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Impact of the carbon tax on the reduction of CO2 emissions in the EU

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Summary

Considered as one of the methods of CO_2 mitigation, the carbon tax can reduce energy consumption, improve energy efficiency and develop renewable energies. Of course, the carbon tax also has its flaws. For example, it will affect the economy, reduce social well-being, the competitiveness of industries and lead to carbon leakage.

Motivated by the controversial question of the real effect of the carbon tax in the mitigation of carbon emissions, we try to estimate its effects in the European Union countries that have adopted this policy, using the propensity scoring method. Our paper focuses on the real mitigation effects during the carbon tax implementation period and tries to provide more information to decision makers by analyzing the results.

The Closest propensity score matching Reconciliation (PSM) methodology used for matching showed a positive and significant impact of the carbon tax with a reduction over the entire period 1990-2019 in the EU.

Jel Classifications: C15, C33, O52, P18, Q52.

Keywords : Energy consumption, Tax carbon, CO2, European countries, PSM methodology

Introduction

Global warming is now an indisputable fact and its damage to human beings has become one of the most serious threats in the world. CO_2 remains the main greenhouse gas (GHG) caused by humans, and the increase in its density is mainly due to the consumption of fossil fuels.

According to the latest assessment report of the Intergovernmental Panel on Climate Change (IPCC), Annual emissions of man-made CO_2 (fossil fuels, cement production) over the period 2002-2011 were 54% above 1990 levels. Faced with the challenge of climate change, the choice to reduce CO_2 emissions and pursue low-carbon development has become inevitable.

In order to reduce CO_2 emissions, many methods have been implemented, including the energy tax, carbon tax, emission standards and emissions trading systems. Among these methods, economists and international organizations (EEA, 1996) strongly recommend a carbon tax, which is a cost-effective instrument for achieving a given reduction target.

The carbon tax is levied on fossil fuels and related products such as coal and gas based on their carbon content to reduce fossil fuel consumption and carbon emissions. The effects of the carbon tax are bilateral.

On the one hand, they encourage energy savings and investment in improving energy efficiency and encourage the substitution of fuel products and thus changes in energy consumption and production structures. On the other hand, they influence investment and consumption behaviour by recycling collected carbon tax revenues. (Baranzini et al. 2000).

However, the carbon tax inevitably has its own flaws. First, in the short term, the carbon tax will increase the price of related products, increase business costs, weaken the competitiveness of energy-intensive industries, and negatively impact economic growth.

Second, the mitigation effects of the carbon tax are uncertain. Businesses can shift increased costs to consumers through higher prices, so the carbon tax will only lead to higher tax revenues rather than lower emissions. Higher price elasticity, which implies more difficulty in transferring the costs of the carbon tax to consumers and thus in achieving better mitigation effects; Otherwise, the costs of the carbon tax will be shifted and the effectiveness of mitigation will be reduced.

Finally, since developing countries are currently responsible for reducing CO_2 emissions, the carbon tax will lead to competitive losses in related industries. The implementation of the carbon tax in developed countries will lead to the immigration of carbon-intensive industries to developing countries with liberalized environmental control policies. As a result, the problem of carbon leakage arises. Carbon leakage will delay the adjustment of the energy structure and the technological development of developing countries, thereby hindering sustainable development.

To support the competitiveness of domestic industries, developed countries would like to impose carbon tariffs on developing countries and adopt carbon tariffs as a new method of trade protection. Currently, only a few countries have implemented a carbon tax because of their negative effects on the competitiveness of domestic industries and the externality of CO_2 mitigation. These countries or regions that have adopted the carbon tax include:

Denmark, Estonia, Finland, France, Ireland, Iceland, Latvia, Norway, Poland, Portugal, the United Kingdom, Slovenia, Sweden, Switzerland, South Africa, Chile, British Columbia (Canada), Japan and Mexico. In addition, a common feature of their implementation is the inclusion of exemption and tax relief (Ekins and Speck, 1999), specifically for energy-intensive industries. In recent years, increasingly serious problems related to energy security, energy conservation and emission reduction have forced many countries, such as France, Japan and China, to put the carbon tax on the agenda. Therefore, the question of how to take advantage of the advantages and avoid the disadvantages of the carbon tax should be a serious concern for these countries.

In order to provide evidence for countries that need to introduce the tax, we estimate the real mitigation effects of the carbon tax on the European Union of 28 countries. The purpose of this exercise is therefore to present and analyse the following issues:

- How do the emission reduction situations in these countries fit in?
- Does the carbon tax affect the reduction of CO2 emissions?
- If so, to what extent are the impacts significant?

1. Review of Empirical Literature

Concerns about the impact of human activities on the environment. The carbon tax is often seen as a cost-effective instrument to reduce emissions. The effectiveness of the carbon tax has been studied by many authors and the results differ according to the impact and objectives. The energy saving or fuel substitution process resulting from the introduction of environmental taxation and the stabilization of emissions at 1988 levels only to the electricity generation sector, and reach only if high tax rates are assumed ($100/ton.C).

Total emissions (all sectors and all fuels) continue to increase, with the implementation of a $100/ton tax. C cannot reduce the rate of growth of emissions. These results would recommend the introduction of several coordinated environmental instruments. Andrea Baranzinia et al(2000) assessed the carbon tax on their competitiveness, distribution and environmental impacts. The results showed that the carbon tax can be an attractive option for environmental policy and that their main negative impacts can be offset by the design of the tax and the use of the tax revenues generated.

Over the past decade, Norway has pursued an ambitious climate policy. The main policy tool is a relatively high carbon tax, which was already implemented in 1991. Annegrete Bruvoll and Bodil Merethe[3] (2004) Larsen studied the carbon tax in Norway and found a significant reduction in emissions per unit of GDP due to reduced energy intensity although total emissions have increased. Despite significant taxes and price increases for certain types of fuel, the impact of the carbon tax has been modest.

Although the partial effect of changes in energy intensity and lower energy mix was a 14% reduction in CO_2 emissions, carbon taxes contributed to the reduction of only 2%. This relatively small effect relates to broad tax exemptions and relatively inelastic demand in areas where the tax is actually implemented. However, given the ultimate objective of the Framework Convention, future carbon taxes could have higher rates than those already imposed and therefore the resulting economic impacts could be more acute. In this context, it has been demonstrated that the use of tax revenues generated will be of fundamental importance in determining the final economic impacts of carbon taxes.

[3]Annegrete Bruvoll , Bodil Merethe Larsen, 2004, Greenhouse gas emissions in Norway: do carbon taxes work?, Energy Policy, 2004, vol. 32, issue 4, pages 493-505

Cheng F. Lee et al[4] (2008) analyze the impacts of the combination of a carbon tax and emissions trading on different sectors of industry. The results show that the GDP loss caused by the carbon tax linked to the petrochemical industry during the period 2011-2020 is 5.7%. However, the value of GDP losses will fall by only 4.7% if carbon taxation is implemented in conjunction with emissions trading. In addition, among sectors related to the petrochemical industry, upstream sectors benefit from emissions trading, while downstream sectors are required to purchase additional emissions permits due to difficulties in meeting their emissions targets.

Tim Callan et al (2009) studied the effects of the[5] carbon tax and income recycling through income distribution in the Republic of Ireland. In absolute terms, a carbon tax of €20 / tCO_2 would cost the poorest households no less than € 3/ week and the richest households more than € 4/ week. A carbon tax is regressive. However, if tax revenues are used to increase social benefits and tax credits, households through the distribution of income can be better without depleting total carbon tax revenues.

Chuanyi Lu et al [6] (2010) examined the impact of the carbon tax on the Chinese economy, as well as the depreciation effects of complementary policies, building a dynamic recursive general equilibrium model. The model can describe the new balance for each sequential independent period (e.g., one year) after carbon tax and complementary policies are imposed, and thus describe the long-term impacts of policies.

The simulation results show that the carbon tax is an effective policy tool as it can reduce carbon emissions with some negative impact on economic growth. Reducing indirect taxes will help reduce the negative impact of carbon taxes on production and competitiveness; In addition, giving households subsidies in the meantime will help boost household consumption.

Therefore, complementary policies used in conjunction with the carbon tax will help cushion the negative effects of the carbon tax on the economy. The EGC dynamic analysis shows the impact of carbon tax policy on GDP is relatively small, but the reduction of carbon emissions is relatively significant.

[4]Cheng F. Lee Sue J. Lin , Charles Lewis, 2008, Politique énergétique, Volume 36, Numéro 2 , Pages 722-729.
[5]Tim Callan, Sean Lyons, Susan Scott, Richard S.J. Tol, Stefano Verde, (2009), The distributional implications of a carbon tax in Ireland, Energy Policy, Volume 37, Issue 2, February 2009, Pages 407–412.
[6]Chuanyi Lu, Qing Tong,Xuemei Liu, (2010), The impacts of carbon tax and complementary policies on Chinese economy, Energy Policy, Volume 38, Issue 11, November 2010, Pages 7278–7285.

As the most effective market-based mitigation tool, the carbon tax is highly recommended by economists and international organizations. Countries such as Denmark, Finland, Sweden, Netherlands and Norway were the first to adopt the carbon tax and as such, Research into the impacts and problems of implementing the carbon tax in these countries will be of great practical importance, thus setting an example for the countries which will levy the tax.

Boqiang Lina, Xuehui Lib[7] (2011), provided an overall estimate of the actual CO_2 mitigation effects in five northern European countries using the Difference in Difference (DID) method. The results indicate that the carbon tax in Finland imposes a significant and negative impact on the growth of its carbon emissions per capita. Meanwhile, the effects of the carbon tax in Denmark, Sweden and the Netherlands are negative but not significant.

The mitigation effects of the carbon tax are weakened because of tax-exempt policies on certain energy-intensive industries in these countries. In Norway, the rapid growth of energy products leads to a substantial increase in CO_2 emissions in the oil drilling and natural gas sectors, the carbon tax has not achieved its mitigation effects.

2. Methodology and Data

2.1. Data Sources and Modelling

The Kaya[8] identity is a useful equation for quantifying total greenhouse gas emissions of carbon dioxide (CO_2) from human sources. However, in this study, carbon emissions are used as a key dependent factor. The traditional model is based on readily available information and can be used to quantify the current carbon level, and how relevant factors must change relative to each other over time to achieve a target level of CO_2 emissions in the future.

The identity has been used, and continues to be important, in the discussion of global climate policy decisions. The Kaya identity shows the total CO_2 emission level as the product of four factors:

$$CO_2 = f(POP, GDPC, EI, CI) \qquad (1)$$

[7] Boqiang Lin, Xuehui Li (2011), The effect of carbon tax on per capita CO_2 emissions, Energy Policy, Volume 39, Issue 9, Pages 5137–5146

[8] Kaya, Y., & Yokobori, K. (Eds.). (1997). *Environment, energy, and economy: strategies for sustainability*. Tokyo: United Nations University Press.

Regarding the selection of covariates, Kaya decomposed the factors related to CO_2 emissions in population (POP), GDP per capita (GDPC=GDP/POP), energy intensity (EI=PE/GDP), and carbon intensity $(CI = \frac{C02}{PE})$ with PE is primary energy. More recently, [6,12,15,19,24,29] also investigated the role of energy taxes and environmental taxes for environmental issues in Europe, China and OECD countries. To determine whether the adoption of a carbon tax policy in EU countries promotes CO_2 reduction, we implement the propensity score matching methodology (hereafter NNM) initiated by Rubin (1974) and developed by Rosenbaum and Rubin [1983]. This estimator was derived by Abadie and Imbens [2011]. This method is increasingly popular and widely used in microeconometrics as well as in different fields such as health, education, etc.

Based on the work of Cameron and Trivedi [2005], Greene [2011], Ghazouani et al [2020] the main regression equation of the endogenous treatment effects model is:

$$CO2_J = \alpha_1 POP_1 + \alpha_2 GDPC_2 + \alpha_3 EI_3 + \alpha_4 CI_4 + \alpha_j T_j + s_j \quad (2)$$

Where:

- **CO_2**: Carbon dioxide emissions
- **GDP** per capita is the gross domestic product divided by the mid-year population. GDPH = GDP / P
- **EI**: Energy intensity (EI): EI = PE / GDP
- **CI:** the carbon intensity (CI).CI = CO_2 / PE
- **POP**: total number of people living in a country, region, city or place.
- β and α are coefficients to be estimated and ε_j are error terms.
- t_j is taken as a dummy variable taking the value 1 if a country adopts a carbon tax policy, and 0 otherwise.

$$t_j^* = w_j\delta + \varphi_j$$

The decision to obtain the treatment is made according to the rule:

$$t_j = \begin{cases} 1 & \text{if } t_j^* > 0 \\ 0 & Otherwise \end{cases}$$

Matching estimators are based on the probable model outcomes, in which each individual has a well-defined outcome for each treatment level. In the binary treatment probable outcome model, y_1 is the potential outcome obtained by an individual if the treatment level is equal to 1 and y_0 is the potential outcome obtained by each individual if the treatment level is equal to 0.

The form of the estimator ATE and ATET is:

$$ATE_t = (CO2_t - CO2_0)$$

$$ATE_t = \{(CO2_t - CO2) \mid t = \hat{t}\}$$

2.2. Sample

Our panel database includes 28 EU economies over the period 1990-2019. The data come from several sources, including Eurostat, the US Energy Information Administration, and the World Bank's development indicators.

- Treatment Group

The carbon tax was first introduced in Finland in 1990. It applied to fuel, coal and natural gas. Slovenia has applied a carbon tax since 1996 for CO_2 emissions resulting from the combustion of fossil fuels. In France, the carbon tax was introduced in 2014; it is a tax on fossil fuels, oil products, natural gas and coal proportional to their CO_2 emissions. The United Kingdom introduced the carbon tax in 2001. It aimed to reduce annual CO_2 emissions by 2.5 million tonnes by 2010. It affects all energy consumers, with the exception of residential and transport.Ireland introduced a carbon tax in 2010 that covers virtually all fossil fuels for the residential and tertiary sectors, transport and agriculture.

- **Control Group**

In this article, we have chosen the member countries of the European Union as our control group, as these countries have not adopted a carbon tax. The selected countries are Belgium, Portugal, Cyprus, Germany, Hungary, Greece, Malta, Romania, Spain, Bulgaria, Czech Lithuania, Estonia, Croatia, the Netherlands, Slovakia, Luxembourg, Italy, Austria, Poland.

3. Results and analysis

3.1 Preliminary Results

The matching method attempts to pair each treated country with one or more untreated countries with the closest possible observable characteristics. The objective of matching is to construct a reference group comparable to the treated group a fi N to allow for an unbiased estimate of the treatment effect on treated individuals, controlling for selection bias [43-45].

- **Summary test of covariate balance**

To get a sense of covariate balance, study the differences with standardized differences and variance ratios. A perfectly balanced covariate has a standardized difference = 0 and a variance ratio = 1. Table 2 mentions the summary of covariate balance for all variables studied, including income, population, energy intensity, and carbon intensity.

Table 2: Summary test of covariate balance

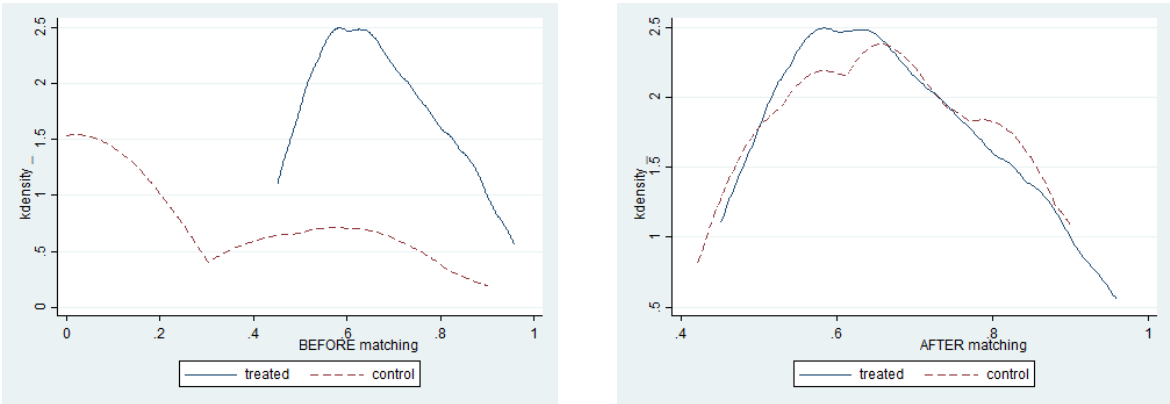
	Standardized differences	
	Base	Paired
GDPC	0.050	0.067
POP	-0.019	-0.074
IC	-0.122	-0.381
IE	-0.250	-0.027
Number obs	28	10
Obs Treatement	5	5
Obs Control	23	5

The result indicates that the variables are balanced or took 5 countries for treatment versus 5 countries for control.

- **Kernel Density**

Kernel density is a non-parametric estimation method to check the probability density for any random variable. It is based on a sample of a statistical population and estimates the density at any point in the support. Figure 1 presents the kernel density for all the variables studied for the European economies.

Figure 1: Kernel Density Test



Kernel density gives density plots of a covariate over the treatment levels of the raw data and the sample (weighted or paired). The kernel density is verified as it reports density plots of a covariate on the raw data processing levels for both weighted and matched samples.

It is important to mention here that if the matched sample of the covariate and density plots of the weighted sample are similar at different treatment levels, the covariate is considered balanced in the weighted and paired samples. Similarly, the density plots for the paired group sample are nearly similar, suggesting that the estimated pairing would balance the covariates.

3.2. Analysis and results

The estimation results of different methods allow us to observe a positive and significant influence of the adoption of the carbon tax on the stimulation of CO_2 emissions reduction. The propensity score matching methodology used for pairing showed a positive and significant impact of the carbon tax with a reduction over the whole period ranging from 2.83% to 3.45% for the average treatment effect (ATE). i.e. the difference between treatment and control countries. The propensity score matching methodology yielded positive and significant results for the average treatment effect on the treated variable (ATET) over the entire period ranging from 2.03% to 2.92%. Table 3 lists the ATE and ATET estimates for the countries studied.

Table 3: Results of the estimation

CO_2 (treat vs 0)	ATE		ATET	
Coef.	-2.83%		-2.29%	
T	-7.18		-15.20	
P>z	0.000		0.000	
[95% Conf. Interval]	-3.45%	-2.93%	-2.92%	-2.03%

The estimation results show that the promotion of carbon tax policies can significantly motivate CO_2 mitigation in the European Union. In particular, our empirical findings that carbon tax policies have a positive impact on CO_2 reduction are consistent with those obtained by Lin et Li[9] [2017] for the case of Denmark, Sweden, and the Netherlands. More recently, Borozan[10], [2018] and He et al.[11] [2019] also reported similar findings for the case of European and G7 countries.

3.3. Discussion of the results

Our analysis has allowed us to determine the effectiveness of the carbon tax, but for this policy to be more effective, certain measures must be taken. The tax achieves its objective if and only if three conditions are met, all polluters are indeed cost minimizers but this condition is notably not met in the case where the polluting agents are public enterprises, power generation companies for example or local authorities; all are well informed about their marginal cost reduction curves and there is no possibility of untaxed polluting emissions but for this condition to be met, as in the case of standards, it is necessary to effectively control the volume of emissions.

However, it is important to consider some cases that make the practice of taxation difficult. Defensive activities and transferable externalities: One way to defend against the effects of an externality is to transfer it (provided it is rivals) to other agents, which induces new inefficiencies.

[9] Lin, B.; Zhu, J. Energy and carbon intensity in China during the urbanization and industrialization process: A panel VAR approach. J. Clean. Prod. 2017, 168, 780–790.
[10] Borozan, D. Efficiency of energy taxes and the validity of the residential electricity environmental Kuznets curve in the European Union. Sustainability 2018, 10, 2464.
[11] He, P.; Chen, L.; Zou, X.; Li, S.; Shen, H.; Jian, J. Energy taxes, carbon dioxide emissions, energy consumption and economic consequences: A comparative study of Nordic and G7 countries. Sustainability 2019, 11, 6100.

Overall, the empirical results allow us to draw few arguments and implications. The empirical results support that energy consumption, income and population could be the main contributors to the increase in pollution levels. European developed economies have experienced high income growth, population growth, and energy intensity, primarily due to rapid industrialization and economic activities in these economies.

Notably, each of these elements requires different policies and monitoring to control emissions of air pollutants. Notably, the increase in population and income levels is driving the use of more resources in terms of natural resources, coal, oil and other fossil fuels. While the abundant consumption of fossil fuels leads to pollution and environmental externalities. At the same time, renewable energy consumption can be a useful tool for reducing greenhouse gas emissions. Similarly, urban income control, relevant population control policies can also limit energy consumption and climate change problems.

It is worth mentioning here that our study agrees with the findings of Borozan[12] [2018]; Hashmi and et Alam[13] [2019] and Shahzad[14],, [2020]. From the empirical results, we can draw few implications. First, the government of developed economies should take necessary measures and regulations, such as replacing fossil fuels with renewable energy source in the overall energy mix and treatment of manufacturing. This is due to the fact that several European countries still dominate in the consumption of fossil and non-renewable fuels. While in order to achieve the mentioned sustainable development goals, cleaner production and sustainability, energy transformation policies are very necessary and needed at this time.

To this end, investments in renewable energy and cleaner energy sources should be encouraged, so that the path to sustainable development can be set. Secondly, the government of European economies, especially countries such as Finland, Denmark, Slovenia, Sweden, France and the United Kingdom need to rethink the carbon tax and environmental tax policies with more effective and necessary pressure to monitor and control energy consumption and carbon emissions.

[12] Borozan, D. Efficiency of energy taxes and the validity of the residential electricity environmental Kuznets curve in the European Union. Sustainability 2018, 10, 2464.

[13] Hashmi, R.; Alam, K. Dynamic relationship among environmental regulation, innovation, CO2 emissions, population, and economic growth in OECD countries: A panel investigation. J. Clean. Prod. 2019, 231, 1100–1109.

[14] Shahzad, U.; Ferraz, D.; Do gan, B.; Aparecida, D. Export Product Diversification and CO2 Emissions: Contextual evidences from Developing and Developed Economies. J. Clean. Prod. 2020, 276, 124146.

In doing so, developed countries in the European region can implement regulations to install carbon treatment plants, greenhouse gas treatment plants, afforestation policies. Similarly, industrial companies should replace their polluting technologies with environmentally friendly machines. Such policies can restrict and reduce the demand for energy, therefore they can mitigate greenhouse gas emissions from the atmosphere.

Carbon taxes can change the competitiveness of firms exposed to competition from countries that do not have carbon taxes or have lower rates. It reduces the competitiveness of companies with high CO_2 emissions. But conversely, if the tax revenues are redistributed, the competitiveness of those with low CO_2 emissions can be improved. Some countries have chosen not to apply the tax to relocatable activities or to apply it at reduced rates. Customs measures, such as "border adjustment taxes", can also be put in place to protect domestic activities.

However, international negotiations may be necessary as this area is highly regulated, including by the World Trade Organization. in order not to harm the competitiveness of domestic industries, countries adopting the carbon tax have exempted energy-intensive or manufacturing industries from taxes. The main tax exemption policies in these countries are as follows:

Denmark imposed a carbon tax on households and businesses. To ensure international competitiveness, all businesses were refunded 50% of the standard rate. Additional rebates were given based on the energy intensity of each company. Sweden reduced the tax burden on manufacturing industries in 1993. for certain energy-intensive industries such as the iron and steel industry, the carbon tax burden was reduced to 1.7% of the value of production. This limit was later reduced to 1.2%. Finland, unlike other Scandinavian countries that differentiate tax rates for private users from those for industrial users, does not allow tax exemptions or breaks for industry.

This study argues that the implementation of relevant policies will be helpful in achieving the economic and sustainable development goals of European countries. In this case, the policy adopted should combine taxation and compensation, because the existence of a transferability implies the creation of a social gain or loss: a tax should be imposed on a victim who transfers the externality, but compensation should be paid to a victim who chooses to keep the externality when he has the possibility of transferring it, because this creates a benefit for others; finally, the last receiver of the nuisance should not receive compensation if he had no possibility of transferring it.

The problem of diffuse pollution: Another type of difficulty is introduced by the treatment of diffuse pollution, i.e. pollution caused by numerous sources of pollution, which are difficult or very costly to identify or control, and which pose both a problem of measuring emissions and, above all, a problem of moral hazard, when the consequences of the behavior of polluters on the overall level of pollution cannot be individualized.

The ambient fiscal mechanisms proposed by Lin and Li [2011]; Wang and Wei [2019] and Shahzad et al [2020] based on incentive theory, consist of a combination of penalties and rewards: each polluter pays a tax or receives a subsidy depending on the overall performance, i.e., to say the deviation from a given level of ambient concentration of pollutants, and has to pay, in case of excessive overall pollution, a lump-sum penalty equal to the total damage created by the excess.

This procedure achieves the intended environmental objective by combating free riders, as it makes each polluter individually responsible for the total pollution and not just his own. However, it has the disadvantage that it can only work if polluters actually believe that their behavior has an impact on the overall level of emissions. Carbon pricing policies have an impact on the competitiveness of the European manufacturing sector, which has seen a decline in output and total employment of 5% and 26% respectively between 2001 and 2016. At the industry level, the jobs destroyed in the companies concerned are compensated by recruitments in other companies of the same sector in the same year, Cui[15][2020].

On average, large energy-intensive firms reduce their carbon emissions more and redeploy more workers than small energy-efficient firms. the carbon tax reduced carbon emissions by about 5% on average. The net effect on employment is much smaller and even slightly positive at +0.8%. Several sectors are experiencing large reductions in carbon emissions, with little redeployment of employees. In contrast, the automotive and plastics sectors experience larger employee redeployments and smaller reductions in their carbon emissions. Other industries, such as metal products, combine high job reallocation with considerable emissions reductions due to their large size.

[15] Cui, L.; Sun, Y.; Song, M.; Zhu, L. Co-financing in the green climate fund: Lessons from the global environment facility. Clim. Policy 2020, 20, 95–108.

While the carbon tax allows the European manufacturing sector to meet its carbon budget and does not negatively affect total employment, it does generate significant redeployment of employees in several industries. Since these redeployments have redistributive effects and generate costs for workers who are forced to change jobs, these results highlight the need for complementary labor market policies that minimize the costs for the workers concerned and facilitate employment adjustments across firms. Moreover, because these transition costs tend to be highly localized in regions specializing in energy-intensive industrial activities, they can also entail potentially large regional effects and thus a high political cost.

Conclusion

Considered as one of the CO_2 mitigation methods, carbon tax can reduce energy consumption, improve energy efficiency and develop renewable energy. Of course, the carbon tax also has its flaws. For example, it will affect the economy, decrease social welfare, competitiveness of industries and lead to carbon leakage.

Motivated by the controversial question of the real effect of the carbon tax in mitigating carbon emissions, we try to estimate its effects in the European Union countries that have adopted this policy, using the propensity score method. Our paper focuses on the actual mitigation effects during the implementation period of the carbon tax and tries to provide more information to policy makers by analyzing the results. The mitigation effect of the carbon tax differs from country to country, On average, the coefficients for the countries adopting the carbon tax are positive, but none of them exceed the significance criterion, showing the limited effects of the carbon tax in these countries.

The different impacts of the carbon tax in different countries stem primarily from the different carbon tax rates, the scope of the tax exemption, and the different use of carbon tax revenues. The environmental externality requires a uniform tax rate for different sectors, which also explains why the carbon tax in some countries e.g. Finland works better than other countries, even though the nominal tax rates are generally lower.

Given the effects of the carbon tax on industrial competitiveness, some countries such as Sweden, and Denmark have given tax exemptions to manufacturing and energy intensive industries that have reduced the mitigating effects of the carbon tax in these countries.

On the other hand, Denmark's experience indicates that, compared to using carbon tax revenues directly as part of tax revenue, recycling tax revenues to businesses for environmental purposes can promote renewable energy development by offsetting the costs Induced by the tax exemption.

In Sweden, even though all of its carbon tax revenues are included in tax revenues, its relatively high carbon tax rate has made the mitigation effects better than those of Denmark, Estonia, Latvia or Poland.

Faced with the serious problem of climate change, the choice of reducing CO_2 emissions and pursuing low-carbon development has become inevitable. It is suggested that adjusting the industrial structure, increasing R&D investment and raising energy prices are reasonable choices for CO_2 emission reduction.

In addition, for countries that need to collect a carbon tax, implementing a flat tax can effectively reduce CO_2 emissions. However, when implementing differential tax rates to avoid a loss of industrial competitiveness, it is necessary to embark the revenue from carbon tax on environmental measures or increase carbon tax rates to mitigate the effects of the carbon tax.

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