National Research University Higher School of Economics

as a manuscript

Stepanov Ilya Alexandrovich

INCENTIVE-BASED INSTRUMENTS FOR GREENHOUSE GAS EMISSIONS REGULATION IN EUROPEAN COUNTRIES

PhD Dissertation Summary
for the purpose of obtaining an academic degree
Doctor of Philosophy in Economics

Academic supervisor:
Igor I. Makarov,
Candidate of Sciences in Economics

JEL: F64; Q54; Q48

Moscow – 2021

Motivation

The climate change has long ceased to be a purely environmental issue; it is directly intertwined with the socio-economic development in most countries and, thereby, being studied within different social sciences, including economics. The greenhouse gas (GhG) emissions regulation becomes an increasingly widespread component of energy and economic policy all over the globe. It serves both for the emissions reduction and the fulfillment of international obligations as well as for addressing a number of pressing domestic economic, social, and industrial issues ranging from energy efficiency improvement to jobs creation and strengthening leadership at the foreign markets.

The Paris Agreement, adopted in 2015 and so far ratified by 191 countries, designates low-carbon transition of the world economy. Actions to combat climate change are outlined as one of the seventeen UN Sustainable Development Goals approved in 2015 by most countries, including Russia.

A growing role of national governments in the international climate agenda emphasizes the issue of choosing a climate policy toolkit. Traditionally, academic literature, public and political discussions on climate policy draw special attention to incentive-based instruments[1] of greenhouse gas emissions[2] regulations. They refer to the carbon price (or price for GhG emissions)[3], which can be introduced in the form of carbon tax, emissions trading system (ETS) also known as a cap-and-trade, or a hybrid instrument that combines both. So far, 60 countries and regions in the world have introduced carbon price in one form or another. [World Bank, 2020]. The possibility of introducing carbon price is currently being considered in Russia [Draft Federal Law on State Regulation ...].

[1] Traditionally, in climate change economics, incentive-based instruments for emissions regulation are understood as a set of instruments which set a price per unit of emissions. Despite the economic nature of other regulatory instruments (like renewable energy tax credits, or concessional lending for the emissions reduction projects), in this dissertation, they will not be referred to as “incentive-based instruments” of GhG emissions regulation.

[2] Greenhouse gases of anthropogenic nature (or including anthropogenic nature) include gases such as CO_2, CH_4, N_2O, HFCs, PFCs, SF_6. CO_2 is considered to be the main greenhouse gas; it accounts for three quarters of all GhG emissions in the world.

[3] The carbon price refers to the payment for GhG emissions expressed in terms of carbon dioxide equivalent.

The growing popularity of the carbon price as a climate policy tool stems from the development of the externality theory in the XX century [Pigou, 1920, Coase 1960]. With the aggravation of climate change, its interpretation as a negative externality in production has gained momentum making the carbon price take a central place in the literature in the domain of climate policy [Hoel, Karp, 2001; Goulder, Parry, 2008; Nordhaus 2017; Bashmakov, 2018].

Energy use is the main economic activity which falls under the regulation of GhG emissions. Fossil fuel emissions account for about 75% of all GhG emissions [IEA, 2019]. At the same time, the energy use has traditionally been regulated by various fiscal policy instruments; taxes on energy products have been imposed since the first half of the XX century [Speck 2006].

While a carbon tax or an ETS put the carbon price *directly*, general energy taxed do the same thing *indirectly* since their tax base usually represents the volume of energy used rather than its carbon content [Speck 2006]. At the same time, the contribution of a particular fiscal instrument to the emissions reduction depends not solely on the price level (e.g. tax rate), but also on the scale of its application, i.e. emissions coverage.

Energy taxes have historically been widespread and cover most sectors of the economy where energy is used [IEA (b)]. Nevertheless, general energy taxes (e.g. excise taxes on fuel, taxes on hydrocarbon extraction, etc.) occupy modest place in the climate policy as well as scarcely discussed in academic literature on climate policy. Incomplete consideration of the role of traditional fiscal energy policy instruments may lead to incorrect assessment of the prospects and opportunities for achieving the climate policy goals.

Brief Literature Review

A wide range of theoretical and empirical work has been devoted to the climate policy instruments. As a rule, direct instruments for emissions regulation (carbon tax and ETS) occupy the central place in the academic literature on climate policy [Hoel, Karp 2001; Pizer 2002; Stavins 2007; Goulder, Schein 2009;

Averchenkov, Galenovich et al. 2013; Makarov, Stepanov 2017; Bashmakov 2018].

A substantial part of the literature focuses on the assessment of the cost-efficiency of different instruments and the analysis of different types and forms of the carbon pricing instruments under certain model assumptions or considering the economic specifics of selected countries. A seminal work done by M. Weitzman highlights that under uncertainty of emissions reduction costs, the advantage of taxing the pollution (e.g. in the form of carbon tax) over establishing the allowances market (e.g. in the form of ETS) depends on the relative elasticity of the functions of marginal benefits and costs of emissions reduction [Weitzman 1974]. Over time, the importance of the uncertainty of emissions reduction costs as a crucial factor of instruments' choice became a matter of broad scientific consensus, and the Weizman's paper laid the theoretical foundations for subsequent research in this area [Hoel, Karp 2001; Pizer 2002]. Nowadays, the analysis is being developed in terms of modeling hybrid climate policy tools (simultaneous use of the emission price and ETS) [Pizer 2002; Jacoby, Ellerman 2004; Stranlund 2015], studying output-based cap in ETS [Ellerman, Wing 2003; Quirion 2005; Newell, Pizer 2008], extending models from static do dynamic form[Kolstad 1996; Tang et al. 2019], etc.

The literature also points out a number of other factors (or combination of factors) which may underlie the choice of the climate policy instruments [Goulder, Parry, 2008]. Among other things, their cost-efficiency depends on the interaction with other measures of fiscal policy [Goulder et al. 1996], transaction costs [Stavins 1995], the level of competition in the market [Mansur 2013].

A substantial part of the literature represents empirical studies devoted to the assessment of the policy instruments' cost-efficiency in selected countries or regions *ex post*. Particularly, part of them dwells on the evolution and performance of the EU ETS and other ETS including on issues of their adaptability to the uncertainty of economic and technological growth [Muûls et al., 2016; Brink et al., 2016; Fan et al, 2017; Mascher 2018; Narassimhan 2018]. Other studies measure efficiency of carbon taxes in different countries. Most of them illustrate the positive role of carbon pricing (in the form of a carbon tax or ETS) in reducing or constraining the emissions growth, but at the same time highlight ways to enhance its cost-efficiency [Murray, Rivers, 2015; Hájek 2019]. There are also papers which show weak performance of either carbon taxes or ETS in terms of emissions reduction [Lin, Li 201; Jaraite-Kažukausk, Di Maria 2016, Green 2021].

The analysis of the direct carbon pricing – via carbon taxes or ETS – has, so far, become a mainstream of climate change economics, while the analysis of the general energy taxes and their role emissions reductions is depicted in the literature rather scarcely. However, in recent year, a growing number of studies is devoted to the issue of combining climate and energy policy instruments [Hood, 2011; Baranzini et al. 2017; Tvinnereim, Mehling 2018; Kaswan 2019; Rosenbloom et al. 2020]. Some of them estimate the *implicit carbon price* which represents a total fiscal burden of a ton of carbon dioxide emissions and combines the effects of carbon tax and ETS as well as the effect of other energy taxes which have an indirect impact on emissions [Schleiniger 2016; OECD, 2016; OECD, 2019; OECD, 2020].

To illustrate, a comprehensive study done by OECD depicts an assessment of effective carbon price which includes a set of price instruments with energy taxes being amongst them [OECD, 2013]. Another OECD study presents a methodology of calculation of an effective carbon rate which includes the price of ETS, as well as rates of the carbon tax and general energy taxes imposed in 41 countries in 2021 [OECD, 2016]. The OECD analysis is based on the detailed taxation statistics in the energy sector, covering the fiscal regulation at the level of different energy sources in different industries [OECD, 2019].

Other studies investigate the relationship between taxation of the energy use and the dynamics of emissions from fossil fuel combustion [Jeffrey, Perkins, 2015; Kettner-Marx, Kletzan-Slamanig, 2018; Liobikienė et al., 2019]. However, the results of the studies do not allow for any unambiguous conclusions on the role of general energy taxes in emissions reduction. Some of them highlight a substantial role of energy taxes in emissions reduction [Lapinskiene et al. 2017]; others state that their contribution is not statistically significant [Liobikienė et al. 2019].

At the same time, the literature on the assessment and the comparison of the impacts of a carbon tax, ETS and general energy taxes on emissions is scarce [Jeffrey, Perkins, 2015; Kettner-Marx, Kletzan-Slamanig, 2018]. Few papers aim at analyzing the impact of energy taxes on the dynamics of emissions in the EU transport sector [Kettner-Marx, Kletzan-Slamanig, 2018]. Others assess the impact of energy taxes on the EU emissions, but do not take into account the role of the European ETS (EU ETS) [Liobikienė et al. 2019].

Jeffrey, Perkins (2015) show the statistically significant role of energy taxes and the EU ETS in reducing the carbon intensity of GDP, but the methodology of their analysis does not allow for comparison of the contribution of general energy taxes and carbon taxes to emissions reduction. There are also no papers on quantitative assessment of the contribution of implicit carbon price and its components on the emissions change. The present study aims to fill this gap.

In Russia, there are few papers devoted to the analysis of the incentive-based regulation of greenhouse gas emissions. Among others, one can note the studies of I.A. Bashmakov, A.A. Golua, O.V. Lugovoi, I.A. Makarov, B.N. Porfiriev, V.Y. Potashnikov. Among Russian researchers dealing with various issues of the economics of climate change as well as with issues of the low-carbon development of the world and Russian economies, it is worth highlighting I.A. Bashmakov, A.O. Kokorin, O. V. Lugovoi, I.A. Makarov, B.N. Porfiriev, V.Y. Potashnikov, S.A. Roginko, G.V. Safonov, M.A. Yulkin.

Research Object and Subject

The research **object** of the study is the state policy of GhG emissions regulation. **The subject** of the research is the contribution of direct (carbon tax and ETS) and indirect (general energy taxes) carbon price to the carbon intensity reduction in the European countries. European countries have a pioneering experience in the incentive-based emissions regulation and so far have built a matured emissions regulation system both at the level of the EU and individual economies. This underlies availability of time series required for a quantitative analysis.

Objectives of the Research

The goal of the research is the evaluation of the implicit carbon price and the comparison of the contribution of direct and indirect carbon pricing instruments to reduction of carbon intensity of GDP in in European countries.

The research **objectives** are following:

• a systematization of theoretical approaches to incentive-based regulation of the negative anthropogenic impact on the environment;

• an assessment of the role and cost-efficiency limitations of the carbon price application as part of the climate policy toolkit, a description of the main features of carbon pricing in European countries;

• a development of the methodology for the assessment of the implicit carbon price including direct and indirect carbon price in European countries;

• a calculation of the implicit carbon price of different types of fossil fuels for selected European countries;

• a regression analysis-based estimation of the contribution of implicit carbon price and its components to carbon intensity reduction in European countries in 2002-2018;

• a regression analysis-based comparison of the contribution of direct and indirect carbon pricing to carbon intensity reduction in European countries in 2002-2018.

Contribution

Research contribution of this study to the existing literature is twofold. First, the study presents a methodology for implicit carbon price calculation which represents a total fiscal burden of a ton of emissions. It includes both the direct carbon price set by carbon taxes and EU ETS as well as indirect carbon price set by general taxes on energy use (e.g. taxes on motor fuels).

The methodology is conceptually based on the approach developed by OECD (2016), which also suggests a framework for implicit carbon price calculation based on the taxation data for various energy sources, as well as an ETS price for emissions. The OECD approach implies recalculation of tax rates set for a unit of energy (liter, ton, kWh) into a tax rate for a ton of emissions, adjusted for the calorific value of various types of fuel (coal, oil, natural gas). However, the OECD approach is based on the processing of detailed statistics and, due to the calculation complexity and limited availability of data on specific tax rates in specific years and countries, it is suitable for describing a static picture - the level of the implicit carbon price in a specific time period.

Since the purpose of this study is to assess the impact of the implicit carbon price on the dynamics of the carbon intensity of GDP, this paper proposes a simpler method for calculating the implicit carbon price and its components (direct and indirect emission prices). It involves calculating the ratio of tax revenue (from energy and carbon taxes) and revenue from the sale of EU ETS permits to the total emissions in specific countries and in specific years, which makes it possible to analyze time series. In addition, this approach makes it possible to indirectly consider the instruments' emissions coverage, which is necessary for their comprehensive comparison in the framework of regression analysis.

The methodology is to some extent a modification of the Eurostat approach, according to which the implicit tax rate on energy is calculated as the ratio of energy tax revenue to energy consumption[4]. The approach used in this study uses emissions from fossil fuels as the denominator instead of energy consumption, resulting in a tax rate per unit of emissions.

Secondly, the scientific novelty of this research stems from the results of regression analysis. A number of papers known to the author consider the relationship between taxation of the use of fossil fuels and the dynamics of greenhouse gas emissions from combustion processes [Jeffrey, Perkins 2015;

[4] Implicit tax rate on energy (ten00120) (available at: https://ec.europa.eu/eurostat/cache/metadata/en/ten00120_esmsip2.htm)

Kettner-Marx, Kletzan-Slamanig 2018; Liobikienė et al. 2019], but do not allow to draw a conclusion about the impact of changes in the implicit carbon price and its components on the dynamics of emissions. Based on the calculation of the implicit carbon price and its components, a panel regression analysis is carried out resulting in the assessment of the implicit carbon price contribution to carbon intensity reduction in the European countries as well in the comparison of the contributions of direct and indirect carbon prices, considering the difference in their emissions coverage.

Methodology

Assessment of the Implicit Carbon Price

The assessment of the implicit carbon price and its components – direct and indirect carbon price (1) – is based on the data on energy and carbon tax revenues, volume and price of the allowances at the EU ETS and the overall emissions of the countries.

$$ICP = INDIRECT + DIRECT \tag{1}$$

$$INDIRECT = \frac{1}{E} * GET \tag{2}$$

$$DIRECT = ICT + IETSP \tag{3}$$

$$ICT = \frac{1}{E} * CT \tag{4}$$

$$IETSP = \frac{1}{E}(P^{ETS} * E^{A\&S}), \qquad (5),$$

where ICP – the implicit carbon price, INDIRECT – the indirect carbon price, DIRECT – the direct carbon price, GET – general energy tax revenues, ICT – the implicit carbon tax, IETSP – the implicit price at the EU ETS, CT – carbon tax revenues, E – a volume of the CO_2 emissions, P^{ETS} – an average annual price at the EU ETS, $E^{A\&S}$ - a volume of EU ETS allowances auctioned or sold.

The analysis is based on the calculation of the ratio of energy tax revenues to the overall emissions in a country; energy tax revenue per a ton of CO_2 emissions from the combustion of fossil fuels represents an implicit energy tax (2). A similar approach is used to calculate the implicit carbon tax – carbon tax revenue per a ton of CO_2 emissions (4). The analysis also includes calculation of an implicit price at EU ETS which is an average annual allowances price at the EU ETS multiplied by volume of the EU ETS allowances auctioned and sold per unit of CO_2 emissions (5). Together with implicit carbon tax, implicit price at the EU ETS makes up direct carbon price (3). The sum of the indirect carbon price, the implicit carbon tax and the implicit price at the EU ETS represent implicit carbon price calculated for each country and year (1).

Regression Analysis

The assessment of the contribution of the implicit carbon price and its components to emissions reduction is based on three fixed-effects panel data regression models. The sample includes data for 31 European countries for 17 years within the period of 2002-2018. 2002 is chosen as a first year due to the launch of the pan-European program to combat climate change, which involves tightening national measures of emissions regulation.

As a dependent variable in the model, the natural logarithm of CO_2 emissions intensity of GDP (CO2) is used. The use of per GDP emissions is a common practice for similar estimates [Zheng et al. 2014; Jeffrey, Perkins 2015]. Among other things, changes in the carbon intensity of GDP can occur due to changes in emissions caused by both a decrease or increase in consumption of fossil fuels, as well as due to increased energy efficiency of industrial processes or switching to less carbon intensive energy sources (from coal to natural gas or renewable energy sources).

As independent variables in the model, the natural logarithms of the implicit carbon price (ICP) and its components – indirect carbon price (INDIRECT) and direct carbon price (DIRECT) are used. To evaluate the contribution of carbon tax and EU ETS to carbon intensity reduction, the direct carbon price is split into the implicit carbon tax (ICT) and the implicit price at the EU ETS (IETSP) (see (3).

ICT is used as a main repressor in the first model (6), DIRECT and INDIRECT - as the main repressors in the second one (7), while ICT and IETSP - in the third one (8).

The natural logarithms of the share of renewable energy in primary energy consumption (REN) and GDP at PPP at constant 2010 prices (GDP) are used as control variables for all three models. The indicator of the share of RES in energy consumption describes structural changes in the fuel and energy balances of countries and can also reflect the country's efforts to develop renewable energy sources (RES) and is often used in models of this type [Jeffrey, Perkins 2015; Liobikienė et al. 2019]. The relationship between the dynamics of emissions and changes in GDP has been the subject of analysis in a number of works [Bengochea-Morancho et al. 2001; Hatzigeorgiou et al. 2011], indicating a positive relationship between the two indicators. Since the indicator of the ratio of emissions to GDP acts as a dependent variable, it is expected that the relationship of this indicator with the volume of GDP will be negative.

The modeling also includes country and time (annual) fixed effects. Country fixed-effects allow to account for latent, time-invariant characteristics of countries that could potentially influence the dependent variable. These characteristics may include the quality of market institutions, the specifics of fiscal regulation, the distribution of market power in the economy, etc. Time fixed-effects represent for year-to-year changes, which may influence the dependent variable, common for each country. To illustrate, these are the fluctuations in energy market prices, the financial crisis of 2008-2009, the European debt crisis (started in 2010), as well as the development of pan-European climate and energy legislation, including regulatory reforms in the EU ETS (transition from the 2^{nd} to the 3^{rd} phase of EU ETS in 2013), changing requirements for motor vehicles engines (transition from Euro-5 to Euro-6 motor vehicle engine standards in 2015), etc.

As a result of checking the time series for stationarity, it was revealed that some of them (ICP, INDIRECT, DIRECT, ICT, IETSP, REN) are nonstationary, and therefore the regressions are estimated for the first difference of all regressors included in the model and the dependent variable.

Models' specification looks as follows (6,7,8). Each model estimates the contribution of the changes in implicit carbon price (6) and its components, broken down into indirect and direct carbon prices (7), as well as into the indirect carbon price, implicit carbon tax, and the implicit price at the EU ETS (8) to the changes in emissions reduction. To formally define the objectives of the quantitative analysis for each model, three working hypotheses have been formulated.

The first model assesses the contribution of the change in implicit carbon price to carbon intensity reduction. ***Hypothesis 1.*** *Changes in the implicit carbon price (ICP) negatively affect changes in carbon intensity.*

Model 1: $\Delta lnCO2_{it} = c + \alpha_1 * \Delta lnICP_{it} + \alpha_2 * \Delta lnGDP_{it} + \alpha_3 * \Delta lnREN_{it} + u_i + v_t + e_{it}$ (6)

Within the second model, the contributions of changes in direct and indirect carbon price to carbon intensity reduction are compared. ***Hypothesis 2.*** *Changes in direct carbon price (DIRECT) and indirect carbon price (INDIRECT) negatively affect changes in carbon intensity, however, the impact of the direct carbon price's change is greater than this of the indirect one.* The hypothesis stems from the fact that, unlike indirect carbon price, the direct carbon price puts the price on carbon directly with respect to the carbon content of the fossil fuel used.

Model 2: $\Delta lnCO2_{it} = c + \beta_1 * \Delta lnINDIRECT_{it} + \beta_2 * \Delta lnDIRECT_{it} + \beta_3 * \Delta lnGDP_{it} + \beta_4 * \Delta lnREN_{it} + +\eta_i + \theta_t + \kappa_{it}$ (7)

The third model is dedicated to compare the contribution of the changes in the levels of the two components of the direct carbon price – the implicit carbon tax and the implicit price at EU ETS - to carbon intensity reduction. ***Hypothesis 3.*** *Changes in implicit carbon tax (ICT) and implicit price at EU ETS (IETSP) negatively affect changes in carbon intensity, however, the impact of the change in implicit carbon tax is greater than this of the implicit price at EU ETS. G*iven the complexities of the EU ETS development, namely the issue of the unpredictability of market prices (especially during 2008-2012), as well as available studies pointing at greater efficiency of carbon taxes as compared to ETSs [Green 2021], it is expected that the EU ETS impact on emissions is lower than this of the carbon taxes in force in European countries.

Model 3: $\Delta lnCO2_{it} = c + \mu_1 * \Delta lnINDIRECT_{it} + \mu_2 * \Delta lnICT_{it} + \mu_3 * \Delta lnIETSP_{it} + \mu_4 * \Delta lnGDP_{it} + \mu_5 * \Delta lnREN_{it} + \xi_i + \rho_t + \phi_{it}$ (8)

The second (7) and third (8) models are based on data for an incomplete sample of 24 European countries for which it was statistically possible to separate tax revenues from carbon and energy taxes. The assessment of the first model (6) is carried out both for a complete sample of 31 European countries and an incomplete sample of 24 countries.

Assessment of the «Carbon Fairness» of Energy Taxation

As part of the work, the calculation of the unit carbon price of different types of energy products is carried out. Such an assessment implicitly shows the so called «carbon fairness» of the energy taxation, i.e. gives an idea of the degree of proportionality of the taxation of coal, oil and natural gas to their carbon intensity.

Given the lack of data on tax revenues by types of energy products, the estimation is based on the recalculation of tax rates per unit (liter, ton, kWh) of energy product into the tax rate per ton of CO_2 emissions with the use of the carbon content coefficients of different energy products. The implicit carbon price is calculated for coal, light oil products, diesel, gasoline, liquefied petroleum gas and natural gas, which differ significantly in terms of carbon intensity - the amount of carbon released during the combustion of a unit of a fuel, adjusted for the calorific value of the type of a fuel. The implicit carbon price for different energy products is calculated as follows.

$$\mathrm{ICP_f} = \frac{\mathrm{TaxRate_f}}{\mathrm{CarbonInt_f}} \tag{9}$$

where $\mathrm{ICP_f}$ – implicit carbon price for a f-type energy product, dollar per ton of CO_2 emissions; $\mathrm{TaxRate_f}$ – tax rate for the use of f-type energy product, dollar per unit (liter, ton, kWh); $\mathrm{CarbonInt_f}$ – CO_2 emissions per unit of energy product combusted, ton per unit of energy product.

Main Findings

Direct and Indirect Carbon Pricing

Incentive-based regulation of GhG emissions could be carried out directly or indirectly. Direct carbon pricing involves the use of either carbon tax or ETS (or their hybrid form combining the elements of carbon tax and ETS). Indirect carbon pricing is realized through general fiscal regulation of energy use (energy taxes and subsidies) which results in GhG emissions.

In the energy sector, there are two principal ways of emissions reduction: either through reduction of energy consumption or switching to less carbon-intensive energy sources. A direct carbon price allows to simultaneously employ both of them. Indirect carbon pricing, on the contrary, could solely contribute to energy consumption reduction and, other things being equal, creates less incentives of emissions reduction against the backdrop of direct carbon pricing. This principal difference makes direct carbon pricing more cost-efficient instrument of climate policy than the direct one provided an equal coverage of emissions by both groups of instruments. This theoretical conclusion often leads to underestimation of the role of energy taxes in achieving climate policy goals, which, due to the scale of their use and coverage of emissions, can have a significant impact on the emissions dynamics.

Implicit Carbon Price in European Countries

While the instruments of direct carbon pricing (carbon taxes and ETS) started to be applied only in the 1990s, and gained popularity just during the last decade, the general energy taxes (excise taxes on fuel, taxes on hydrocarbon production, etc.) have a longer history and cover a larger share or emissions [OECD 2018].

The implicit carbon price combining both direct and indirect carbon prices in European countries is presented in the Figure 1. The indirect carbon price is generally higher than the direct one. The difference stems from the lower tax base for the direct carbon price compared to the tax base of the indirect carbon price, due to much greater coverage of the latter. Countries with more matured carbon taxation systems (see for e.g. Sweden and Norway) have markedly higher direct carbon prices (Figure 1).

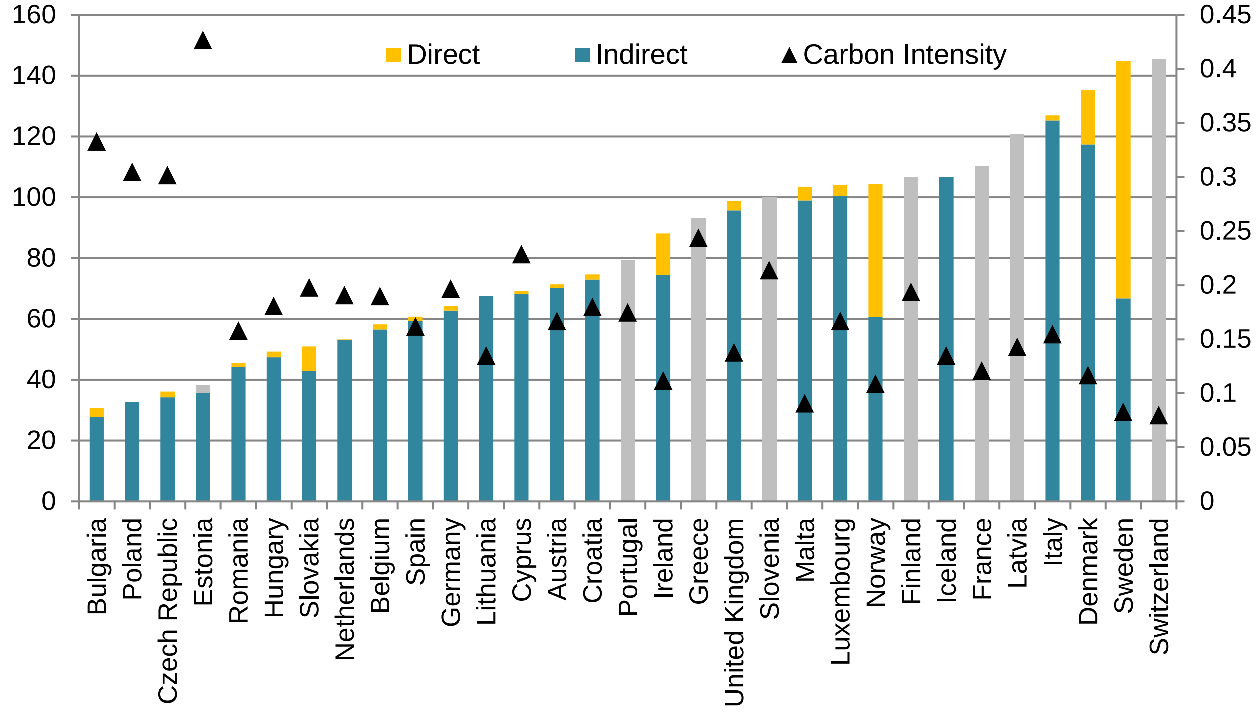

Figure 1. Implicit Carbon Price (Direct + Indirect Carbon Prices) in European Countries in 2018, Euro per Tonne of CO_2 and Carbon Intensity of GDP, $kgCO_2$ per 2010 USD

Note: for the countries marked in grey, it is hard to distinguish contributions of each of the instruments to the Implicit Carbon Price for statistical reasons. In particular in the mid-1990s, Finland moved to a combined energy-carbon tax which uses both the amount of consumption and the carbon component as the tax base, therefore, making it hard to split the total revenue flow into carbon tax revenues and general energy taxes revenues.

Sources: authors' calculation based on [Eurostat], [Ember], [European Environment Agency] and [Euromonitor International]

The highest fiscal burdens on a tonne of CO2 emissions is found in Switzerland, Sweden, and Denmark – the level of the ICP is 145, 144, and 135 euro per tonne of CO2 emissions respectively. Bulgaria, Poland, and the Czech Republic have the lowest ICP – 36, 33, 31 euro per tonne, respectively.

Figure 2 shows ICP dynamics during the period 2002-2018. In all European countries, the ICP grows with time, reflecting the increasing fiscal burden on a ton of CO_2 emissions. While in case of direct carbon pricing, the growth is attributed to growing carbon tax rates, indirect carbon price is growing due to introduction of new energy taxes and the extension of their tax base [Eurostat 2020].

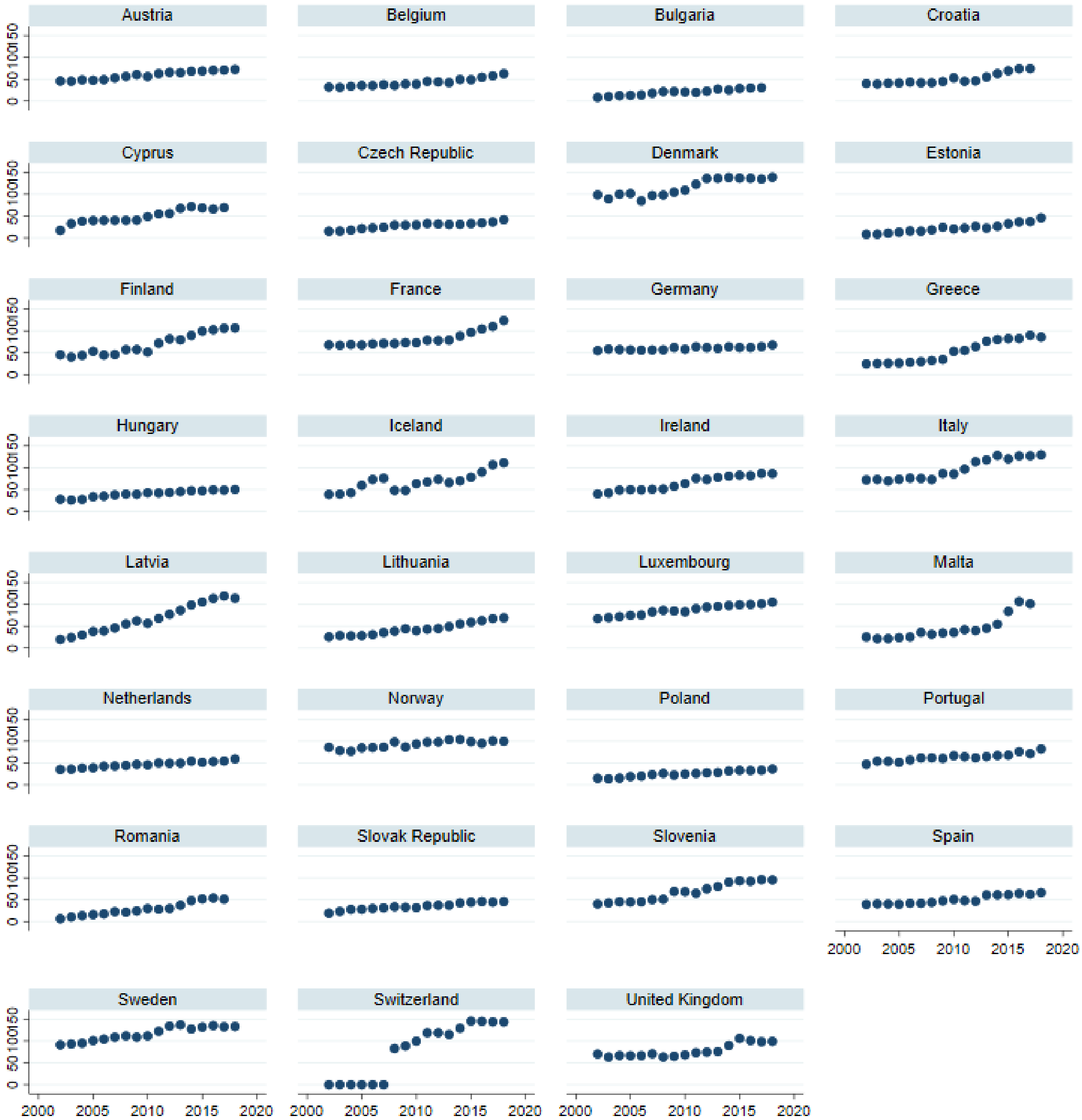

Figure 2. Implicit Carbon Price Dynamics in European Countries in 2002-2018, Euro per ton of CO_2 Emissions from Fossil Fuel Combustion

Sources: authors' calculation based on [Eurostat] and [IEA]

Quantitative Assessment of the Direct and Indirect Carbon Price Contribution to Emission Reduction

The results of the regression analysis are depicted in the Table 4. It shows the estimated values of the regression coefficients and the level of significance of the coefficients estimations in the equations (6), (7) and (8).

Table 4 – Results of the regression analysis

Variable Name	Variable Code	**1 model *(6)*** **31 countries**	**1 model *(6)*** **24 countries**	**2 model *(7)***	**3 model *(8)***
Implicit Carbon Price	Δln ICP	-0,630*	-0,894**	-	-
Indirect Carbon Price	Δln INDIRECT	-	-	-0,909**	-0,910**
Direct Carbon Price	Δln Δln DIRECT	-	-	-0,627**	-
Implicit Carbon Tax	Δln ICT	-	-	-	-0,695*
Implicit Price at EU ETS	Δln IETSP	-	-	-	-0,451
GDP	Δln GDP	-0,176***	-0,181***	-0,181***	-0,181***
Renewable share in consumption	Δln REN	-0,289**	-0,257*	-0,258*	-0,256*
Country and time fixed effects		+	+	+	+
	_cons	1,389**	-0,004	-0,004*	-0,004*
	R^2	0,272	0,273	0,273	0,274
	F-test	F(19,30) = 21,74***	F(19,23) = 41,78***	F(20,23) = 53,16***	F(21,23) = 70,31***
	SSE	0,101	0,083	0,083	0,083
	SEE	0,058	0,060	0,060	0,060
	N[5]	521	402	402	402

*Significance: *p<0,1; ** p<0,05; *** p<0,01*

Sources: authors' calculation

Based on the estimation of the first model (6), we cannot reject H1 on the negative impact of the implicit carbon price on the emissions. A 1% increase in the growth of the ICP on average leads to an approximately 0.6% reduction of the carbon intensity growth in the model for 31 countries and to 0.9% in the model for 24 countries (Table 4).

The H2 model (2) intended to compare the impact of indirect and direct carbon pricing on CO_2 emission shows that both the INDIRECT and the DIRECT contribute to carbon intensity reduction. A 1% increase in the growth of INDIRECT and DIRECT on average leads to a 0.9% and 0.6% decrease in the

[5] The number of observations for the extended model is 521 for 31 countries and 17 time periods (527), except for observations for 6 countries for which data on a number of indicators in 2018 is not available;
The number of observations for the main model is 402 for 24 countries and 17 time periods (408), except for observations for 6 countries for which data on a number of indicators in 2018 is not available.

growth of carbon intensity correspondingly (Table 4). However, the results of the F-test for the significance of the difference in the coefficients do not allow stating the differences in the estimates of the coefficients of DIRECT and INDIRECT. Therefore, we should reject H2. The estimation results show to a significant comparable contribution of both types of instruments to carbon intensity reduction.

The results show that energy taxes have played a significant role in carbon intensity reduction in European countries against the backdrop of direct carbon pricing instruments. When planning a climate policy toolkit, failure to take into account the whole set of fiscal instruments in force in fuel and energy complex is fraught with an incorrect assessment of the regulator's capabilities to influence the dynamics of emissions. Indirect carbon pricing, given the scale of their use, can serve a tangible tool of climate policy, especially in cases where the possibility of employing direct carbon pricing is limited.

Results of the H3 model (8), intended to compare the contribution of implicit carbon tax and implicit price at EU ETS to carbon intensity reduction, shows that only the former has a statistically significant coefficient, therefore, we should reject the H3. A 1% increase in the growth of the implicit carbon tax on average leads to 0.7% decrease in carbon intensity growth. Insignificance of the coefficient of the implicit price at the ETS can be explained by the insignificant short-term impact of the market price changes on the behavior of emitters. Instead, it is expectations of the price level which can underlie their actions [Bayer, Aklin 2020].

When planning their emissions/production, emitters included in the system, are guided not by market price fluctuations but rather by the expectations of the future market price dynamics determined by the benchmarks of the emissions reduction set by the regulator which a specific regulatory phase (2008-2012 – the first phase and 2013-2020 – second phase). In other words, emitters understand that even if the price is low today, the price will rise in the future. Therefore, expectations of the market price growth (combined with the contribution of the EU

ETS safeguard mechanism) could stimulate emitters to reduce emissions even when market prices are low.

«Carbon Fairness» of Energy Taxation

Estimation of the implicit carbon price for different energy products is shown do be disproportional to the amount of carbon content of energy products (see for e.g. the case of Germany - Figure 3). The results also indicate a significant discrepancy in the levels of the implicit carbon price paid by industry and households.

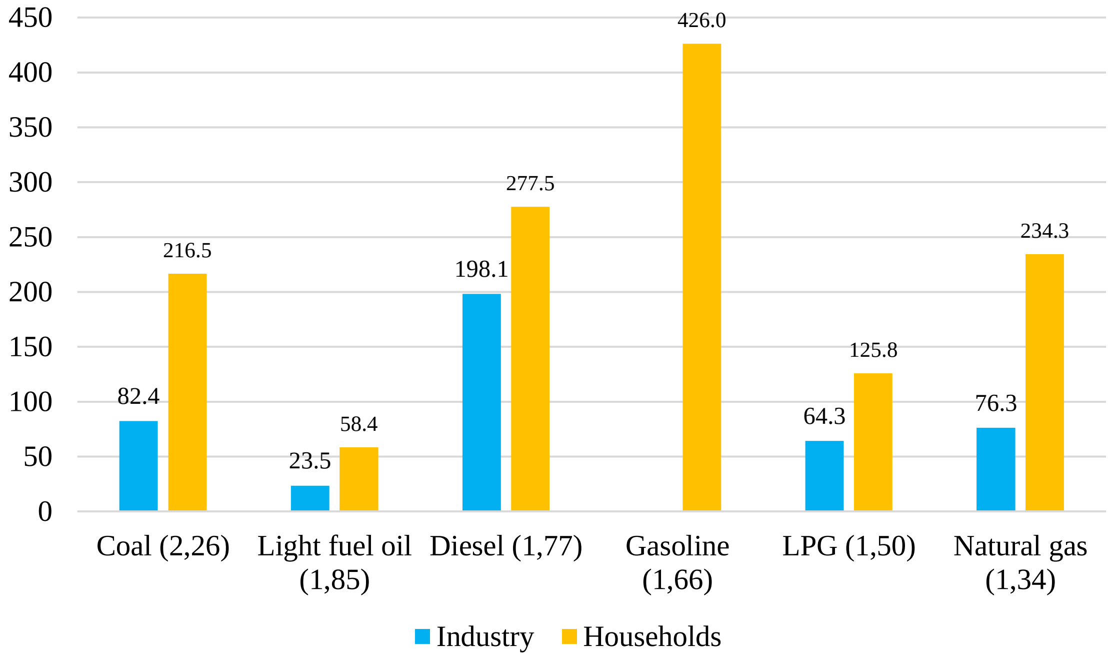

Figure 3 – Implicit carbon price in Germany by different type of energy product in 2017, USD per ton CO_2

Note: the values in brackets next to the name of the type of energy product characterize its carbon intensity (kg CO_2 per thousand toe). Carbon price for natural gas and coal are adjusted for the taxation of electricity generated by natural gas and coal electricity generation' facilities; LPG – liquefied petroleum gases.

Sources: authors' calculation [IEA] and [WRI]

Discrepancies in the values of the implicit carbon price calculated for different energy products and the sectors of the economy demonstrate a significant potential for improving the energy tax system's ability to contribute to emissions' reduction by changing the fiscal conditions for inter-fuel competition and increasing the «carbon fairness» of the energy taxation.

List of Author’s Original Papers

The research findings are outlined in a number of academic papers, including:

1. Stepanov I., Energy Taxation and Its Role in Greenhouse Gas Emissions Reduction // *HSE Economic Journal*, 2, 2019
2. Makarov I., Stepanov I. Paris Agreement on Climate Change and its Impact on the World Energy Sector // *Urgent Problems of Europe*, 1, 2018
3. Makarov I., Stepanov I., GhG Emissions Regulation: Options and Challenges for Russia // *Moscow University Economics Bulletin*, 6, 2017
4. Grigoriev L. M., Makarov I. A., Sokolova A. K., Pavlyushina V. A., Stepanov I. A. Climate Change and Inequality: How to Solve These Problems Jointly? // *International Organizations Research Journal*, 1, 2020

Also, the author's publications on the research topic include:

5. Stepanov I., Albrecht J. Decarbonization and Energy Policy Instruments in the EU: Does Carbon Pricing Prevail? / *NRU Higher School of Economics. Series EC "Economics"*. 2019. No. 211.
6. Stepanov I. A. 2019. Conventional Energy Taxes vs. Carbon-Based Incentive Instruments in Emission Regulation, in: *Proceedings of the 3rd Annual Meeting of the Portuguese Association of Energy Economics & 5th Meeting of Environmental and Energy Economics*. Braga, Portugal: UMinho Editora.
7. Chelsea L. C., Stepanov I. A., Vlasov K., Ward E. M. Permafrost Degradation and Coastal Erosion in the US and Russia: Opportunities for Collaboration in Addressing Shared Climate Change Impacts, in: *The Stanford US-Russia Forum Research Journal* Vol. 9. Stanford: Stanford University, 2018. Ch. 7. P. 57-63.
8. Makarov I., Stepanov I. Environmental Factor of Economic Development of Russian Arctic // *ECO* № 11, 2015.

9. Stepanov I. France // in the book *«Energy subsidies in the modern world – Case of the G20»* edited by Kurdin A.A., Grigoriev L. M., Moscow 2014.

The author's publications related to the research include:

10. Makarov I.A., Suslov D.V., Stepanov I.A., Serova D.A. Pivot to nature; new environmental policy in Russia under conditions of green transformation of world economy and international affaires / ed. S.A. Karaganov, *International Affaires*, 2021
11. Makarov I. A., Stepanov I. A., Kashin V. Transformation of China's development model under Xi Jinping and its implications for Russian exports // Asian Politics and Policy. 2018. Vol. 10. No. 4. P. 633-654.
12. Makarov I. A., Stepanov I.A. China: Evolution of Total Output in the Context of the Transformation of Economic Development Model // *Far Eastern Affaires*, 2, 2018
13. Stepanov I. A. Prospects for energy cooperation between Russia and the APR countries in the book *«Energy of Eurasia: new trends and prospects»*, IMEMO RAS, Moscow, 2016.
14. Makarov I. A., Sokolova A., Stepanov I. A. Prospects for the Northern Sea Route Development // *International Journal of Transport Economics*. 2015. Vol. 42. No. 4. P. 431-460.

As well as five chapters in the monograph edited by Makarov I.A. «Turn to the East. Development of Siberia and the Far East in the context of the strengthening of the Asian track of Russian foreign policy», International Relations, 2016.