Implication of electricity taxes and levies on Sustainable Development Goals in the European Union

Amin Karimu[+,1] and Ranjula Bali Swain [*, 2,3]

[1]University of Ghana Business School, Legon, Ghana

[2]Misum, Stockholm School of Economics, Stockholm, Sweden
[3]Södertörn University, Stockholm, Sweden

Abstract

Environmental/energy taxes are supposed to benefit the environment but may also have macroeconomic benefits such as increase in employment and economic growth. The current high electricity prices in the European Union (EU) due in part as a result of high taxes may have some influence on some of the sustainable development goals (SDGs). In this study, we examine the synergy and trade-off effects of electricity taxes on selected SDGs for EU countries. Using panel data and panel vector autoregressive estimation approach, our findings revealed that higher household electricity taxes reduces both carbon emission and unemployment, which is in line with the double- divided hypothesis of such taxes. Whereas higher industry electricity taxes increase responsible production and consumption (SDG12) and a reduction in unemployment. Moreover, there is evidence of a strong synergy effect between electricity taxes, unemployment and carbon emission but a trade-off between tax and SDG9 (innovation and sustainable infrastructure). Furthermore, taxes contribute significantly to future variation of unemployment, carbon emission, economic growth, responsible production and consumption in the EU.

Keywords: Electricity, EU, Household, Industry, Tax, Sustainable development goals

JEL Classification: H2, Q56, O13, O14, Q41, Q43

[+] Email: a.karimu@ug.edu.gh.
[*] Email: Ranjula.Bali@hhs.se.
Research grant from Swedish Energy Agency is gratefully acknowledged.

1. Introduction

Retail electricity prices have substantially increased in the last decade in the European union (EU) and this has been blamed on the increase in renewable support policy to promote renewables in the power sector. Admittedly, the renewable support policy has led to a significant increase in the share of renewables in the electricity generation mix, which is good for some of the sustainable development goals (SDGs) such as climate action (SDG13), responsible production and consumption (SDG12) among others. There are suggestions in the literature (e.g., Ortega and del Rio, 2016) that the renewables support policies implemented in various EU countries may have led to increases in retail prices of electricity in the past decade. For instance, between 2009 and 2013, total wind energy support cost increased about three-fold (4.883 million euros to 12.447million euros), and that of PV solar support increased about four-fold, from 5.855 million euros to 23.128 (Ortega and del Rio, 2016).

Conversely, a recent study by Trujillo-Baute (2018) found that though the cost of renewable support policy in the electricity sector is a contributing factor to the increases in retail electricity price, nonetheless, it is not a major contributor. The authors identified energy cost due to taxes and levies, network cost and energy own cost (wholesale electricity price) as the major contributing factors to the retail price increases in the EU, especially in the household sector.

Granted that electricity tax is a major contributor to the high electricity price experienced in the region for the past decade, will a high electricity tax policy be counter-productive to or in-line with the quest of improving on some of the SDGs such as access to affordable and clean energy (SDG7), economic growth and employment (SDG8), reduction in carbon emission and SDG12?

The main objective of this study is to determine the effects of electricity taxes and levies on SDGs in the EU-28 and Norway, and given the impact, assess the causal effects on SDGs to understand their trade-offs, synergy and complementarities to inform policy. Furthermore, the study will assess the heterogeneity of electricity taxation on the SDGs via analysing households' electricity taxes separately from that of industrial electricity taxes. This is because the tax and levies cost are generally passed on to the final consumer, which has direct effect on energy price, and indirect effect on the various SDGs that are closely linked to energy (electricity in this case) such as access to affordable and clean energy, jobs creation and employment outcomes due to the cost of energy, emission effect due to the high price effect of taxes.

The heterogeneity is important due to the current policy of imposing relatively higher taxes on the household electricity consumption relative to that of industrial electricity consumption. This study aims in providing the effect of electricity taxes and levies policy on these various sustainable development goals in terms of how such a tax policy is in line with promoting some of the SDGs that are positively interlinked with the electricity tax policy, and how to remedy the trade-offs with some of the SDGs that are negatively interlinked with such taxes with additional policy measures to reduce such negative effects.

In the extent literature, most of the prior studies on electricity taxes were focus on distributional effects (Barker and KoKhler, 1998; Speck ,1999; Ekins et al., 2011; Oueslati, 2017), price effect (Trujillo-Baute et al.,2018; Borozan, 2018), emissions effect (Brännlund et al., 2014; Haites, 2018; Kettner-Marx and Kletzan-Slamanig , 2018) and barriers to the acceptability of such taxes in the EU (Carattini et al., 2017; Weishaar,2018). None of these studies explicitly considered the effect of electricity price or taxes on the SDGs in order to understand the potential interlinkages between such policies on the environment (SDG13), welfare (SDG7) and the macroeconomic (SDG9, SDG8, SDG12).

Applying a panel vector autoregressive (PVAR) estimation approach, findings from the study revealed that electricity tax is a significant causal factor to some of the SDGs. Specifically, there is evidence of a double-divided of electricity tax from the household sector. It promoted the reduction in both carbon emission (SDG13) and unemployment. Nevertheless, this was not the case for the industry sector since there was no evidence of a significant reduction in carbon emission. Furthermore, the finding also revealed heterogeneity of electricity tax effect across the two sectors (household and industry). Whereas household electricity tax had a significant effect on unemployment (SDG8W), innovation and sustainable infrastructure (SDG9) and climate action (SDG13), industry electricity tax had a significant effect on economic growth (SDG8G), unemployment and responsible production and consumption (SDG12). Our evidence also revealed some interlinkages between some of the SDGs and also between tax and some of the SDGs.

In what follows, we will present a brief overview of electricity taxation in the EU, provide a brief review of the literature in section 3, before moving on to discuss the data and methodology in Section 4 and the results in Section 5. The summary and conclusions are discussed in the final section.

2. Overview of Environmental/Energy Taxation in European Union member states

Historically, energy taxes have been implemented in the EU as early as 1917 and 1924, specifically in Denmark and Sweden for revenue reasons rather than environmental concerns (Speck,1999). But at these early stages, energy taxes were mainly on oil. Since the 1990s, various forms of energy and carbon taxes have been implemented by various countries in the EU to tackle both environmental and revenue goals (Hasselknippe and Christiansen,2003). These taxes cover a range of different fuels and different segments of the energy system, including the electricity sub-sector. Though the environmental reasons for such taxes maybe appealing in attracting support for such policies, nonetheless they do not appear to be the overriding reason by politicians for their implementation. The reason being that some of the fuels with much more carbon content (coal) are taxed relatively less compare to others (gasoline), which has a less carbon content than coal.

The evolution of energy taxes in the EU member states can generally be grouped into four phases. The first phase covers the period such taxes were first introduced by some of the members states such as those in the Nordic region up until the first oil crisis. In this period, energy taxes were implemented to raise revenue. The second phase cover the oil crisis in the 1970s, where security concern was an important issue. As a consequence, energy taxes in the second phase were designed to incentivised more efficient use of energy. During the 1980s, energy taxes were designed by EU -member states based on environmental principles and in 1990s, the fourth phase, climate change consideration took a centre stage in the EU energy taxation.

In the EU Council Directive 92/82/EEC, various minimum excise duties were established for different energy sources such as mineral oils used as propellants or for heating and for different application areas. Generally, fuels used for heating purposes were subjected to lower tax rates than those for transport (Kettner-Marx and Kletzan-Slamanig, 2018). In 2003, the directive was revised (Directive 2003/96/EC) which provided new minimum tax rates for propellants, heating fuels and electricity. In the case of electricity, differentiated minimum tax rates were defined for businesses and non-businesses. The goal of the directive is to established minimum tax rates for different energy sources and application areas in the EU.

Energy taxes are part of the EU portfolio of energy related environmental policy instruments which include the EU emission trading system (EUETS) and the renewable energy directive. EUETS is a policy that target at reducing emission by putting a cap on emission from industry; the renewable energy directive on the other hand is aimed at reducing energy security concerns that the EUETS creates by promoting renewable energy supply to replace the high polluting energy sources. These three policy instruments are often implemented concurrently.

Irrespective of the final agreement on the established minimum rates for electricity taxation in the EU, there is still significant differences in electricity tax rates both for households and industry across the EU member countries, whereas the Nordic countries such as Denmark have close to 60 percent of the household retail electricity prices made-up of electricity taxes, Spain has only 20 percent of the retail prices contributed by taxes (Eurostat, 2018).

3. A Brief literature Review

The concept of carbon tax-energy tax has been explored in depth by economists since the 1988 Toronto Conference on the Changing Atmosphere: Implications for Global Security conference. The concerns for human activities on the environment was formally discussed at a global level at the conference, with a suggestion of creating a world atmosphere fund financed in part by a carbon/energy tax, and to reduce carbon emissions by 20% in the year 2005. The research since than can be broadly grouped into four themes: carbon tax and energy tax effect on emissions; the impact of these taxes on income distribution; the price effect of such taxes and “others” (which include research on such taxes on issues such as berries to effective introduction and implementation of such taxes, investment effect and influence on technology)

Table 1 below summarizes some of the main studies in the literature by type of study (theoretical, empirical, reviews), time periods studied, the geographical scope, and the main findings of the study.

The summary review literature suggests that most of the early research on carbon-energy taxes, especially in the early 1990s, were focused on the carbon emission effects generally influenced by events during that period, especially after the 1988 Toronto conference on the charging atmosphere and the awareness thereafter about global emissions and the need to curb them. Some of the early research on the emission effect of carbon/energy tax are those from the Nordic countries as reviewed by Andersen (2004).

The finding from the early studies suggest some reduction of emission by carbon/energy taxes, which ranges between 3 to 5 per cent in Sweden, about 5 per cent in Denmark and as high as 30 per cent in Norway (Andersen, 2004).

Later research within this theme (Brännlund et al., 2014; Kuo et al., 2016; Haites, 2018; Borck and Brueckner , 2018 ; Kettner-Marx and Kletzan-Slamanig , 2018) all found some emission reduction from carbon/energy taxes but at magnitudes that are on the average smaller than the earlier studies. One potential reason for this maybe that the early studies were done in a period when few policy instruments (besides carbon/energy tax) were implemented to help reduce emissions. Therefore, most of the emission reduction during the early period was a result of carbon/energy taxes. In recent years, several policy instruments are simultaneously implemented, and the emission reduction is the cumulative impact of multiple policy instruments, thereby reducing the magnitude effect of only carbon-energy tax on emission.

The studies that investigated the emission effect of such taxes at the firm and enterprises level, also found some emission reduction effect. Brännlund et al. (2014) found carbon taxes to have improved environmental performance in Swedish industrial sectors, driven by the reduction in energy intensity in their operations. Whereas Kuo et al. (2016) suggested that enterprises in Taiwan tended to switch to a low carbon production technology, which has a reduction effect on emission.

After much discussion and some evidence on the potential contribution of carbon/energy tax on emission, it was natural for researchers to question and asses its distributional implications, especially the incidence of such taxes on different income groups in society, thus, whether the tax burden is heavy on the poor, the rich or proportional. Studies within this theme (Barker and KoKhler ,1998; Speck, 1999; Ekins et al., 2011; Dissou and Siddiqui, 2014; Thomas and Flues, 2015; Levinson, 2016: Oueslati et al., 2017) generally found such taxes to be mildly regressive on average for develop countries, generally progressive for developing countries and that the incidence of such taxes tended to depend on the type of energy carrier. For instance, Thomas and Flues (2015) found that taxes on transport fuels are not regressive on average, taxes on heating fuels are mildly regressive, whiles taxes on electricity are more regressive relative to those on heating fuels.

Of the selected studies, 4 researched around the effect of carbon/energy taxes on retail prices of electricity, which is partly motivated by the rising prices of retail electricity prices in the last decade, especially in Europe even after deregulating the electricity sector. Findings from these studies (Apergis, 2012; Chiu et al., 2015; Trujillo-Baute et al.,2018; Borozan, 2018) were quite similar across majority of these studies, which tended to indicate that on the average, such taxes have a positive effect on retail electricity price. Trujillo-Baute et al. (2018) study was based on European member countries, where the focus was rather on renewable support policy on retail electricity price. In their analysis, they also assess the impact of taxes and levies, which tended to have a much larger (positive) effect on prices relative to the renewable support cost.

The other European based study within the theme is Borozan (2018), who studied the influence of energy taxes on electricity consumption via both the direct and indirect impacts. The indirect impact is assessed via electricity prices. The finding indicates that energy taxes influence electricity consumption more efficiently through energy prices than directly in the countries studied.

The reviewed literature also contains studies on diverse issues (barriers to energy taxes, influence on technology, investment effect) that are not directly on prices, distribution and carbon effects. Some of these other studies includes focus on topics such as barriers to effective introduction and implementation of carbon/energy taxes, investment effect on energy intensity, influence on technology among others. These other studies are classified as the "others" theme. Selected studies within this theme includes; Martin (2014), Carattini et al. (2017), Weishaar (2018).

Among the selected studies on the "other" theme, only one (Martin, 2014) focused on assessing the impact of carbon/energy taxes on energy intensity for UK manufacturing plants based on a micro-panel data. Finding from their study revealed that carbon taxes had a strong negative impact on energy intensity and electricity use in UK manufacturing plants.

The other two studies within the "other" theme (Carattini et al., 2017; Weishaar,2018) were focused on understanding the factors that affect the acceptability of such carbon-energy taxes. The study was an experimental study on Swiss society on voting on a large bailout of energy taxes. The finding revealed that perception of ineffectiveness, distributional and competitiveness concerns reduced the acceptability of such taxes. Whereas the work by Weishaar,2018 was a review assessment of such taxes since their implementation in the EU member states, with a focus on the Nordic countries. Findings from the review suggest that barriers faced by such taxes are similar across the studied countries. These barriers relate to revenue recycling, competitiveness issues and the challenge to get a large political support.

The general conclusion from the brief prior literature review is that, first none of studies explicitly mention any of the SDGs, though in principle some of them have considered them in a narrow and less focused way. For instance, the theme on emission effect of such taxes is related to SDG13 (climate action), where emission is one of the target indicators for SDG13, the theme on distribution effect of such taxes is also related to SDG 10 (reduce inequality) and the theme on the price effect may have some relation with SDG7 (access to affordable and clean energy). However, none of these studies have explicitly considered all the SDGs and the influence of carbon-energy taxes on such goals to provide a clear empirical evidence on trade-offs, synergy and complementarities of such tax policies on these goals towards a sustainable development path. This study will provide such an evidence for European member states to inform carbon-energy tax policy and sustainable development.

Table 1: Summary of Studies

AUTHORS / YEAR	Research type	DATA	COUNTRY	Finding	THEME
Nicholas Apergis (2012)	Empirical	2001 to 2014	New Zealand	Energy tax (prices) have long-run asymmetric effects on electricity prices, with only positive changes in carbon prices signalling a complete pass-through.	Tax effect on energy price
Chiu et al. (2015)	Theory & Empirical	2002 to 2013	Taiwan	Energy price effect of energy tax and emission trading are equivalent under perfect competition, but not under imperfect competition. Evidence from oil market indicate a lower price effect of energy tax relative emission trading	Tax effect on energy price
Trujillo-Baute et al. (2018)	Empirical	2007 to 2013	EU member Countries	RES support cost has positive effect on retail electricity price, but the size of the effect is smaller than that of energy only cost, taxes and levies and network cost. Differences across consumer types (residential and industrial) was observed	Tax effect on energy price
Borozan (2018)	Empirical	2005 to 2016	EU member Countries	Energy taxes influence electricity consumption more efficiently through energy prices than directly. The finding also indicates that the efficiency of energy taxes can be aided by combining changes in energy prices and policy measures that change the electricity consumption behaviour patterns.	Tax effect on energy price
Barker and KoKhler (1998)	Empirical	Survey data 1988,1992,1993	11 EU member Countries	The distribution effect of carbon /energy tax in the EU are not so regressive.	Distributional effect of energy taxes
Speck (1999)	Review of empirical studies	1990 to 1999	Developed & Developing	The review shows that energy taxes are mildly regressive for developed OECD countries and even progressive in developing countries.	Distributional effect of energy taxes
Ekins et al. (2011)	Empirical	Household spending survey data for 2005	European Countries	The results suggest that environmental taxes in Europe are generally not regressive, although the results differ by country and for different socio-economic groups. With the acceptability of such taxes depended on how the worst affected groups are mitigated.	Distributional effect of energy taxes
Dissou & Siddiqui (2014)	Theory & Empirical	SAM-2004	Canada	The relationship between carbon/energy taxes and inequality are non-monotonic (U-shaped) due to the opposing effect of carbon tax on changes in factor prices and changes in commodity prices. Carbon/energy taxes tend to reduce	Distributional effect of energy taxes

				inequality via changes in factor prices and tend to increase inequality via changes in commodity prices.	
Thomas & Flues (2015)	Empirical	Household budget surveys, 2009 to 2012	21 OECD Countries	The distributional effects of energy taxes differ by energy carrier. taxes on transport fuels are not regressive on average but generally heterogenous across countries. In some countries the effects of taxes on transport fuels are progressive, and others more proportional. Taxes on heating fuels are mildly regressive, whiles taxes on electricity are more regressive relative to those on heating fuels.	Distributional effect of energy taxes
Levinson (2016)	Theory & Empirical	National Household Travel Survey-2009	USA	The theory prediction indicates that regulations targeting energy efficiency is more regressive than energy taxes under the condition of revenue-equivalence between the two. The empirical evidence in automotive fuel consumption, appliances, and residential construction all supported the theoretical prediction.	Distributional effect of energy taxes
Oueslati (2017)	Empirical	1995 to 2011	34 OECD Countries	Finding indicate that in the absence of revenue recycling mechanisms, the impact of energy tax on income inequality is moderately positive. Whereas in the case, where such mechanisms have been implemented, there is a stronger negative energy tax effect on income inequality.	Distributional effect of energy taxes
Andersen (2004)	Review of empirical studies	1990 to 2000	Nordic Countries	The review suggests that the implementation of CO2 tax in Sweden has resulted in an estimated reduction of emission by 3% to 5%. About 5 % in Denmark and 30% in Norway	Carbon/energy tax effect on emissions
Brännlund (2014)	Empirical	1990 to 2004	Sweden	Environmental performance has improved in all the sectors and that the firms' carbon intensities responds to changes in both the CO2 tax and fossil fuel price. The emission intensity is however more sensitive to the tax.	Carbon/energy tax effect on emissions
Kuo (2016)	Theory with numerical simulation	-	Taiwan	The case study indicate that the appropriate levels of tax can have a reduction effect on emission by enterprises due to the fact that it induces enterprises to alter their production	Carbon/energy tax effect on emissions

				processes towards a low carbon production path.	
Haites (2018)	Review of empirical studies	2005 to 2015	World	Carbon/energy taxes in European countries and in British Columbia prior to 2008 reduced emissions from business-as-usual. After 2008, Countries covered by European emission tax experienced emission reduction, but largely from other mitigation than the carbon/energy taxes. .	Carbon/energy tax effect on emissions
Borck & Brueckner (2018)	Theory with calibration	-	USA	It suggests that optimal taxation reduces the levels of both activities (housing consumption and commuting), which lowers the level of emissions per capita by 11.4%.	Carbon/energy tax effect on emissions
Kettner-Marx & Kletzan-Slamanig (2018)	Empirical	2004 to 2015	EU Countries	The price elasticity is –0.31 for petrol and –0.16 for diesel, which suggest an increase in prices due to energy or carbon taxation can contribute to reducing greenhouse gas emissions from the transport sector.	Carbon/energy tax effect on emissions
Martin et al. (2014)	Empirical	1993 to 2004	United Kingdom	The estimated the impact of a carbon/energy tax on manufacturing plants energy intensity. They find that carbon/energy taxes had a strong negative impact on energy intensity and electricity use.	Others-energy intensity
Carattini et al. (2017)	Empirical	2015	Switzerland	That perception of ineffectiveness, distributional and competitiveness concerns reduced the acceptability of energy taxes. Also, providing proper information on the functioning of environmental taxes reduces the gap between economists' prescriptions and preferences of the general public.	Others-acceptability of energy taxes
Weishaar (2018)	Review	1990 to 2018	EU member Countries	Impediments to the introduction of carbon/energy tax relate to revenue recycling, competitiveness issues and the challenge to get a large political support. Employing a consensus approach increases acceptability.	Others-acceptability of energy taxes

4. **Data and Modelling strategy**

The main source of data is the Eurostat's data base on energy price components and that on SDGs. Key variables are; electricity taxes and levies, Key SDGs that are closely associated with energy and their associated target indicator variables. The period of data coverage is determined by data availability in the data set. The data on disaggregated price data for electricity into its components such as production cost, network charges, taxes and levies are only available on consistent basis starting from 2007 to 2018, whiles that for SDGs start from 2000 to 2017. However, Some of the SDGs have missing data for the years 2017 and 2018. Due to that the data coverage is restricted to the period from 2007 to 2016 for EU-28 countries plus Norway.

The key variables of interest include electricity taxes and levies (both households and industrial customers) and indicators for selected SDGs. The electricity taxes and levies variable are sourced from Eurostat for both consumers and the industry. The data is based on average half-yearly electricity prices and its disaggregated components quoted in Euros per kWh for the two group end-users (households and industry). Further the data is classified based on annual consumption bands from very small band (annual consumption below 1 000 kWh) to very large band (annual consumption above 15000 kWh) for the household end-users, and a very small band (annual consumption below 20 MWh) to very large band (annual consumption above 150 000 MWh) for industrial end-users[1]. For this study we relied on the taxes and levies from the medium consumption bands for both households and industry. Thus, Band-DC (Medium): annual consumption between 2500 and 5 000 kWh for household and Band-IC: annual consumption between 500 and 2000 MWh for industry. The choice of consumption band is consistent with previous studies such as Trujillo-Baute (2018).

The tax and levies for the two end-users is presented in figure 1, which shows the averages for each country over the period (2007 to 2016). Denmark has the highest taxes and levies on households (0.180 Euros /kWh) followed by Germany (0.121 Euros /kWh). Malta on the other hand has the least average electricity taxes on households (0.007 Euros /kWh). The top five countries with the highest household electricity taxes in the region in order of ranking are; Denmark, Germany, Portugal, Italy and Sweden.

[1] Details of the methodology used by Eurostat for the data collection can be found via their website (https://ec.europa.eu/eurostat/data/database)

In the case of industrial electricity taxes and levies, Italy has the highest average taxes and levies (0.052 Euros /kWh) followed by Germany (0.041 Euros /kWh) and Malta has the least in the region, with zero taxes. The highest average household taxes on electricity is about 246 percent higher than the highest industrial average taxes in the region, suggesting the policy direction of these taxes in the region within the context of competitiveness concerns versus environmental motives of the policy maker.

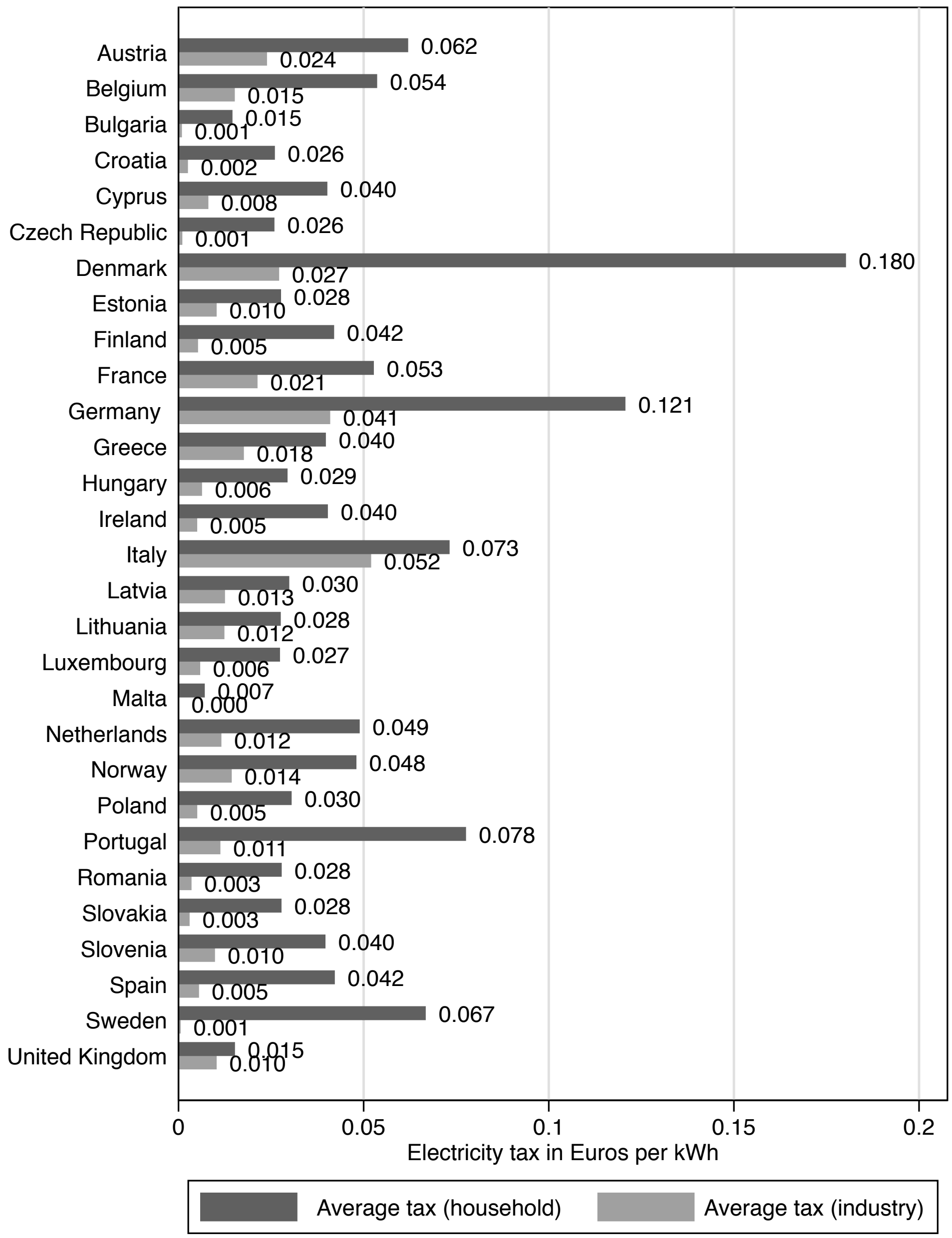

Figure 1: Average electricity taxes and levies for EU-28 countries and Norway (2007-2016)

The next set of variables are the SDGs, our focus is not on all the SDGs but rather those that are directly connected to energy use. Specifically, we are interested in SDGs 7, 8, 9, 12 and 13. The indicators used to capture each of these SDGs are presented in Table A1 in the Appendix. The indicators for SDG7 include primary energy consumption, final energy consumption, final energy consumption in households per capita, share of renewable energy in gross final energy consumption by sector, energy dependence by product, and greenhouse gas emissions intensity of energy consumption.

Indicators for SDG 8 are divided into two components. An unemployment component (8W) and a growth component (8G) of SDG8. Indicators for SDG8W are young people neither in employment nor in education and training by sex, long-term unemployment rate by sex and inactive population due to caring responsibilities by sex. Indicators for SDG8G are real GDP per capita, resource productivity and domestic material consumption.

In the case of SDG9, the indicators used are gross domestic expenditure on research and development by sector, employment in high and medium-high technology manufacturing sectors and knowledge-intensive service sectors, research and development personnel by sector, patent applications to the European Patent Office, share of collective transport modes in total passenger land transport by vehicle, share of rail and inland waterways activity in total freight transport, and average CO_2 emissions per km from new passenger cars.

For SDG12, the indicators comprise of consumption of toxic chemicals by hazardousness, resource productivity and domestic material consumption, average CO_2 emissions per km from new passenger cars, volume of freight transport relative to GDP, primary energy consumption, final energy consumption, energy productivity, and share of renewable energy in gross final energy consumption by sector.

Another directly connected SDGs to energy is SDG13, under which we use greenhouse gas emissions per capita (CO_2) from WDI. We used CO_2 to represent SDG13 due to the fact that it is a major climate concern globally, has reliable data information and furthermore, is a major reason used by policy makers to promote renewable electricity and justification of carbon-based taxation. Each SDG is captured by several indicators that are listed, which complicate any meaningful econometric analysis due to overlapping of some of the target variables across some of the SDGs. For instance, we have final energy consumption as one of the indicators for both SDG7 and SDG12. We combine each of the target variables under each SDG into one index via principal component analysis approach.

The summary statistics for the variables for the study is reported in Table A1 in the Appendix, which reveals strong heterogeneity among countries in terms of primary energy consumption, final energy consumption, tax on industry electricity and patent application, as their respective standard deviations are of larger magnitude than their means. A variable with a larger standard deviation relative to its mean, suggests high variability in the variable and therefore a strong heterogeneity.

4.2 The Model

We employ the Panel Vector Autoregressive (PVAR) approach to the data in order to model the interlinkages between electricity taxes and the selected SDGs and to determine the causal impacts. In the PVAR framework, each variable in the system is explained by its own lags, lagged values of the other variables, time fixed effect and unobserved individual effect. The panel autoregressive distributed lag model for this study is presented compactly as

$$y_{it} = \sum_{t=1}^{n} \pi_i' y_{it-1} + \mu_{it} \quad (1)$$

where y is k*1 vector of k variables, π_i' is a k*k vector of parameters to be estimated and μ_{it} is a composite term that is made up of time fixed effects (v_t), unobserved individual effect (γ_i) and random error term (ε_{it}). In equation (8), y is a vector which is composed of electricity taxes and levies, SDG 7, SDG 8, SDG 9, SDG 12 and SDG 13.

SDG7 represent affordable and clean energy, SDG8 is decent work and economic growth (decomposed into work and growth), SDG9 is industry, innovation and infrastructure, SDG12 is responsible production and consumption and SDG13 is climate action. All the equations stacked in equation (1) are estimated jointly as a system, which makes it possible to trace the feedback effect from each variable on the other. Thus, we can assess the potential trade-offs or complementarity of electricity taxes directly on each of the selected SDGs and how each of the goals also influence the others. The above system of equation is estimated for the household model, where “Tax” is taxes and levies on household electricity usage. The same system of equation is estimated for the industry model, where “Tax” is replaced with taxes and levies on industrial electricity usage.

The PVAR approach avoids the usual problem of endogeneity, given the interdependent nature of the variables that are of interest in the study. Moreover, important policy questions such as, how specific variables of interest respond to unexpected changes in other variables can also be analysed via the PVAR approach. For instance, whether unexpected changes in electricity taxes in order to combat climate change causes a positive, negative or no reaction by SDG13, can be assessed from the PVAR approach for the countries under study.

Given the lag dependent structure, estimating a system of fixed effect model will suffer from nickel bias (where the lag depended variable is correlated with the fixed effect) in a small sample. The standard procedure to address such a bias, as suggested by Arellano and Bover (1995) is to use a generalized method of moment procedure (GMM), where lagged variables are used as instruments.

In estimating the above model, the empirical strategy follows two steps. In the first step, the PVAR model is estimated for both household tax model and industry tax model. This step will provide estimates for each of the variables in the model and makes it possible to assess the interlinkages and causal impacts. In the second step, we provide causality test to determine nature of interlinkages between the various variables in the model, followed by the variance decomposition analysis.

5. Results and Discussion

We first present the results based on step one, followed by step two in that order as outlined in the empirical strategy. Before discussing the step 1 results based on the PVAR approach, it is important to first discuss the model fit and the stability of the model. More importantly since we are interested in establishing causal effects to determine the nature of interlinkages of electricity taxes and the selected SDGs, the stability of the model is very important. Furthermore, given the interest in assessing how each of the SDGs variance is explained by electricity taxes and levies, hence model stability is once again an important requirement. It is also important to first established whether the model fit the data generation process (DGP) before discussing the results.

First, with regard to the model fit, since the model estimation approach is based on generalized method of moment (GMM), we perform the Hansen-J test for over-identification, which is more of a specification test to determine if the over-identifying restrictions are valid. The test results reported in Table 2 and 3 for household and industry respectively, suggest that our models fit the data generation process.

The model stability is checked by calculating the modulus of each eigenvalue of the estimated PVAR model. If all moduli of the companion matrix are strictly less than 1, the VAR model is stable (Hamilton, 1994; Lutkepohl, 2005). The results reported in Table A2 in the Appendix, suggest that both models (household and industry tax model) are stable. Our estimated models therefore satisfy both the model fit test and the model stability test.

5.1 PVAR results (household model)

First, the household model estimates are presented followed by the discussion on the model estimates. The results as reported in Table 2 is presented by first considering the tax equation (1) to determine how household electricity taxes respond to each of the selected SDGs. Next, we focus on how each of the SDGs respond to household electricity taxes via equations 2 to 7.

Considering the results based on the tax equation (equation 1), previous level of taxes and each of the SDGs (except goal7 and goal 9) are significant causal factors to household electricity taxes in the EU-28 countries and Norway. Specifically, goal8W and goal12 had positive impact on taxes with elasticity values of 0.08, 0.92, respectively. Whereas goal8G and goal13 had negative impact on household electricity taxes with respective elasticity values of -0.86 and -0.24.

The results from SDG 7 (equation 2) suggests that all the SDGs (except SDG9) are significant causal factors. Specifically, SDG 7 responded positively to its previous level, SDG8W, SDG12 and SDG13 with respective elasticity values of 0.81, 0.05, 0.32 and 0.19. It also responded negatively to SDG8G with elasticity value of -0.16.

Furthermore, finding from SDG8G (equation 3) indicates that each of the SDGs (except SDG13) are significant causal factors for SDG8G. Whereas in the case of the unemployment equation (SDG8W), all variables are significant causal factors, except SDG9.

Table 2: PVAR Household electricity taxes estimates

Response of:	Response to Tax_{t-1}	$SDG7_{t-1}$	$SDG8G_{t-1}$	$SDG8W_{t-1}$	$SDG9_{t-1}$	$SDG12_{t-1}$	$SDG13_{t-1}$
Tax_t	0.318***	0.133	-0.861***	0.075*	0.092	0.916***	-0.236***
	(5.83)	(0.86)	(-5.54)	(1.82)	(1.55)	(6.04)	(-3.62)
$SDG7_t$	-0.028	0.807***	-0.164***	0.046***	-0.034	0.319***	0.186***
	(-1.64)	(11.71)	(-4.50)	(3.25)	(-1.62)	(5.94)	(5.23)
$SDG8G_t$	-0.033	-0.130**	0.091**	0.042**	-0.156***	0.666***	0.006
	(-1.37)	(-2.42)	(2.44)	(2.50)	(-6.43)	(12.31)	(0.19)
$SDG8W_t$	-0.367***	2.059***	-0.394***	0.973***	0.141	-0.770***	0.977***
	(-4.56)	(8.81)	(-2.59)	(16.70)	(1.60)	(-3.40)	(7.27)
$SDG9_t$	-0.252***	-1.060***	-0.664***	0.134***	0.521***	1.247***	-0.647***
	(-4.36)	(-5.30)	(-3.80)	(3.54)	(6.38)	(4.91)	(-7.17)
$SDG12_t$	0.027	-0.013	-0.365***	0.052***	-0.005	1.147***	0.104***
	(1.26)	(-0.23)	(-7.62)	(3.19)	(-0.22)	(19.03)	(2.91)
$SDG13_t$	-0.141***	-1.317***	0.506***	-0.169***	-0.027	-0.184*	-0.972***
	(-3.15)	(-8.55)	(6.04)	(-4.93)	(-0.53)	(-1.66)	(-11.84)
Observation	202						
J-Stats	155.219						
P-value	[0.305]						

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results based on SDG9 equation also revealed that taxes and each of the SDGs are significant causal factors at any of the conversional significance level. Whilst from the SDG12 equation, SDG8G, SDG8W and SDG13 are the significant causal factors. The finding further showed that all the variables are significant causal factors except SDG9 in influencing SDG13.

Figure 2 present the variance decomposition of each of the variables in the household model to a tax shock. Accordingly, the contribution of household electricity tax shock to the variance of economic growth (SDG8G) is about 18% at a 5-year horizon, which increases to about 22% at the 10-year horizon. Correspondingly, tax shock contribution to the variance of SDG 9, 12 and 13 are 8%, 9% and 6%, respectively at the 10-year horizon. At the 5 -years horizon, tax shock accounted for about 1 %, 13% and 5% of the variation in SDG9, SDG12 and SDG13, respectively.

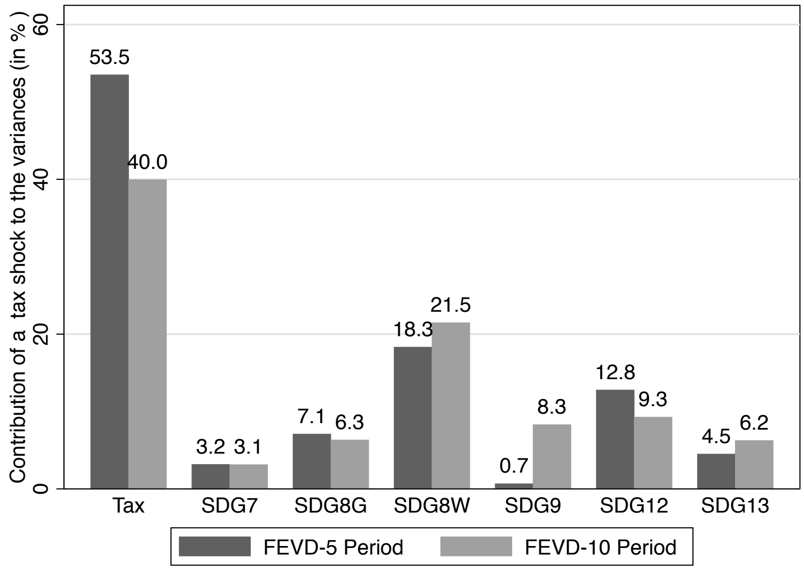

Figure 2: Forecast error variance decomposition for a tax shock in the Household model

5.1.1Discussion of household's electricity tax model results

Clearly, Table 2 showed that household electricity tax in the EU28 and Norway only has a significant influence on only three of the selected SDGs (SDG8W, SDG9 AND SDG13) even at the conservative 1 percent significance level.

Specifically, the negative significant effect of electricity tax on unemployment (SDG8W) can be explained by the theory of double-divided associated with environmental/energy tax reform (ETR) policy (e.g., Goulder, 1995). Theoretical work on the double-divided of ETR suggest that in a case of involuntary unemployment, taxes on energy can provide both environmental and employment benefits as long as the revenues from such taxes are recycled in a manner that replaces some of the distortionary taxes on labour (e.g., income tax, social security tax). With the recycling targeting at reducing the labour cost for employers, labour demand increases and thereby reducing the level of unemployment. This finding is consistent with finding from the broader literature on the environment and macroeconomic effect of ERT such as Capros et al. (1997), Bayar (1998), Jansen and Klaassen (2000). These studies found consistently, a positive effect of ERT on employment, which can be interpreted to mean a reduction in unemployment.

The negative effect of household electricity taxes on SDG9 is in line with findings from studies on taxation and innovation such as Akcigit et al., (2018), they showed that taxes generally have a negative effect on innovation. Additionally, Akcigit et al., (2018) showed that the negative effect is particularly pronounced in the case of taxes on personal income and corporate taxes. This implies that as the returns to innovation are lowered by these taxes, it reduces individuals and firms' incentive to invest in innovation.

Also, a negative effect of electricity tax on carbon emission is consistent with prior literature on ERT (Wendner, 2001; Patuelli et al., 2005; Andersen and Skou, 2010; Haites 2018). This can be explained via the price effect of taxes on final retail electricity price. As prices of electricity become expensive due to the taxes, consumers respond to that either through conservation measures or efficient use of electricity or both.

Furthermore, findings also revealed that some of the SDGs are interlinked. For instance, SDG13 showed bi-causal relationship with SDG7, SDG8W and SDG12. SDG12 has a bi-causal relationship with SDG8W, SDG8G, SDG13. Whereas SDG12 has a bi-causal relationship with SDG7, SDG8W, SDG9 and SDG12. These casual relations can be inferred from Table 2 or based on the causality test reported in Table A4 in the appendix, where the null hypothesis of no causality is tested using a chi-square test statistic, rejecting the null suggest causality.

In brief, conclusion from these estimates is that, household electricity tax is a causal factor to SDG8W, SDG9 and SDG13, whereas SDG8G, SDG8W, SDG12 and SDG13 are significant causal factors for household electricity taxes in the EU. Moreover, the results further showed that increases in taxes on household electricity consumption can help achieve SDG8 via reduction in unemployment and help achieve SDG13 via reduction in CO2, suggesting a synergy between tax and these SDGs (SDG8 and 13). Nonetheless, in the case of SDG9, the finding revealed a trade-off relationship with household electricity tax.

Regarding the nature of causal relationship between household electricity tax and SDGs, only SDG8W and SDG13 showed bi-causal interlinkages with household electricity tax. Whereas in the case of SDG9 there is no evidence of interlinkages but rather a unit-directional causation from SDG9 to household electricity tax. Moreover, the variance decomposition suggests that household taxes accounts for a significant variation of the selected SDGs, which range from 3.1% (SDG7) to 22 % (SDG8W) at the 10-year horizon.

5.2 PVAR results (Industry model)

The industrial model results are reported in Table 3 and revealed that previous level of industrial electricity tax, SDG8W and SDG9 are the significant causal factors for industrial electricity taxes (equation 1) with respective elasticity values of 0.85, 0.27 and -0.19. From SDG7 equation, the estimated tax effect is not significant at any of the conventional significance level. Suggesting that industrial electricity tax is not a significant causal factor for SDG7 in the EU-28 and Norway.

Table 3: PVAR Industry electricity taxes estimates

Response of:	Response to Tax_{t-1}	$SDG7_{t-1}$	$SDG8G_{t-1}$	$SDG8W_{t-1}$	$SDG9_{t-1}$	$SDG12_{t-1}$	$SDG13_{t-1}$
Tax_t	0.851^{***}	-0.254	0.078	0.274^{***}	-0.188^{**}	0.211	-0.237
	(7.04)	(-0.78)	(0.74)	(4.64)	(-2.12)	(0.71)	(-1.59)
$SDG7_t$	0.039	0.658^{***}	0.298^{***}	0.021	0.006	-0.039	0.105^{**}
	(1.10)	(8.01)	(4.84)	(1.01)	(0.18)	(-0.39)	(2.00)
$SDG8G_t$	-0.056^{**}	0.152	-0.285^{***}	0.007	0.043	0.827^{***}	0.265^{***}
	(-2.01)	(1.64)	(-5.09)	(0.25)	(1.44)	(7.09)	(5.95)
$SDG8W_t$	-0.642^{***}	1.581^{***}	-2.201^{***}	0.906^{***}	0.014	1.232^{***}	0.626^{***}
	(-5.56)	(5.68)	(-6.56)	(10.02)	(0.10)	(3.20)	(4.05)
$SDG9_t$	0.047	-0.277	-1.680^{***}	0.001	0.480^{***}	1.620^{***}	0.055
	(0.49)	(-1.05)	(-6.51)	(0.02)	(4.81)	(4.12)	(0.40)
$SDG12_t$	0.117^{***}	-0.001	-0.518^{***}	0.009	-0.032	0.887^{***}	0.044
	(3.74)	(-0.01)	(-8.98)	(0.39)	(-0.91)	(7.26)	(0.96)
$SDG13_t$	0.064	-1.001^{***}	-0.680^{***}	-0.116^{**}	0.012	0.262	-0.067
	(0.76)	(-5.52)	(-4.96)	(-2.46)	(0.15)	(1.07)	(-0.60)
Observation	167						
J-Stats	102.436						
P-value	[0.360]						

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results further revealed that industrial electricity tax has a significant negative effect on both SDG8G and SDG8W with elasticity values of -0.06 and -0.64, respectively. Suggesting a negative tax effect on each of these goals. Whereas from the SDG9 equation, tax is not a significant causal factor. The industrial electricity effect on SGD12 is positive (0.12) and significant, whiles in the case of SDG13, tax is not a significant causal factor.

Furthermore, the variance decomposition of each of the variables to the industry model to tax shock is presented in figure3. Admittedly, industry electricity tax shock account for a significant variation of each of the SDGs in the model, irrespective of the time horizon (5 or 10 years) presented. Specifically, industry electricity tax shock accounted for about 48.1% of the variation in unemployment (SDG8W) at the 10-year horizon. It also accounted for about 28.9%, 48% and 9.7% variation in SDG9, SDG12 and SDG13, respectively. Certainly, the contribution of industry electricity taxes to future variation of each of the SDGs are much significant in magnitude relative those from the household electricity tax model. This among other things suggest that increases in the level of taxes on industry electricity consumption is likely to have the greatest impact on future direction of the selected SDGs within the EU relative to increases in household electricity taxes.

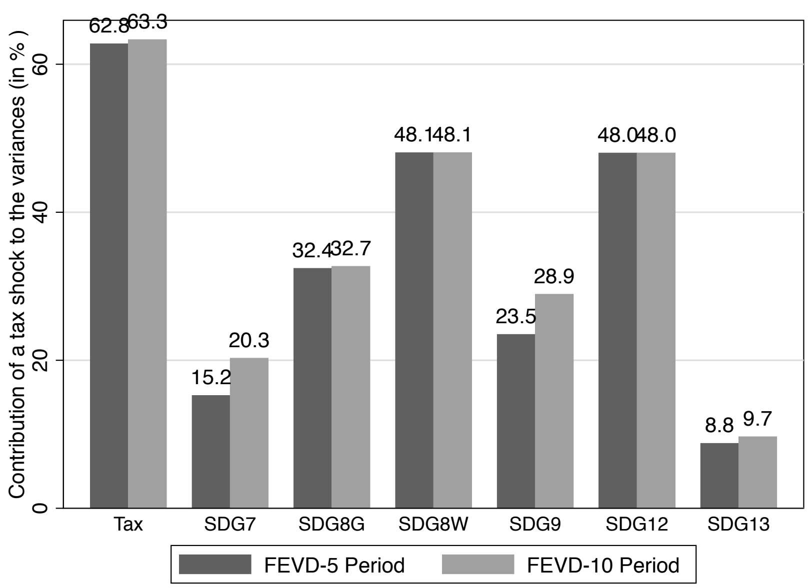

Figure 3: Forecast error variance decomposition for a tax shock in the industry model

5.2.1Discussion of industry electricity tax model results

Similarly, the industry tax model revealed that tax is a significant causal factor for only three of the SDGS (SDG8G, SDG8W and SDG12). Conversely, two of the SDGs (SDG8G and SDG12) that industrial electricity tax has a significantly influence on are different from those found in the household tax model, suggesting the heterogeneity of electricity tax effect across the two sectors (household and industry).

The negative effect of tax on economic growth (SDG8G) is in line with some of the studies on Europe as documented in a metal analysis by Patuelli et al., (2005) and for energy intensive industries by Andersen and Skou (2010). Our finding is however contradictory to some of the previous studies on EU Environmental/Energy Tax Reform (ETR) policy (e.g., Cambridge Econometrics,1998; Capros et al., 1997; Bayar, 1998; Jansen and Klaassen,2000), especially when recycling of tax revenue is incorporated into the analysis. We argue that the negative tax effect on economic growth may be explained via the recycling effect and also the inability to shift cost from labour-intensive sectors to energy intensive sectors in the region. Out of the 28 countries in our sample, only nine of the countries[2] have an explicit environmental tax and revenue recycling policy (in line with the ETR policy). Out of the nine, only six countries focus on the recycling of such tax revenues into reducing pension contributions by employers, a channel that produce the most gains both for employment and economic growth as documented in meta study by Patuelli et al., (2005).

Furthermore, the negative impact of unemployment (SDG8W) is in line with the theory of double divided of such taxes (e.g., Goulder, 1995), which is also consistent with previous empirical studies (Cambridge Econometrics,1998; Capros et al., 1997; Bayar, 1998; Patuelli et al., 2005; Anderson, 2010).

On the other hand, tax is not a significant causal factor for SDG9. A possible explanation for this may be that, due to the electricity tax policy for industry, which in the EU is very low relative to the household sector. In most of the countries, average household electricity taxes are more than twice that of industrial taxes, making industry's innovation component of SDG9 less responsive to electricity taxes. Moreover, given government support policy such as tax deductible on investment in innovation by industry, taxes tend to have little effect on the marginal benefit of innovation by industry.

Conversely, the positive effect of industrial electricity on SGD12 may be explained via the cost of production channel. Cost of production increases with higher electricity tax, especially in electricity intensive industries (EII) such as chemical, machinery, paper, food and steel, given that electricity is the major energy carrier in these industries (Åhman and Nilsson, 2015). The cost restriction of a higher electricity tax will force EII either to produce and consume responsibly or relocate. If the cost of

[2] Belgium, Denmark, Finland, Germany, Italy, Netherland, Sweden, United Kingdom and Norway

relocation is higher relative to being innovative, they will adopt more responsible production and consumption processes.

On the other hand, industry electricity tax has no significant effect on carbon emission (SDG13) at any of the conventional significance level. This may be explained by the watered-down regulation, soft tax deals and preferential pricing that they are benefitting (Climate Action Network Europe, 2018)

Additionally, the findings also revealed that some of the SDGs are interlinked. For instance, SDG7 showed bi-causal relationship with SDG8G. SDG8G has a bi-causal relationship with SDG7, SDG12 and SDG13. Whereas SDG12 has a bi-causal relationship with only SDG8G. On the other hand, SDG13 has a bi-causal relationship with SDG8G and SDG8W. Electricity tax is only interlinked with SDG8W (bi-causal relationship). These casual relations can be inferred from Table 3 or based on the causality test reported in Table A3 in the appendix.

In summary, industrial electricity taxes influences SDG8 via economic growth and unemployment components of this goal, it also influences responsible production and consumption (SDG12) in the EU-28 and Norway. In all, the effect of industrial electricity tax on the economy via SDG8 and 12 learn support to the macroeconomic benefits of such energy taxes in a narrow sense of the broader environmental tax reform policy.

6. Conclusion

The aim of this study was to explore the impact of electricity taxes on selected SDGs closely connected to energy within the EU in order to determined potential interlinkages and trade-offs with the electricity tax policy and these SDGs. Using the PVAR approach for a panel of 28 EU countries and Norway for, we estimated the electricity tax effect on SDGs, utilising the differences in tax rates between industry and the household sectors.

Several interesting findings emerge. First, in general, increase in electricity tax within the EU has a significant on some of the SDGs. Second, the effect of electricity tax on SDGs are differs depending on whether the tax is on households or industry. In particular, household electricity tax influence SDG8W, SDG9 and SDG13, whereas in the case of industry, it influences SDG8G, SDG8W and

SDG12. Third, there is evidence of interlinkages between electricity tax and some of the SDGs and trade-offs with others (SDG9 with industry electricity tax). Last but not the least, tax increases will have a significant impact on future variation of some of the SDGs, particularly unemployment, economic growth, responsible production and consumption and carbon emission. The future variation effect of electricity tax on SDGs is more pronounced with industry taxes relative to household taxes.

Our results also have some policy implications. The double-dividend proposition of ETR with a specific reference to electricity taxation is a reality within the EU. Policy makers can achieve environmental goals such as reducing carbon emission with a higher electricity taxes, especially on household electricity, which also has the added benefit of reducing unemployment if there is a strong revenue recycling that will reduce the labour cost of employers via a reduction in social security contribution. Correspondingly, the finding from the meta-analysis by Patuelli et al. (2005), which suggested the employment benefits of such taxes is greatest when the generated revenue from such taxes are recycled into reducing social security contribution, provide the policy direction of such recycling policy.

Nonetheless, in the industrial sector, the electricity tax policy within the overall EU energy policy, based on our finding, imply that there is a need to reform the taxes, especially electricity tax component if the environmental benefit of such taxes is to be realised. The current EUETS policy and industry electricity tax policy does not encourage industry, especially electricity intensive industries to innovate and adopt production processes that are less polluting to the environment. Accordingly, the industry tax policy needs to be revised-upward if the overriding interest of EU policy makers is more on achieving environmental benefit relative to industry competitiveness.

Reference

Åhman, M. and Nilsson, L.J., (2015). Decarbonizing industry in the EU: climate, trade and industrial policy strategies. In *Decarbonization in the European Union* (pp. 92-114). Palgrave Macmillan, London.

Akcigit, U., Grigsby, J., Nicholas, T. and Stantcheva, S., (2018). *Taxation and Innovation in the 20th Century* (No. w24982). National Bureau of Economic Research.

Andersen, M. S. (2004). Vikings and virtues: a decade of CO2 taxation. *Climate Policy*, *4*(1), 13-24. Bayar, A.H., 1998. Can Europe Reduce Unemployment Through Environmental Taxes. *A General Equilibrium Analysis*.

Andersen, P. and Skou, M., (2010). Europe's experience with carbon-energy taxation. *SAPI EN. S. Surveys and Perspectives Integrating Environment and Society*, (3.2).

Apergis, N. (2018). Electricity and carbon prices: Asymmetric pass-through evidence from New Zealand. *Energy Sources, Part B: Economics, Planning, and Policy*, *13*(4), 251-255.

Arellano, M. and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of econometrics*, 68(1):29-51.

Barker, T., & Köhler, J. (1998). Equity and ecotax reform in the EU: achieving a 10 per cent reduction in CO2 emissions using excise duties. *Fiscal Studies*, *19*(4), 375-402.

Borck, R. and Brueckner, J.K., (2018). Optimal energy taxation in cities. *Journal of the Association of Environmental and Resource Economists*, *5*(2),481-516.

Borozan, D. (2018). Efficiency of Energy Taxes and the Validity of the Residential Electricity Environmental Kuznets Curve in the European Union. *Sustainability*, *10*(7), 2464.

Brännlund, R., Lundgren, T. and Marklund, P.O., 2014. Carbon intensity in production and the effects of climate policy—evidence from Swedish industry. *Energy Policy*, *67*,844-857.

Capros, P., Georgakopoulos, T., Zografakis, S., Van Regemorter, D. and Proost, S., 1997. Coordinated versus uncoordinated European carbon tax solutions analysed with GEM-E3 linking the EU-12 countries. *Economic Aspects of Environmental Policy", published in Edward Elgar Publishers*.

Carattini, S., Baranzini, A., Thalmann, P., Varone, F. and Vöhringer, F., (2017). Green taxes in a post-Paris world: are millions of nays inevitable? *Environmental and Resource Economics*, *68*(1), 97-128.

Chiu, F. P., Kuo, H. I., Chen, C. C., & Hsu, C. S. (2015). The energy price equivalence of carbon taxes and emissions trading—Theory and evidence. *Applied energy*, *160*, 164-171

Climate Action Network Europe. (2018). European Fat Cats. EU Energy Intensive Industries: paid to pollute, not to decarbonise. Available: http://www.caneurope.org/docman/fossil-fuel-subsidies-1/3310-european-fat-cats-report-april-2018/file

Dissou, Y., & Siddiqui, M. S. (2014). Can carbon taxes be progressive? *Energy Economics*, *42*, 88-100.

Ekins, P., Pollitt, H., Barton, J., & Blobel, D. (2011). The implications for households of environmental tax reform (ETR) in Europe. *Ecological Economics*, *70*(12), 2472-2485.

Econometrics, C., (1998). *Industrial benefits from environmental tax reform in the UK* (No. 1).

Cambridge Econometrics Technical Report.
Goulder, L.H., (1995). Environmental taxation and the double dividend: a reader's guide. *International tax and public finance*, *2*(2),157-183.
Haites, E., (2018). Carbon taxes and greenhouse gas emissions trading systems: what have we learned? *Climate policy*, *18*(8), 955-966.
Hamilton, J.D., 1994. *Time series analysis* (Vol. 2, pp. 690-696). Princeton, NJ: Princeton University Press.
Jansen, H. and Klaassen, G., (2000). Economic impacts of the 1997 EU energy tax: simulations with three EU-wide models. *Environmental and Resource Economics*, *15*(2), 179-197.
Kettner-Marx, C. and Kletzan-Slamanig, D., (2018). *Energy and carbon taxes in the EU: Empirical evidence with focus on the transport sector* (No. 555). WIFO Working Papers.
Kuo, T.C., Hong, I.H. and Lin, S.C., (2016). Do carbon taxes work? Analysis of government policies and enterprise strategies in equilibrium. *Journal of cleaner production*, *139*, 337-346.
Lütkepohl, H., 2005. *New introduction to multiple time series analysis*. Springer Science & Business Media
Martin, R., De Preux, L.B. and Wagner, U.J., (2014). The impact of a carbon tax on manufacturing: Evidence from microdata. *Journal of Public Economics*, *117*, 1-14.
Oueslati, W., Zipperer, V., Rousselière, D. and Dimitropoulos, A., (2017). Energy taxes, reforms and income inequality: An empirical cross-country analysis. *International Economics*, *150*,80-95.
Patuelli, R., Nijkamp, P. and Pels, E., (2005). Environmental tax reform and the double dividend: A meta-analytical performance assessment. *Ecological economics*, *55*(4), 564-583.
Speck, S., (1999). Energy and carbon taxes and their distributional implications. *Energy policy*, *27*(11), 659-667.
Thomas, A., & Flues, F. (2015). *The distributional effects of energy taxes*. OECD Taxation Working Papers 23.
Trujillo-Baute, E., del Río, P., & Mir-Artigues, P. (2018). Analysing the impact of renewable energy regulation on retail electricity prices. *Energy Policy*, *114*, 153-164.
Weishaar, S.E., (2018). *Introducing carbon taxes at member state level: Issues and barriers* (No. 557). WIFO Working Papers.
Wendner, R., (2001). An applied dynamic general equilibrium model of environmental tax reforms and pension policy. *Journal of Policy Modelling*, *23*(1),25-50.

Appendix

Table A1: Descriptive Statistics

Variable	Mean	SD	N
Tax (household electricity)	0.043	0.031	493
Tax (Industry electricity)	0.012	0.014	270
SDG7			
Primary energy consumption	57.196	77.667	493
Final energy consumption	36.182	49.458	493
Final energy consumption in households per capita	597.576	207.419	493
Energy productivity	6.496	2.896	493
Share of renewable energy in final energy consumption	17.451	13.778	493
SDG8G			
Real GDP per capita	25302.440	17223.200	491
Resource productivity	1.470	0.941	493
SDG8W			
Young people not in employment, education and training	14.052	5.334	480
Long term unemployment rate	3.985	3.043	462
Inactive population due to caring	20.374	12.566	487
SDG9			
Gross domestic expenditure on R&D by sector	1.444	0.859	482
Employment in high- and medium-high technology	42.826	11.230	493
R&D personnel by sector	0.990	0.505	455
Patent applications	1879.019	4205.444	491
Share of transport modes in passenger land transport	18.967	6.327	432
Share of rail and inland, waterways in freight transport	32.935	15.589	450
SDG12			
Resource productivity	1.457	0.887	493
Energy productivity	6.496	2.896	493
SDG13			
CO2 emission per capita	8.021	3.531	435

Table A2: Stability test for both household tax and industry tax PVAR model

Eigenvalue for stability test (household model)

Real	Imaginary	Modulus
0.944	-0.209	0.967
0.944	0.209	0.967
0.844	0.000	0.844
-0.799	0.000	0.799
0.461	-0.170	0.492
0.461	0.170	0.492
0.030	0.000	0.030

Note: The model is stable when all moduli of the companion matrix are strongly less than 1.

Eigenvalue for stability test (industry model)

Real	Imaginary	Modulus
0.838	0.373	0.917
0.838	-0.373	0.917
0.238	0.635	0.678
0.238	-0.635	0.678
0.614	0.000	0.614
0.426	0.000	0.426
0.237	0.000	0.237

Note: The model is stable when all moduli of the companion matrix are strongly less than 1.

Table A3: Causality Test-PVAR model

Causality test for household PVAR model

Equation	Excluded	Chi2	DF	P-value
Tax				
	SDG7	0.743	1	0.389
	SDG8(Growth)	30.696	1	0.000
	SDG8(Unemployment)	3.303	1	0.069
	SDG9	2.405	1	0.121
	SDG12	36.476	1	0.000
	CO2	13.107	1	0.000
SDG7				
	Tax	2.676	1	0.102
	SDG8(Growth)	20.286	1	0.000
	SDG8(Unemployment)	10.571	1	0.001
	SDG9	2.630	1	0.105
	SDG12	35.301	1	0.000
	CO2	27.362	1	0.000
SDG8(Growth)				
	Tax	1.885	1	0.170
	SDG7	5.866	1	0.015
	SDG8(Unemployment)	6.252	1	0.012
	SDG9	41.323	1	0.000
	SDG12	151.634	1	0.000
	CO2	0.034	1	0.853
SDG8(Unemployment)				
	Tax	20.838	1	0.000
	SDG7	77.550	1	0.000
	SDG8(Growth)	6.722	1	0.010
	SDG9	2.544	1	0.111
	SDG12	11.527	1	0.001
	CO2	52.859	1	0.000
SDG9				
	Tax	19.018	1	0.000
	SDG7	28.114	1	0.000
	SDG8(Growth)	14.466	1	0.000
	SDG8(Unemployment)	12.497	1	0.000
	SDG12	24.108	1	0.000
	CO2	51.435	1	0.000
SDG12				
	Tax	1.588	1	0.208
	SDG7	0.051	1	0.821
	SDG8(Growth)	58.007	1	0.000
	SDG8(Unemployment)	10.172	1	0.001
	SDG9	0.048	1	0.826
	CO2	8.442	1	0.004
CO2				
	Tax	9.949	1	0.002
	SDG7	73.173	1	0.000
	SDG8(Growth)	36.519	1	0.000
	SDG8(Unemployment)	24.313	1	0.000
	SDG9	0.276	1	0.599
	Tax	2.745	1	0.098

Note: DF is degree of freedom, chi2 is chi-square test statistic, excluded are the variables we are testing for causality in the model.

Causality test for Industry PVAR model

Equation	Excluded	Chi2	DF	P-value
Tax				
	SDG7	0.612	1	0.434
	SDG8(Growth)	0.549	1	0.459
	SDG8(Unemployment)	21.516	1	0.000
	SDG9	4.479	1	0.034
	SDG12	0.504	1	0.478
	CO2	2.540	1	0.111
SDG7				
	Tax	1.220	1	0.269
	SDG8(Growth)	23.432	1	0.000
	SDG8(Unemployment)	1.030	1	0.310
	SDG9	0.031	1	0.859
	SDG12	0.155	1	0.693
	CO2	3.987	1	0.046
SDG8(Growth)				
	Tax	4.058	1	0.044
	SDG7	2.699	1	0.100
	SDG8(Unemployment)	0.064	1	0.800
	SDG9	2.061	1	0.151
	SDG12	50.228	1	0.000
	CO2	35.412	1	0.000
SDG8(Unemployment)				
	Tax	30.919	1	0.000
	SDG7	32.207	1	0.000
	SDG8(Growth)	42.985	1	0.000
	SDG9	0.011	1	0.917
	SDG12	10.234	1	0.001
	CO2	16.389	1	0.000
SDG9				
	Tax	0.239	1	0.625
	SDG7	1.104	1	0.293
	SDG8(Growth)	42.434	1	0.000
	SDG8(Unemployment)	0.000	1	0.987
	SDG12	16.948	1	0.000
	CO2	0.159	1	0.690
SDG12				
	Tax	14.019	1	0.000
	SDG7	0.000	1	0.993
	SDG8(Growth)	80.729	1	0.000
	SDG8(Unemployment)	0.152	1	0.697
	SDG9	0.837	1	0.360
	CO2	0.919	1	0.338
CO2				
	Tax	0.576	1	0.448
	SDG7	30.503	1	0.000
	SDG8(Growth)	24.590	1	0.000
	SDG8(Unemployment)	6.064	1	0.014
	SDG9	0.023	1	0.881
	Tax	1.141	1	0.285

Note: DF is degree of freedom, chi2 is chi-square test statistic, excluded are the variables we are testing for causality in the model.