

To confirm the validity of the estimates, we implement the FMOLS model that incorporates several econometric advantages. Fully Modified Ordinary Least Squares Fully Modified Ordinary Least Square (FM-OLS) was initially designed by Phillips and Hansen (1990) with an inbuilt historical aim to provide optimal estimates of co-integrating regressions. This method modifies the OLS to account for serial correlation effects and endogeneity in the regressors resulting from the existence of a co-integrating relationship (Phillips and Hansen, 1990). The results presented in Table 7 are similar to the MMQR output. Accordingly, gross domestic product and square Gross Domestic Product in the model specification (1) have positive and negative effects on GHG emissions. The result indicates that a 1% increase in Gross Domestic Product will lead to a significant increase in the GHG emission in the EU by 55.531%, square Gross Domestic Product negative and statistically significant, thereby revalidating the EKC hypothesis already established in the previous sections. PD, RE, and ET have a statistically significant negative impact on GHG emissions. The parameter estimates for model 2 also show that PD, CP, and ET have a stronger effect on agricultural output, while Gross Domestic Product is statistically insignificant.

Prioritizing knowledge addendum results adds to the growing body of evidence in two new research areas. The first collection of studies reveals that environmental taxes and renewable energy are successful

Table 7
Robustness with long-run.

FMOLS	Weighted	Grouped	Weighted	GroupedModel 1	Model 2
Y	55.531^{c}	122.917^{b}	Y	0.024	−0.024
Y^{2}	−1.104^{c}	−2.167^{b}	PD	0.115^{a}	0.162
PD	−2.643^{b}	−0.772^{c}	CP	−0.208^{b}	0.007^{a}
RE	−0.040^{b}	−0.195^{a}	ET	0.174^{a}	0.120^{c}
ET	−0.282^{b}	−0.162^{c}			

Note: The 1%, 5%, and 10% statistically significant levels are represented as ^{a}, ^{b}, and ^{c} respectively.

tools against environmental damages, as evidenced by the negative correlation between GHG emissions and environmental taxes and renewable energy. The second set of studies shows how environmental taxes and crop production affect environmental quality, leading to the double dividend hypothesis. It supports the emerging number of empirical entries supporting the double dividend (DD) hypothesis in different countries by several authors (see Jorgenson et al., 2013; Chen et al., 2017; Orlov et al., 2013; Allan et al., 2014; Jiang and Shao, 2014; Sajeewani et al., 2015; Chisari and Miller, 2015; Chen et al., 2017). Surprisingly few studies in the literature explain the environmental impact of the dividend hypothesis under varied levels of environmental taxes and crop production. In this study, we demonstrate how environmental taxes and crop production can reverse the negative environmental impact of economic activities by encouraging the co-benefit of a cleaner environment. However, opposing studies by Goulder (2013), Meng et al. (2013), Zhang et al. (2016), Pereira et al. (2016), and Othman (2017) still document no evidence to support the DD hypothesis for an environmental-related tax; thus, the debate is ongoing.

4.1.2. *Panel granger causality evidence*

In this section, we implemented Dumitrescu and Hurlin (2012) non-causality test. D-H panel causality test classified in econometric parlance under a more recent Granger causality test was proposed by Dumitrescu and Hurlin (2012). The merits of the test over conventional causality tests reside in the fact that the D-H causality test is robust in the presence of cross-sectional dependence and heterogeneity issues. Table 8 explores the two main types of hypotheses: (a) double dividend hypothesis, (b) feedback hypothesis, which borders on checks on cause and effect from one variable to another under the auspice of the D-H panel causality test. Accordingly, a unidirectional causality relationship runs from economic performance/growth, population density, and environmental tax revenue environmental pollution in the EU economies, leading to the double dividend hypothesis. In line with these findings, it is obvious that these exogenous variables can be helpful in reducing environmental degradation by using a pollution tax generated to fund tax reductions in other areas of the economy. The crop production index has a bidirectional relationship with pollution, confirming the feedback hypothesis.

5. Conclusion and policy

This study aims to investigate the relationship between environmental taxes and agricultural growth and determine the nature of the relationship between the use of taxation as an instrument for environmental policy and GHG emissions in the largest agrarian European Union member countries utilizing the recently developed MMQR technique. This study is beneficial because it provides detailed explanations for the correlation between variables along various quantiles for 1995–2020, which standard approaches may overlook. In model 1, the study tested the EKC hypothesis in the sample country across quantiles, confirming the inverted EKC hypothesis (U-shaped invested curve). ET exerts a negative impact on GHG emissions, which is more potent in the countries at the lower quantile than those in the upper quantiles. In model 2, the crop production index (Cp) has a greater impact on CO_2 emissions in countries in the upper quantiles. At the same time, ET is positively linked with agricultural growth from the middle and upper quantiles, and the magnitude of the effects of the independent variables on agricultural growth varies according to the quantiles, confirming the presence of the double dividend hypothesis at the upper and middle quantiles in the agrarian European Union member countries. Further investigation reveals a unidirectional causality relationship that runs from economic performance/growth, population density, and environmental tax revenue environmental pollution in the EU economies, leading to the double dividend hypothesis. The crop production index has a bidirectional relationship with pollution, confirming the feedback hypothesis. Although the current study is limited in the scope of both the cases of the countries being considered for the investigation and the sector (limited to the agricultural sector) which could be reconsidered in future endeavour, the findings suggest arrays of important policy relevance.

Table 8
Robustness with Granger causal relationship.

Relationship	W- Statistic	Zbar-Statistic	Probability
Y dnhc > CE	4.725^{b}	1.980	0.048
CE dnhc > Y	1.452	−0.623	0.534
PD dnhc > CE	5.580^{a}	2.659	0.007
CE dnhc > PD	3.511	1.015	0.310
RE dnhc > CE	4.090^{c}	1.801	0.072
CE dnhc > RE	1.539	−0.554	0.580
ET dnhc > CE	4.501^{a}	8.77	0.00
CE dnhc > ET	0.47	−0.75	0.45
PD dnhc > AG	5.812^{a}	2.843	0.005
AG dnhc > PD	3.235	0.795	0.428
CP dnhc > AG	4.619^{c}	1.895	0.058
AG dnhc > CP	5.689^{a}	2.746	0.006

Note: dnhc > implies 'does not homogeneously cause'.

5.1. *Policy implication*

There is no doubt about the significance of the highlighted findings to the EU's largest agrarian economies and the EU member states at large. The policy options peculiar to the above findings include; a) The result further pointed to the relevance of clean and/or alternative energy source in mitigating environmental degradation especially in the Europe region where the implementation of energy transition policy is significantly ahead of other global regions. Thus, the governments of the selected agrarian economies would be able to reap more benefit of environmental taxation by riding on more rapid adoption of the alternative forms of energy through a resilient environmental tax system that increases the cost of using traditional fossil fuels for agriculture, transportation, and industrial use. Given that the result opined increased value-add to agriculture through increased environmental tax, then it is safe to clamor for more investment in sustainable agriculture through policy mechanism that support entrepreneurial activities and more private sector investment. In order to ramp up the sustainable agriculture activities, decision makers in the examined countries could facilitate the availability of credit facilities, subsidy for clean agricultural technologies, and the provision of other capital and financial-related supports Moreover, the governments of the selected agrarian economies could deploy higher proportion of tax revenue generated from anthropogenic activities to ease the burden of their citizens through extant tax reductions in other areas in favour of social welfare.

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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.

Data availability

Data will be made available on request.

References

Agboola, M.O., Bekun, F.V., 2019. Does agricultural value added induce environmental degradation? Empirical evidence from an agrarian country. Environ. Sci. Pollut. Control Ser. 26 (27), 27660–27676. https://doi.org/10.1007/s11356-019-05943-z.

Allan, G., Lecca, P., McGregor, P., Swales, K., 2014. The economic and environmental impact of a carbon tax for scotland: a computable general equilibrium analysis. Ecol. Econ. 100, 40–50. https://doi.org/10.1016/j.ecolecon.2014.01.012.

Alola, A.A., Nwulu, N., 2022. Do energy-pollution-resource-transport taxes yield double dividend for Nordic economies? Energy, 124275.

Alola, A.A., Alola, U.V., 2018. Agricultural land usage and tourism impact on renewable energy consumption among Coastline Mediterranean Countries. Energy Environ. 29 (8), 1438–1454.

Alola, A.A., Yalçiner, K., Alola, U.V., 2019. Renewables, food (in) security, and inflation regimes in the coastline Mediterranean countries (CMCs): the environmental pros and cons. Environ. Sci. Pollut. Control Ser. 26 (33), 34448–34458.

Baranzini, A., van den Bergh, J., Carattini, S., Howarth, R., Padilla, E., Roca, J., 2016. Seven Reasons to Use Carbon Pricing in Climate Policy (Working Paper 253). Centre for Climate Change Economics and Policy, London.

Bashir, M.F., Ma, B., Shahbaz, M., Jiao, Z., 2020. The nexus between environmental tax and carbon emissions with the roles of environmental technology and financial development. PLoS One 25 (11), e0242412. https://doi.org/10.1371/journal.pone.0242412, 15.

Bollen, J., Guay, B., Jamet, S., Corfee-Morlot, J., 2009. OECD economics department working papers No. 693. In:) Co-benefits of Climate Change Mitigation Policies: Literature Review and New Results. OECD, Paris.

Bonnet, C., Bouamra-Mechemache, Z., Corre, T., 2018. An environmental tax towards more sustainable food: empirical evidence of the consumption of animal products in France. Ecol. Econ. 147, 48–61. https://doi.org/10.1016/j.ecolecon.2017.12.032.

Bourne, M., Childs, J., Philippidis, G., Feijoo, M., 2012. Controlling greenhouse gas emissions in Spain: what are the costs for agricultural sectors? Spanish J. Agric. Res. 10 (3), 567. https://doi.org/10.5424/sjar/2012103-564-11.

Bovenberg, A.L., de Moojj, R.A., 1994. Environmental levies and distortionary taxation and labor market distortions. Eur. J. Polit. Econ. 10 (4), 655–683. https://doi.org/10.1016/0176-2680(94)90032-9.

British Petroleum, 2021. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. (Accessed 10 January 2022). Accessed.

Chen, W., Zhou, J.F., Li, S.Y., Li, Y.C., 2017. Effects of an energy tax (carbon tax) on energy saving and emission reduction in Guangdong province-based on a CGE model. Sustainability 9 (5), 681. https://doi.org/10.3390/su9050681.

Chien, F., Ananzeh, M., Mirza, F., Bakar, A., Vu, H.M., Ngo, T.Q., 2021. The effects of green growth, environmental-related tax, and eco-innovation towards carbon neutrality target in the US economy. J. Environ. Manag. 299, 113633.

Chisari, O.O., Miller, S.J., 2015. CGE Modeling: the Relevance of Alternative Structural Specifications for the Evaluation of Carbon Taxes' Impact and for the Integrated Assessment of Climate Change Effects: Simulations for Economies of Latin America and the Caribbean. Inter-American Development Bank, Washington DC.

Deng, H.-M., Liang, Q.-M., Liu, L.-J., Anadon, L.D., 2017. Co-benefits of greenhouse gas mitigation: a review and classification by type, mitigation sector, and geography. Environ. Res. Lett. 12 (12), 123001 https://doi.org/10.1088/1748-9326/aa98d2.

Dumitrescu, E., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Econ. Modell. 29, 1450–1460, 2012.

European Union Statistics. https://ec.europa.eu/eurostat/data/database, 2022–. (Accessed 10 January 2022).

European Environmental Agency, 2022. https://www.eea.europa.eu/publications/the-role-of-environmental-taxation. (Accessed 15 October 2022). Accessed.

Fraser, I., Waschik, R., 2013. The double dividend hypothesis in a CGE model: specific factors and the carbon base. Energy Econ. 39, 283–295. https://doi.org/10.1016/j.eneco.2013.05.009.

Freire-González, J., 2018. Environmental taxation and the double dividend hypothesis in CGE modelling literature: a critical review. J. Pol. Model. 40 (1), 194–223. https://doi.org/10.1016/j.jpolmod.2017.11.002.

Freire-González, J., Ho, M.S., 2019. Carbon taxes and the double dividend hypothesis in a recursive-dynamic CGE model for Spain. Econ. Syst. Res. 31 (2), 267–284. https://doi.org/10.1080/09535314.2019.1568969.

Gemechu, E.D., Butnar, I., Llop, M., Castells, F., 2012. Environmental tax on products and services based on their carbon footprint: a case study of the pulp and paper sector. Energy Pol. 50, 336–344. https://doi.org/10.1016/j.enpol.2012.07.028.

Ghazouani, A., Jebli, M.B., Shahzad, U., 2021. Impacts of environmental taxes and technologies on greenhouse gas emissions: contextual evidence from leading emitter European countries. Environ. Sci. Pollut. Control Ser. 28, 22758–22767.

Goulder, L.H., 2013. Climate change policy's interactions with the tax system. Energy Econ. 40 https://doi.org/10.1016/j.eneco.2013.09.017. S3–S11.

Hedenus, F., Wirsenius, S., Johansson, D.J.A., 2014. The importance of reduced meat and dairy consumption for meeting stringent climate change targets. Climatic Change 124 (1–2), 79–91. https://doi.org/10.1007/s10584-014-1104-5.

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. J. Econom. 115 (1), 53–74.

Inkábová, M., Andrejovská, A., Glova, J., 2021. The impact of environmental taxes on agriculture– the case of Slovakia. Pol. J. Environ. Stud. 30 (4), 3085–3097. https://doi.org/10.15244/pjoes/130729.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

Jaeger, W.K., 2013. Double dividend. Encyclopedia of Energy, Natural Resource, and Environmental Economics 37–40.

Jiang, Z., Shao, S., 2014. Distributional effects of a carbon tax on Chinese households: a case of Shanghai. Energy Pol. 73, 269–277. https://doi.org/10.1016/j.enpol.2014.06.005.

Jorgenson, D.W., Goettle, R.J., Ho, M.S., Wilcoxen, P.J., 2013. Double Dividend: Environmental Taxes and Fiscal Reform in the United States. MIT Press, Cambridge, MA.

Kosonen, K., Nicodeme, G., 2009. The Role of Fiscal Instruments in Environmental Policy. Retrieved from. https://dipot.ulb.ac.be/dspace/bitstream/2013/53982/1/RePEc_sol_wpaper_09-026.pdf.

Kotnik, Z., Klun, M., Skulj, D., 2014. The effect of taxation on green house gas emissions. Transylvanian Review of Administrative Sciences 10 (43), 168–185.

Levin, A., Lin, C.F., Chu, C.S.J., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. J. Econom. 108 (1), 1–24.

López, R., Galinato, G.I., Islam, A., 2011. Fiscal spending and the environment: theory and empirics. J. Environ. Econ. Manag. 62 (2), 180–198. https://doi.org/10.1016/j.jeem.2011.03.001.

Machado and Silva (2019) Machado, J.A., Silva, J.S., 2019. Quantiles via moments. J. Econom. 213 (1), 145–173.

Mardones, C., Lipski, M., 2020. A carbon tax on agriculture? A CGE analysis for Chile. Econ. Syst. Res. 32 (2), 262–277. https://doi.org/10.1080/09535314.2019.1676701.

McKitrick, R., 1997. Double dividend environmental taxation and Canadian carbon emissions control. Canadian Public Policy - Analyse De Politiques XXIII (4). Retrieved from. https://www.jstor.org/stable/3552072.

Meng, S., 2015. Is the agricultural industry spared from the influence of the Australian carbon tax? Agric. Econ. 46 (1), 125–137. https://doi.org/10.1111/agec.12145.

Meng, S., Siriwardana, M., McNeill, J., 2013. The environmental and economic impact of the carbon tax in Australia. Environ. Resour. Econ. 54 (3), 313–332. https://doi.org/10.1007/s10640-012-9600-4.

Muoneke, O.B., Okere, K.I., Nwaeze, C.N., 2022. Agriculture, globalization, and ecological footprint: the role of agriculture beyond the tipping point in the Philippines. Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-022-19720-y.

Orlov, A., Grethe, H., 2012. Carbon taxation and market structure: a CGE analysis for Russia. Energy Pol. 51, 696–707. https://doi.org/10.1016/j.enpol.2012.09.012.

Orlov, A., Grethe, H., McDonald, S., 2013. Carbon taxation in Russia: prospects for a double dividend and improved energy efficiency. Energy Econ. 37, 128–140. https://doi.org/10.1016/j.eneco.2013.01.008.

Othman, J., 2017. Carbon and energy taxation for CO2 mitigation: a CGE model of the Malaysia. Environ. Dev. Sustain. 19, 239–262. https://doi.org/10.1007/s10668-015-9725-z.

Pearce, D., 1991. The role of carbon taxes in adjusting to global warming. Econ. J. 101 (407), 938–948.

Pedroni, P., 1999. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxf. Bull. Econ. Stat. 61, 653–670.

Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econom. Theor. 20 (3), 597–625.

Pereira, A.M., Pereira, R.M., Rodrigues, P.G., 2016. A new carbon tax in Portugal: a missed opportunity to achieve the triple dividend? Energy Pol. 93, 110–118. https://doi.org/10.1016/j.enpol.2016.03.002.

Phillips, P.C., Hansen, B.E., 1990. Statistical inference in instrumental variables regression with I (1) processes. Rev. Econ. Stud. 57 (1), 99–125.

Qing, L., Alwahed Dagestani, A., Shinwari, R., Chun, D., 2022a. Novel Research Methods to Evaluate Renewable Energy and Energy-Related Greenhouse Gases: Evidence from BRICS Economies. Economic Research-Ekonomska Istraživanja. https://doi.org/10.1080/1331677X.2022.2080746, 1–17.

Qing, L., Chun, D., Ock, Y.S., Dagestani, A.A., Ma, X., 2022b. What myths about green technology innovation and financial performance's relationship? A bibliometric analysis review. Economies 10 (4), 92.

Sadiq, M., Wen, F., Dagestani, A.A., 2022. Environmental footprint impacts of nuclear energy consumption: the role of environmental technology and globalization in ten largest ecological footprint countries. Nucl. Eng. Technol. 54 (10), 3672–3681. https://doi.org/10.1016/j.net.2022.05.016.

Sajeewani, D., Siriwardana, M., Mcneill, J., 2015. Household distributional and revenue recycling effects of the carbon price in Australia. Climate Change Economics 6 (3), 1550012. https://doi.org/10.1142/S2010007815500128.

Säll, S., Gren, I.-M., 2015. Effects of an environmental tax on meat and dairy consumption in Sweden. Food Pol. 55, 41–53. https://doi.org/10.1016/j.foodpol.2015.05.008.

Ulucak, R., Danish, Kassouri, Y., 2020. An Assessment of the Environmental Sustainability Corridor: Investigating the Non-linear Effects of Environmental Taxation on CO2 Emissions. Sustainable Development, pp. 1–9. https://doi.org/10.1002/sd.2057, 2020.

Wesseh, P.K., Lin, B., 2019. Environmental policy and 'double dividend' in a transitional economy. Energy Pol. 134, 110947 https://doi.org/10.1016/j.enpol.2019.110947.

World Development Indicators, 2021. https://data.worldbank.org/indicator. (Accessed 10 January 2022). Accessed.

Zhang, X., Guo, Z., Zheng, Y., Zhu, J., Yang, J., 2016. A CGE analysis of the impacts of a carbon tax on provincial economy in China. Emerg. Mark. Finance Trade 52 (6), 1372–1384. https://doi.org/10.1080/1540496X.2016.1152801.