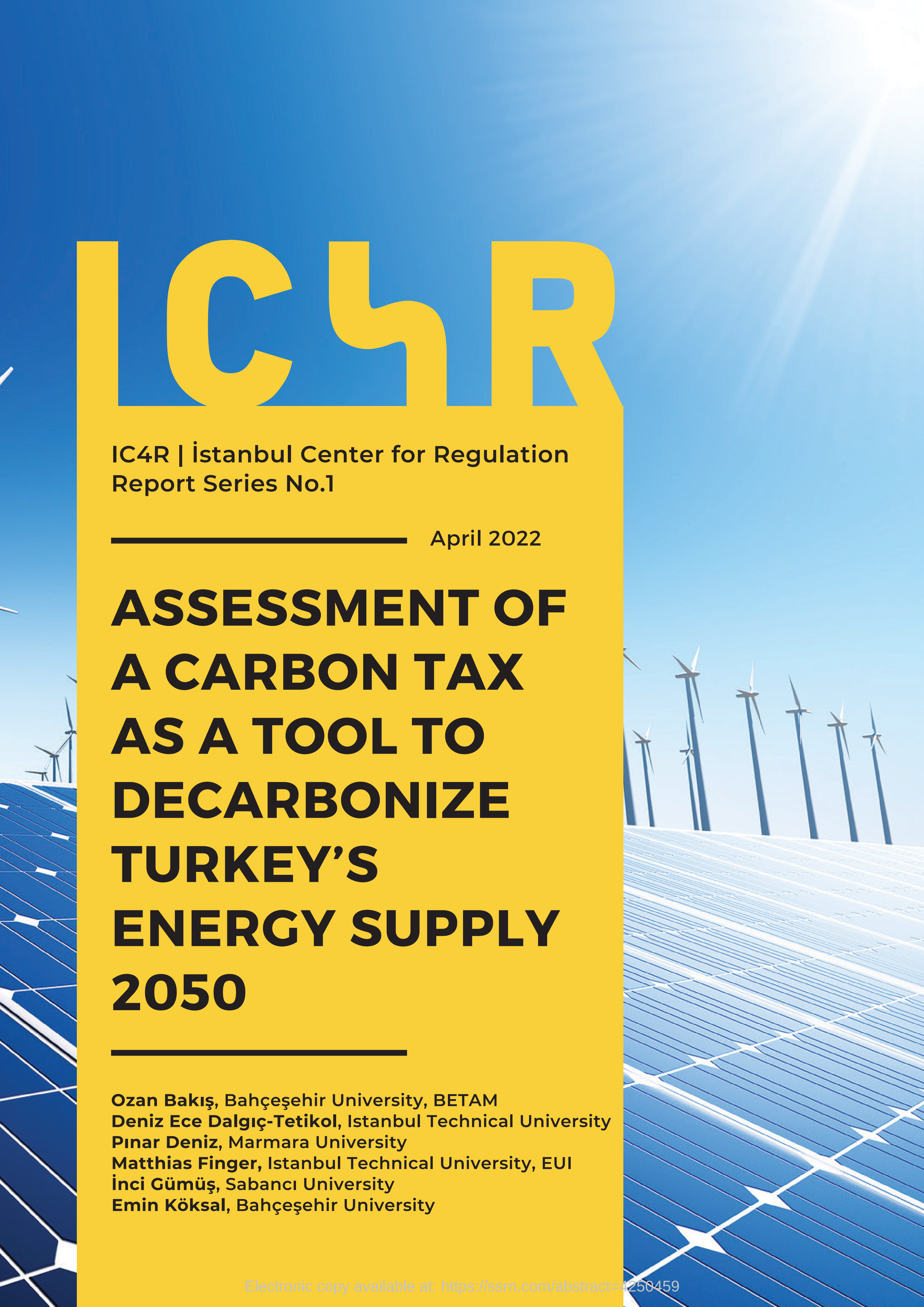


IC4R | İstanbul Center for Regulation
Report Series No.1

April 2022

ASSESSMENT OF A CARBON TAX AS A TOOL TO DECARBONIZE TURKEY'S ENERGY SUPPLY 2050

Ozan Bakış, Bahçeşehir University, BETAM
Deniz Ece Dalgıç-Tetikol, Istanbul Technical University
Pınar Deniz, Marmara University
Matthias Finger, Istanbul Technical University, EUI
İnci Gümüş, Sabancı University
Emin Köksal, Bahçeşehir University

Foreword

I am pleased to present to you the first issue of our new Report Series. The series aims at concise yet thorough treatment of an infrastructure topic of policy relevance for Turkey and the region. We plan to publish two such Reports every year.

This first issue is dedicated to Turkey's energy transition. To recall, Turkey has signed and ratified the Paris Agreement and announced its Intended Nationally Determined Contributions (INDC). This report discusses policy options as to how to meet its commitment. More concretely, the report aims at quantifying the economic costs and impacts of possible climate mitigation policies, so as to decide which policy and policy mix best fits Turkey's needs as an emerging country while at the same time meeting its global responsibility. Let me stress in particular the fact that while the report indicates possible options for Turkish policymakers, its main contribution lies in its underlying model, which allows to simulate many more options, should policymakers want to explore them and their consequences. This report itself is based on a more detailed study entitled Assessment of a Carbon Tax as a Tool to Decarbonize Turkey's Energy Supply 2050 which IC4R had written for the World Energy Council Turkey in 2021.

At IC4R we indeed see our role as one of helping policymakers and regulators make informed decision about infrastructure development, financing and pricing, among others. Besides the traditional infrastructures in the energy, transport and communications sectors, IC4R also increasingly wants to contribute the policy and regulation of emerging digitalization and its economic and social implications.

I hope, you will enjoy reading this first issue of our new Report Series!

Dr. Alparslan Bayraktar

President of the Board

Istanbul Center for Regulation

Content

Acronyms

BAU	Business-as-Usual
CBA	Carbon Adjustment Mechanism
CERC	Climate Equity Reference Calculator
CGE	Computable General Equilibrium
COP	Conference of Parties
COP21	21st Conference of Parties
DICE	Dynamic Integrated Climate Economy Model
DID	Difference-in-Difference
DSGE	Dynamic Stochastic General Equilibrium
E-DSGE	Environmental Dynamic Stochastic General Equilibrium
EEA	European Economic Area
EGD	European Green Deal
EMBIG	Emerging Markets Bond Index Global (JP Morgan)
EMRA	Energy Market Regulatory Authority
EU	European Union
ETS	European Union Emissions Trading System
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GHH	Greenwood-Hercowitz-Huffman (preferences)
IAMS	Integrated Assessment Models
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
MtCO2e	Metric tons of Carbon dioxide equivalent
NDC	Nationally Determined Contribution
OECD	Organization for Economic Co-operation and Development
RBC	Real Business Cycle
RICE	Regional Integrated Climate Economy Model
TOE	Tone of Oil Equivalent
TÜBITAK	Scientific and Technological Research Council of Turkey
TURKSTAT	Turkish Statistical Institute
TÜSIAD	Turkish Industry and Business Association
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value Added Tax
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

1. Introduction

As has been amply documented by science and validated by the Intergovernmental Panel on Climate Change, global warming is a reality. In response to global warming, the international community has devised ambitious policies that are enshrined in the Kyoto Protocol and most recently, in the Paris Agreement. Most of the countries, including Turkey, have signed on to the Paris Agreement, signaling their willingness to take responsibility vis-à-vis the international community and future generations. Turkey has furthermore defined and communicated its Intended Nationally Determined Contributions to this collective effort.

It is legitimate for a country like Turkey to assess how it can realistically meet its Intended Nationally Determined Contributions. This is where the present study comes in. Our study aims to quantify the economic costs and impacts of possible climate mitigation policies. This will help Turkey decide which policy and policy mix best fits its needs, while at the same time meeting its global responsibility. While the study indicates possible options for Turkish policymakers, its main contribution lies in its underlying model, which makes it possible to simulate many more options than the ones outlined in this document.

Thanks to our model, we can perform multiple simulations for the 2021-2050 period to analyze the effects of different policies on main economic aggregates such as GDP, employment, emissions, and demand for different energy types. We study the effect of various carbon taxes based on for two different tax policies: (1) taxes become effective in the next year, and (2) taxes become effective in five years. We then analyze the effects of a subsidy on renewable energy implemented with carbon taxes on all polluting energy types. Our model is also capable of showing the effects of exogenous shocks on the economy. In that context, we examine the economy's behavior in response to changes in total factor productivity and changes in the international prices of oil and natural gas.

The following section presents Turkey's emissions' structure in international comparison. Section 3 discusses state-of-the-art policy measures to mitigate global warming and explains the choice of a combined carbon tax and subsidies for renewables. Section 4 discusses and assesses the existing studies of the effects of climate change mitigating policy measures on the Turkish economy. Section 5 provides a non-technical summary of the model and states conducted simulations. We present our results in Section 6, before Section 7 concludes and makes recommendations for policymakers in Turkey.

2. Turkey's GHG Emissions Structure

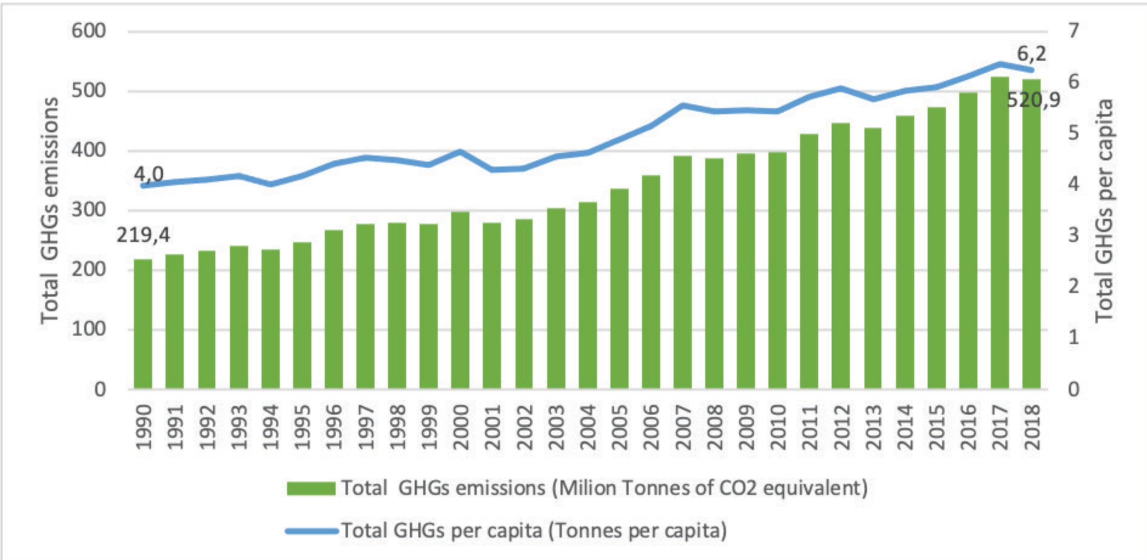
Presenting the GHG emissions structure, its historical trend, and comparing it with other countries is essential to establish the facts. The primary aim of this section is to identify the trends, the composition, and the sources of GHG emissions to prepare a basis for the report's subsequent sections.

2.1. Historical trends in Turkey's GHG emissions

Emission statistics in Turkey are published regularly by the Turkish Statistical Institute (TURKSTAT). The indicators of the emissions are calculated according to the IPCC guidelines, which were developed by the UNFCCC. The guidelines consider the human-made emissions of major GHGs. In particular, the emission statistics refer to total emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (F-gases).

The current GHG emissions dataset historically goes back to 1990 with annual frequency. The first inventory was published in 2006, and the latest data is published in 2020 (which gives the emissions statistics for the year 2018). The latest list shows that the total GHG emissions had increased from 219.4 $MtCO_2e$ in 1990 to 520,9 $MtCO_2e$ in 2018. Figure 1 illustrates the above-mentioned statistics in detail.

Figure 1 - Historical trend in GHG emissions of Turkey (1990–2018)



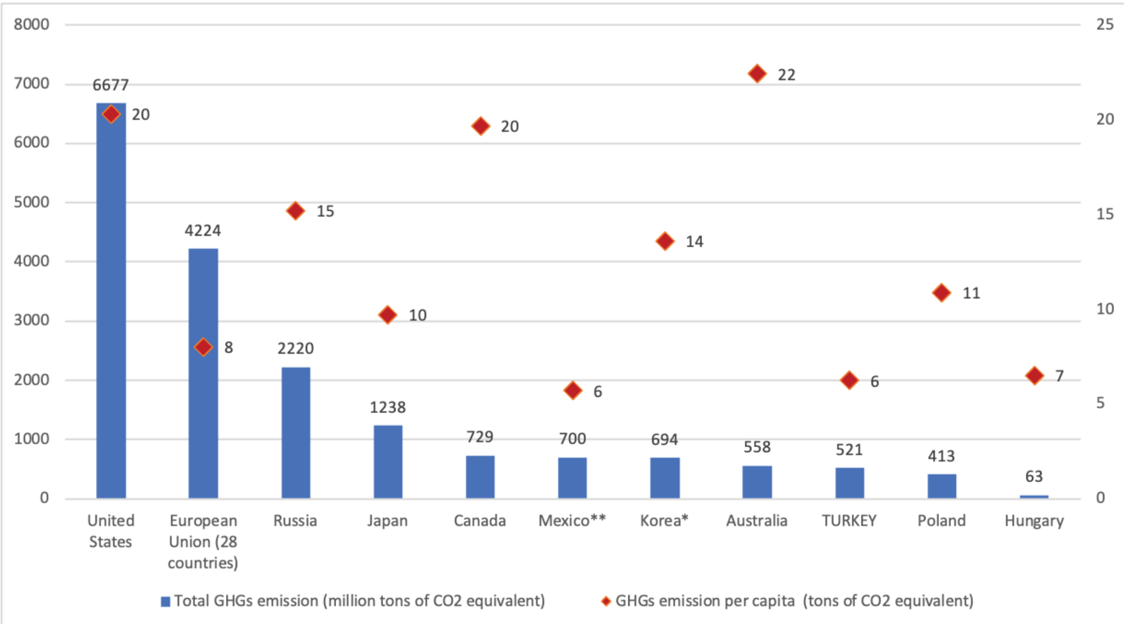
Source. TURKSTAT (2020)

GHG emissions and economic activities are generally correlated and are closely related to the structure of a country's production (Popp et al., 2010; Hossain, 2011; Cherniwchan, 2012; Sadorsky, 2013). Figure 1 gives indications for such a correlation in the case of the Turkish economy. During the economic crises in 1994, 2001, 2008, and during the downturn in the year 2018, the increase in total and per capita GHG emission has ceased. Accordingly, during the period in which the economic activities accelerate – for example, between 2002–2007 or 2010–2017 – the emissions have increased.

Let us compare Turkey with other countries by examining the differences and the similarities in their GHG emission and trends. Note that the number of countries that may be comparable with Turkey in terms of GDP per capita or industrialization are limited due to data availability. Although Turkey is an Annex I country, the countries with which it can be compared – in terms of GDP per capita or industrialization – are mostly non-Annex I countries. Therefore, comparable countries should be selected among the countries in Annex I and non-Annex I.

Whereas Figure 2, compares the total GHG emissions and per capita emissions with selected countries, Figure 3 shows the direction in total GHG emissions since 1990.

Figure 2 - GHG emissions in selected countries in 2018

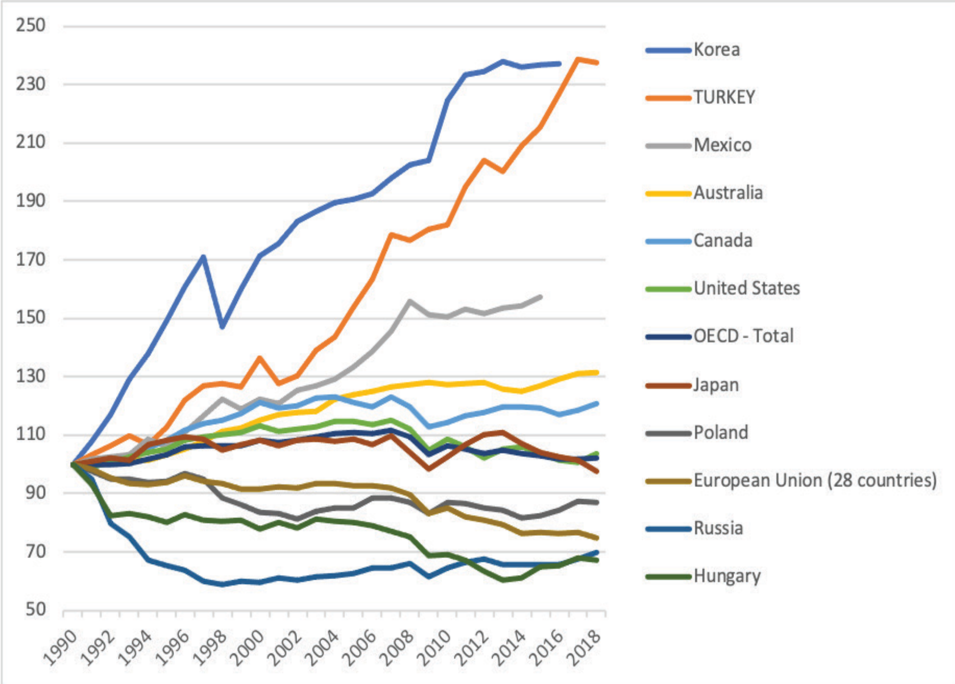


**Data from 2016, **Data from 2015*

Source. OECD (2020)

Figure 2 shows, the United States and the EU have the highest emissions compared with the rest of the selected countries. However, in the EU, per capita emissions are relatively lower than in the other industrialized countries and not much higher than the per capita emissions in Turkey or Mexico.

Figure 3 - GHG emission trends in selected countries 1990–2018 (1990 = 100)



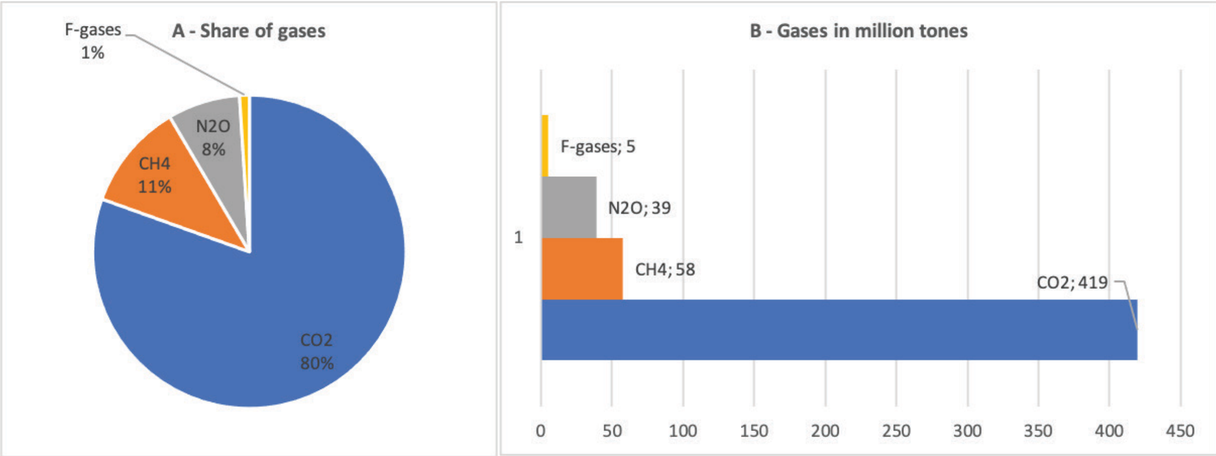
Source. OECD (2020)

Figure 3 shows that the GHG emissions in Turkey have the highest trend among OECD countries, after South Korea. However, it is worth recalling that Turkey emits less than 1 percent of global GHG emissions. Furthermore, the countries in Figure 3 – except for Mexico – have already completed their industrialization phases. In most of these countries, the share of manufacturing industries (which are relatively carbon- intense) has been declining, and the services industries have been increasing.

2.2. Breakdown of emissions by gases and sectors

When we look at the emission composition of greenhouse gases in Turkey, as seen in Figure 4, the vast majority of the emissions stem from CO_2 emission. The primary reason for this situation is the energy use and related fossil combustion in the economy.

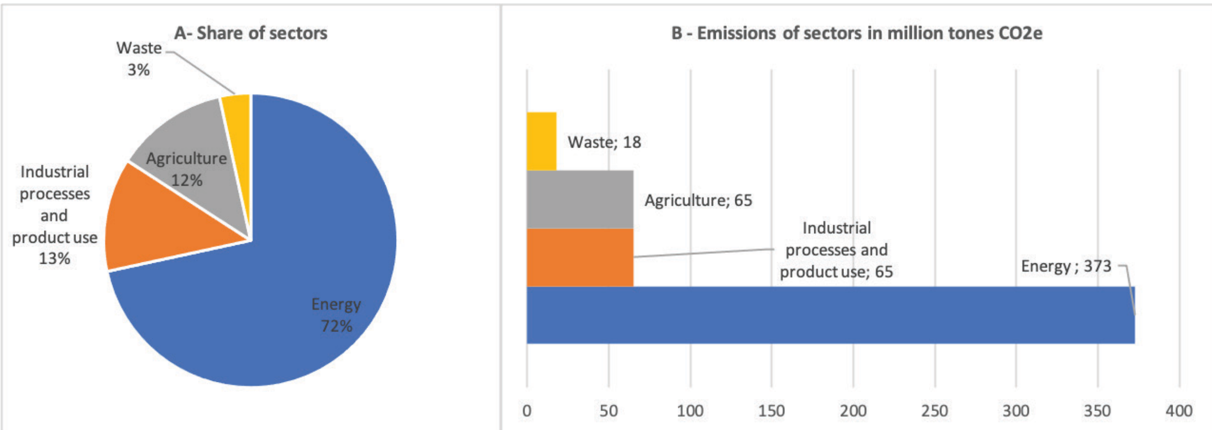
Figure 4 - Emissions in Turkey by gases in 2018



Source. TURKSTAT (2020)

GHG emissions of the different sectors in 2018 are shown in Figure 5. It appears that the energy sector's emissions have a higher share than those of the other sectors. While the energy sector emitted 72 percent of the total GHGs in 2018, emissions due to industrial processes and agriculture constitute 12 and 11 percent of the total emissions, respectively. The waste sector emits only 3 percent of the total emissions.

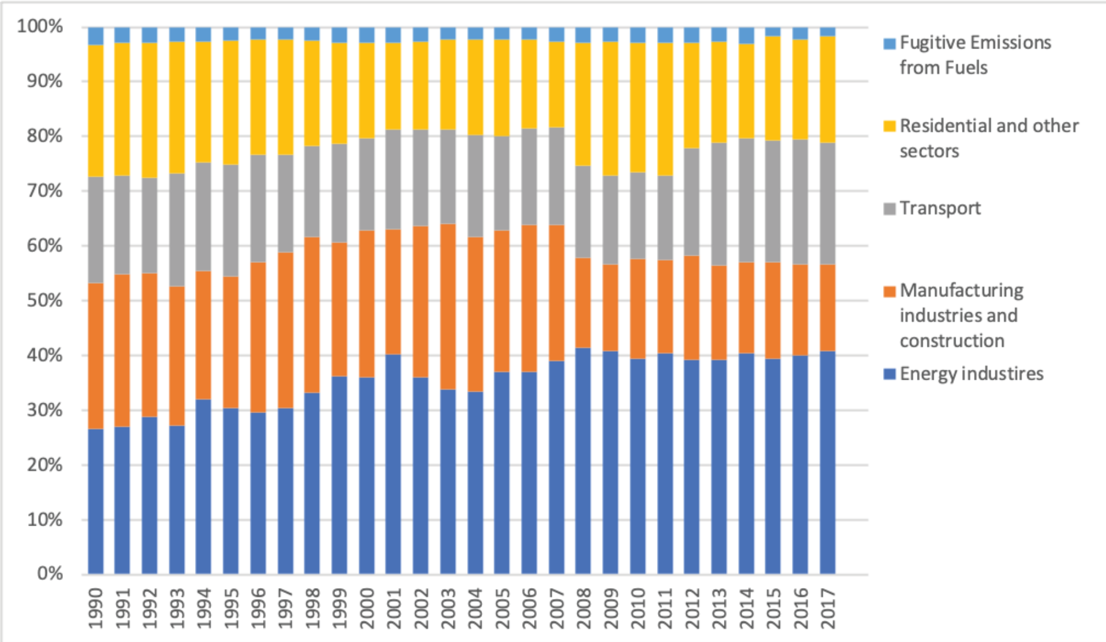
Figure 5 - Sectoral share of GHG emissions in Turkey in 2018



Source. TURKSTAT (2020)

In short, the problem child is the broad energy sector. Therefore, it is useful to break down the energy sector into its major components. Such a detailed picture will be necessary when designing policies for mitigation.

Figure 6 - Shares of GHG emissions in the energy subsectors in Turkey (2018)



Source. OECD (2020)

As shown in Figure 6, most energy related GHG emissions stem from the energy industries, typically electricity generation (40 percent), followed by transport and housing (approx. 20 percent each). GHG emissions from electricity generation have steadily increased since 1990, from 27 percent in 1990 to 42 percent in 2017. GHG emissions from the other three subsectors do not increase and, in manufacturing, even decrease.

Based on the above figures we can draw some conclusions: the energy sector is the major source of GHG emissions in Turkey, accounting for over 70 percent of GHG emissions, and has consistently been so since 1990. In light of Turkey's development path, we conclude that mitigation policies for GHG emissions should primarily focus on the energy sector. And since the overwhelming majority of the energy sector's GHG emissions stem from CO_2 (slightly under 90 percent), we recommend focusing the national emissions reduction policies on CO_2 reductions.

3. Policy Measures to Reduce GHGs

There are at least four policy areas that affect GHG emissions: energy, transport, housing, and industrial policies. Therefore, the goal should be to develop policy measures covering a broad range of areas, rather than just one such area. Among the possible cross-sectoral policy measures, two stand out: emissions-trading and a carbon tax. For understandable reasons (no authority to levy taxes EU-wide, increased power thanks to administering a trading system), the EU favors emission trading. However, the academic literature is controversially discussing both measures. In academia, but there is a preference for a carbon tax.

3.1 EU ETS (cap-and-trade principle)

The EU Emissions Trading System (EU ETS) is the EU's preferred policy measure to combat climate change. The EU ETS applies to all EU Member States, plus Iceland, Liechtenstein, and Norway. It aims to limit emissions from more than 11,000 heavy energy-consuming installations (power stations & industrial plants) and airlines operating between these countries. The EU ETS currently covers around 45 percent of the EU's greenhouse gas emissions.

The EU ETS works as follows: a cap is set on the total amount of certain greenhouse gases emitted by installations covered by the system. This cap is reduced over time to ensure that that total emissions fall. Within that cap, installations (typically companies) either receive (for free) or have to buy emission allowances; it is also possible to buy a limited amount of such allowances from emission-saving projects worldwide.

The cap on these allowances ensures that they have a value. Each year, the amount of allowances is reduced, meaning that each installation reduces its emissions or faces hefty fines. If an installation reduces its emissions below its cap, it can either save these allowances for later or sell (trade) them on the ETS market, hence the name "cap-and-trade." Thus, cap-and-trade is a market-based system that ensures efficiency: emissions will be reduced where their cost is least. Also, a robust carbon price promotes investment into clean (that is, low-carbon) technologies.

The three main arguments in favor of a cap-and-trade system from a public policy and government perspective are as follows:

- Certainty regarding the quantity of reduced GHG emissions which contributes significantly to governments' international credibility in matters of fighting global warming.
- Cost-effectiveness: while a cap-and-trade system increases the overall cost for the economy (and for consumers), it provides cost efficiency.
- Revenue for government: if the initial allowances are either sold or auctioned, this creates

an additional income source for governments.

However, there are also at least two major challenges for a government to consider:

- Market design: the cap-and-trade system creates a new and artificial market. Governments must design this market and monitor and manage it constantly in the long run. Designing such a cap-and-trade market is challenging the market design must adapt over time.

- Market size: for a cap-and-trade market to deploy its full effects, market size is decisive, which is one reason why the EU, with its 450 million inhabitants, chose this particular policy instrument. While Turkey would most probably have the required market size, it remains nevertheless a quite limited market which, sooner or later, would probably have to be coupled with the EU ETS, thus reducing Turkey's autonomy in climate policy-making.

3.2 Cap-and-trade versus carbon tax

There is disagreement among economists regarding the choice of specific carbon- pricing policy instruments, with some supporting carbon taxes (Nordhaus, 2007) and other cap-and-trade mechanisms (Ellerman et al., 2003; Keohane, 2009; Gollier and Tirole, 2015). However, economists (Goulder and Schein, 2013; Stavins, 2019) claim that the specific designs of carbon taxes and cap-and-trade systems may be more consequential than the choice between the two instruments. What appears at first to be a dichotomous choice between two distinct policy instruments often turns out to be a choice of design elements along a policy continuum.

Based on academic literature (Stavins, 2019), the two policy instruments lead to similar outcomes in terms of emission reductions, abatement costs, possibilities they create for raising revenue, costs to regulated firms and competitiveness effects. However, there are also areas where the outcomes of the two policy instruments differ. The following table summarizes the dimensions that distinguish the cap-and-trade system and carbon tax and compares the relative efficacy of each. Under the assumption that these policy instruments are properly designed and implemented, the theoretical discussions suggest that a carbon tax could be a more effective instrument to curb carbon emissions.

Table 1 - Dimensions along which cap-and-trade and carbon tax make difference

	Cap-and-trade	**Carbon tax**
Macroeconomic effect: growth versus recession	Unfavorable in period of growth	Unfavorable in period of recession
Macroeconomic effect: inflation	Unfavorable in case of inflation	
Macroeconomic effect: technological change		Better policy control
Price volatility	Increases volatility	
Interactions with other complementary policies		Favorable to complementarity
Ease of linkage with policies in other jurisdictions	Easier linkages across jurisdictions	
Potential for market manipulation and regulatory intensity	Requires stronger regulatory oversight	
Transaction costs		Minimize transaction costs
Complexity and administration	Requires high institutional needs	Easier to administer

Source. Authors

3.3 Assessment of the macroeconomic and social impacts of a carbon tax

A carbon tax appears to be more appropriate policy instrument to reduce CO_2 emissions than a cap-and-trade system, especially for emerging economies. Also, a carbon tax does have some macroeconomic effects, as currently discussed in the academic literature. These are typically estimated using computable general equilibrium (CGE) models. Some (albeit fewer) academics use dynamic stochastic general equilibrium models (DSGE) and other econometric models. We performed an extensive literature review: while different models give different results, most find modest (if any) reductions in GDP from implementing a carbon tax. Overall, we found a lack of evidence for the claim of adverse macroeconomic impacts from a carbon tax.

There are also criticisms regarding negative social impacts of the carbon tax system. Those social impacts are mostly related to adverse redistribution effects. Büchs et al. (2011) examines two issues in this context. The first is how the burden of the global warming mitigation policy is distributed and how it can be designed to avoid unfair distributional effects. The second is how to increase public acceptability of such policies to influence the likelihood of government adoption. As the authors have argued, those two issues are closely related to the design of the policies. carbon taxes may put unfair burdens on low- income families with greater energy needs (Büchs and Schnepf, 2013). Therefore, the origins of the global warming mitigation policies' unfair burdens should be analyzed, and effective complementary policies should be formulated. According to Büchs and Schnepf (2013), those complementary policies may vary from financial compensation to improving the efficiency of disadvantaged groups' energy use.

On the other hand, political acceptability is an essential issue when choosing appropriate climate change mitigation policies. As Vona (2019) noted, public acceptability of such policies is substantially reduced in the presence of job losses. Therefore, policymakers should combine revenue recycling schemes and compensation packages to mitigate the negative social impacts and increase public acceptability. In sum, carbon taxes may have adverse social impacts, such as unfair sharing of the burden and job losses. However, the design of the policies combined with compensation schemes may alleviate those adverse effects.

3.4 Subsidies for renewables

Carbon taxes generate additional income for governments, which raises the question of how to best use these proceeds. In general, additional taxes are most readily accepted by the public if they are revenue-neutral; that is, passed on to the consumers. Such taxes are even more accepted, and certainly even more effective, if they are used to enhance the same policy objective that is already pursued by a carbon tax, in this case decarbonization.

Carbon taxes are a cost-effective way of reducing carbon emissions: they not only avoid putting an undue burden on government budgets, but can raise significant revenue for governments, which can be used to reduce other taxes, promote low- carbon technologies, energy efficiency improvements, and renewable energy (Conway et al., 2017).

A carbon tax is particularly appropriate in this regard: all, or at least some, of the proceeds of a carbon tax can be effectively used to promote the parallel development of renewables (solar, wind, hydro, geothermal) without negatively impacting the national budget. The right combination of carbon taxes and renewables subsidies can yield the highest effects (Carl and Fedor, 2016).

Using the proceeds of the carbon tax to subsidize renewables can even alleviate the national budget if renewables have already been subsidized (Galinato and Yoder, 2010). Thus, carbon revenues can be used to offset the negative macroeconomic impacts of higher energy costs under carbon pricing schemes. Therefore, we not only model a carbon tax, but the combination of a carbon tax and subsidies for renewables.

3.5 Reduction of taxes on labor

The revenue recycling feature of a carbon tax policy can generate other positive output effects. Alternative ways of implementing a carbon tax are earmarking revenues to support low-carbon technology projects and reducing other taxes, the so-called revenue-neutrality policy. The revenues generated by collecting carbon taxes can also be “balanced” by reducing other existing taxes. When the tax is designed to be neutral, the revenue is returned to enhance the same policy objective. When the tax system is set up under neutral revenue, there can be an increase in total employment relative to the baseline scenario. In this respect, when emissions reduction and unemployment policies are combined, reduction policies based on energy tax can create expanding effects on employment (TÜSIAD, 2016).

3.6 Conclusion

After pondering the academic discussion in this matter, we conclude that a carbon tax is preferable to an emissions trading system mainly because it is institutionally much easier to implement. It also generates the proceeds that can subsequently be used to subsidize renewables and labor. Combining those policy measures seems to be the most appropriate way to transition to a low-carbon economy for an emerging economy.

4. Turkey's Responsibilities and How to Meet Them

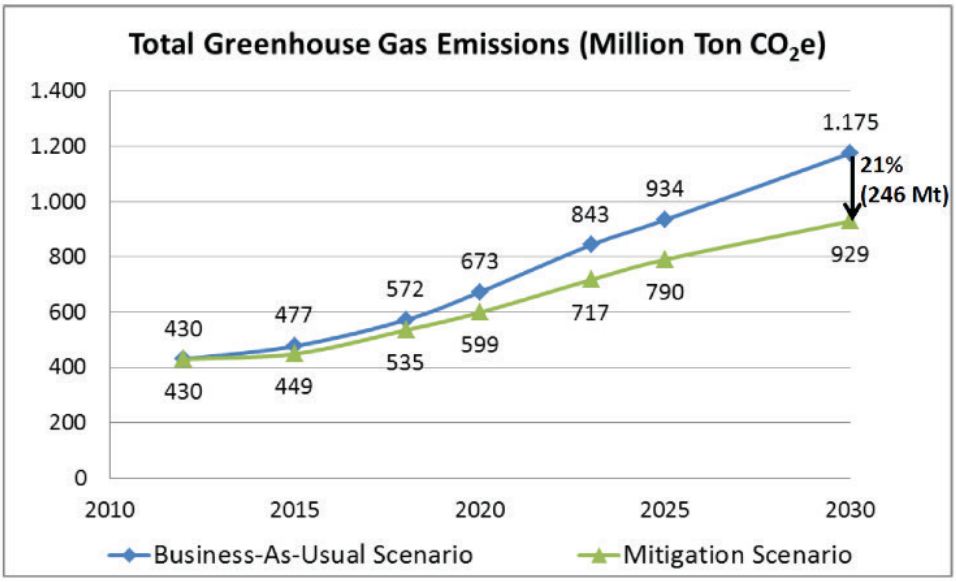
In this section, we will discuss Turkey's current responsibilities vis-à-vis the Paris Agreement. We then present and critically discuss the four studies that have already been conducted to assess the implications of Turkey's commitments on its economy.

4.1 The Paris Agreement and Turkey's INDCs

Turkey is one of the participants of the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC), which took place in Paris in December 2015. In this section, two aspects regarding Turkey's participation in the Paris Agreement will be discussed: its Intended Nationally Determined Contributions (INDCs) and its possible liabilities.

Turkey had submitted its INDCs before COP21. In the related document, Turkey pledges to reduce its GHG emissions by 21 percent along its Business-As-Usual (BAU) path by 2030 (see Figure 7).

Figure 7 - Turkey's emission reduction declaration in the INDC



Source. Republic of Turkey Intended Nationally Determined Contribution

Its INDCs will stem from all areas of the Turkish economy, particularly energy, industrial processes, product use, agriculture, land-use change and forestry, and waste. The emission target pertains to all GHGs included in the national inventory. To achieve its mitigation target in a cost-effective manner, Turkey expects to use carbon credits from international market mechanisms and to receive international financial, technological, and capacity building support, including finance from the Green Climate Fund.

Although Turkey is listed as an Annex I country (to the UNFCC), decision 1/CP.16[1] recognizes special conditions for Turkey. The main reason why Turkey was classified as an Annex I country was its OECD membership at the time of the UNFCC in 1992. Until 2001 Turkey was listed both in Annex I (countries subject to the more severe restrictions on emissions) and in Annex II (countries expected to financially and technologically support the developing countries). However, in 2001 in Marrakech, the UNFCC removed Turkey from Annex II and invited the conference of the parties to recognize the special circumstances of Turkey as an Annex I country.

This ambiguity continues to exist in the Paris Agreement, as countries remain categorized according to their development levels. Accordingly, their obligations are determined by their categorization. While developed countries are expected to take the lead by undertaking economy-wide absolute emission reductions, developing countries are only expected to increase their mitigation efforts. They are encouraged to implement economy-wide emission reductions in light of national circumstances. Moreover, Article 9.1 indicates developed countries' requirements to provide financial resources to assist developing countries in continuation of their existing obligations under the Convention. For all other countries, the Agreement does not impose any obligation, but Article 9.2 does encourage voluntary support. As Turkey's classification under the Agreement is ambiguous, it is not clear whether it can benefit from international financial support in order to reduce its GHG emissions.

4.2. Studies on Turkey

Very few studies have attempted to assess Turkey's climate change mitigation policies and their impacts on the Turkish economy. Below, we present and discuss the four studies that we consider most relevant in this regard.

The first major study was conducted by Yeldan et al. in 2015 and it was published just before COP21 in Paris, thus providing recommendations for the preparation of Turkey's INDCs. Yeldan et al. developed a Computable General Equilibrium (CGE) model of the Turkish economy in order to assess the impact of selected climate policy instruments. The study spans the Turkish economy's 2015–2030 growth trajectory, focusing on carbon emissions and relevant instruments of abatement. The authors' main results indicate that with certain policy instruments, compared to the BAU scenario, the estimated GDP growth rate in 2020 would be 3.3 percent, rather than 4 percent. However, this gap narrows after 2025 and disappears in 2030. The model also estimates slightly lower employment rates than the BAU scenario and parallel to the decline in the GDP growth rates.

The second major study was commissioned by the Turkish Industry and Business Associ-

1 Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010, available at https://unfccc.int/resource/docs/2010/cop16/ eng/07a01.pdf, accessed on October 30th 2020.

ation (TÜSİAD) in 2016. After evaluating Turkey's GHG emissions and energy structure, the study discusses the effectiveness and feasibility of the market-based emission reduction mechanisms, namely, taxation, and emissions trading. The authors suggested an alternative policy in the form of "neutral taxation" in which carbon taxes are neutralized by a corresponding reduction in employment taxes. This alternative policy yields better results than the mere carbon tax policy both in terms of GDP and employment levels. GDP is 2 percent lower by 2025 and 3.7 percent lower by 2030 than in the BAU scenario. The employment level would be 0.2 percent higher than in the BAU scenario by 2030.

The third major study is the book Macroeconomics of Climate Change in a Dualistic Economy by Acar et al., published in 2018. Acar et al. (2018) also employed a CGE model to calculate the BAU scenario and estimate various environmental policies' effects. The authors simulate a policy package consisting of the following four instruments: (1) elimination of coal subsidies, (2) carbon taxation, (3) renewable energy investment fund, and (4) energy efficiency. They found that the implementation of the four above-mentioned policy instruments leads to a slight initial loss in GDP.

The final major and most recent study is by TÜSİAD (2020). It specifically focusses on the impacts of the European Green Deal (EDG) on the Turkish economy under different scenarios. The authors evaluate the impacts of a possible carbon border adjustment mechanism (CBA) through a CGE model under three scenarios (BAU, carbon price of EUR 30/tCO_2e and EUR 50/tCO_2e for Turkey's exports to the EU), plus one alternative scenario (in which Turkey adopts carbon pricing mechanism) for a period up to 2030. The study results suggest that GDP in 2030 is estimated to be 2.7 percent lower in EUR 30/tCO_2e, 3.6 percent lower in the EUR 50/tCO_2e scenarios than in the BAU scenario. However, under the alternative scenario, GDP will be 5.7 percent higher than in the EUR 30/tCO_2e and 6.6 percent higher than in the EUR 30/tCO_2e scenarios in 2030.

In sum, there have already been a few studies about the effects and achievability of Turkey's INDCs. We have analyzed of those studies in this section. However, all of these studies rely on computable general equilibrium (CGE) models, which limit their usefulness for policy-making, as we will see in the next section. Therefore, we will quantify the effects of various policy measures on the Turkish economy by way of what we feel is a much more appropriate model, a dynamic stochastic general equilibrium (DSGE) model.

5. Nontechnical Summary of the Model

In this section, we present a nontechnical summary our model along with the different scenarios we simulate for the 2020–2050 period. We start the section by discussing how our model relates to the literature on macroeconomic modeling of climate policies. We then explain the tax and subsidy policies and the exogenous changes in prices and technology that we use in the simulations in the next section.

5.1. Adding climate to macroeconomic models

The climate directly affects economic activities and is also affected by them. Economic models that analyze this two-way interaction are called integrated assessment models (IAMs). The main channel through which economic activities affect climate change is GHG emissions, particularly CO_2 emissions that raise the temperature on earth. CO_2 emissions are a by-product of energy use in production or consumption.

Early IAMs were not microeconomics-based models. They were mainly augmented growth models where a carbon-cycle model and a climate model were added to the Solow model of growth (e.g., Nordhaus, 1977; Nordhaus and Boyer, 2000). Recent IAMs, also called E-DSGE models, add an environmental module to a standard DSGE model to overcome the above shortcomings. These are macroeconomic models derived from microeconomic foundations and can be used to characterize not only the optimal allocations, but also suboptimal allocations because they fully specify the decentralized equilibrium.

We should note that CGE models share some similarities with E-DSGE models in that they are not only based on microeconomic foundations, but they also fully characterize decentralized equilibrium. The two disadvantages of CGE models compared to E-DSGE models are that CGE models are mainly static and deterministic by nature, meaning that they fail to model forward looking behavior of key aggregates such as consumption and savings in a stochastic environment. However, CGE models are usually better for short-run policy analysis because they capture the sectoral structure of the economy better as compared to DSGE models.

In this study, we analyze the effects of carbon taxation on CO_2 emissions, GDP, employment, and investment using an E-DSGE model calibrated to the Turkish economy. We focus on CO_2 emissions due to fossil fuel use in Turkey. Since CO2 emissions are a by-product of fossil fuels, reducing CO2 emissions involves a cost in terms of GDP growth and social welfare. Our model allows us to calculate the amount of CO2 emissions in the baseline (business-as-usual – BAU) scenario and in alternative scenarios of carbon taxes.

5.2. Our model

We use a standard small open economy model extended to include energy production and use based on Heutel (2012), Henriet et al. (2014), Fried (2018), and Hassler et al. (2016). The economy is composed of households, firms, and government:

Households provide labor and capital to firms and consume the final good produced by firms.

There are two types of firms. Some firms produce the final good while others produce the intermediate inputs (energy), which in our model are domestic coal and renewable energy. Final good (Y) production is done using capital (K), labor (L_Y), and energy (E) according to the following production function

$$Y = F_Y(K, L_Y, E)$$

Energy is a composite of primary energy sources

$$E = F_E(O, N, G, M, R)$$

where oil (O), imported coal (N, mainly hard coal), and natural gas (G) are imported at international prices, while domestic coal (M, mainly lignite) and renewable energy (R) are produced domestically. Imported energy prices are determined exogenously and are autocorrelated. Domestic coal (lignite) and renewable energy are produced using labor as input

$$M = F_M(L_M), \quad R = F_R(L_R)$$

where M and R denote domestic coal (lignite) and renewable energy, respectively. L_M and L_R refer to labor used in production of domestic coal and renewable energy, respectively.

Government collects taxes and redistributes tax income to households (transfers) and firms (subsidies for renewable energy, if any)

Carbon emissions are the key variable in the model. We assume that carbon emissions are proportional to the use of different energy sources. Thus, total emission in the economy is given by

$$\epsilon = \eta_M M_t + \eta_N N_t + \eta_O O_t + \eta_G G_t \tag{5.1}$$

where η_i is the emission factor for energy type i.

The government taxes each type of energy according to its carbon content. The carbon tax is an excise (per unit) tax, different from ad valorem (proportional) taxes such as value added tax (VAT). If carbon taxes were a proportional tax, then, when energy prices increase, carbon taxes would increase as well even if the carbon content is the same. This is why the literature models carbon taxes as a payment per unit of CO_2 emitted, independently of the energy prices. Since the carbon content of each energy type is different, the effective tax rate for energy type *i* is calculated using the emission factors as

$$\tau^i = \eta_i \times \tau, \quad i = M, N, O, G. \tag{5.2}$$

where τ is the tax rate for 1 ton of CO_2. For each energy type, the effective carbon tax is equal to τ times the emission factor (carbon content) of that type of energy. The effective carbon tax rate for, say, 1 TOE of lignite would equal $\eta M \times \tau$. As renewable energy does not have any carbon emissions, there is no carbon tax on renewable energy, $\tau^R = 0$.

Following the related literature (Henriet et al., 2014; Fried, 2018; Heutel, 2012), the government side of the proposed model is kept as simple as possible in order to focus on the role of policies to reduce CO_2 emissions. For this, we abstract from government debt and investment. The government redistributes all the income generated from taxation to households as transfers. Therefore, the government budget is balanced at each moment.

5.3 Simulations

We perform the following simulations for the 2021-2050 period.

- A carbon tax on all polluting energy types, effective next year
- A carbon tax on all polluting energy types, effective in five years
- A carbon tax on all polluting energy types, increasing over 15 years
- A carbon tax on all polluting energy types and subsidies for renewable energy and employment, effective next year
- Increasing energy efficiency over the next 30 years
- Changes in productivity
- Changes in coal, gas or oil prices

It is possible to combine several of these policies, if desired. For instance, we may study the effect of carbon taxes during a period characterized by both negative productivity shocks and high oil prices. Since it would be difficult to disentangle one effect from the other, we analyze the above policies separately for the 2021–2050 period.

In the simulations, we will experiment with different tax rates and compare their effects. The tax rates that we will use are 10, 20, 30, 40, 50 TL per ton of CO_2. Henriet et al. (2014) analyzed the effects of a carbon tax of 32 Euros per ton of CO_2 and found that such a carbon tax reduces CO2 emissions by 25 percent. Since there are important differences in purchasing power of TL and Euro, we use the hourly minimum wage as a benchmark for a comparison of the tax rates. As of 2019, the average hourly minimum wage, was about 10 Euros in France as of 2019.2. The carbon tax to hourly minimum wage ratio is about 3 in France. In Turkey, the monthly minimum wage was 2020 TL in 2019 and a worker works about 45 hours a week, so the hourly minimum wage was about 10 TL in 2019. Thus, a carbon tax of about 30 TL per ton of CO2 is similar to the tax rate used by Henriet et al. (2014), which is expected to reduce CO_2 emissions by 25 percent if production structures are similar in France and in Turkey. Therefore, we use a 30 TL tax per ton CO_2 in the simulations along with lower and higher values.

6. Results

In this section, we perform multiple simulations where we analyze the effects of different policies on main economic aggregates, such as GDP, employment, CO_2 emissions and demand for different energy types.

6.1. A carbon tax on all polluting energy types

We start by studying the effects of carbon taxes on macroeconomic aggregates and energy use for two different tax policies: taxes become effective in the next year and taxes become effective in five years. The results are reported for five different tax rates: 10TL, 20TL, 30TL, 40TL and 50TL per ton of CO_2 in 2019 TL.

Table 2 - The effects of tax policies on long-run equilibrium

	10	20	30	40	50
GDP	-0.8	-1.7	-2.5	-3.2	-3.9
Consumption	-0.5	-0.9	-1.4	-1.8	-2.3
Employment	-0.4	-0.8	-1.1	-1.4	-1.8
Capital	-0.8	-1.7	-2.5	-3.2	-3.9
Carbon tax revenue as a percentage of GDP	0.25	0.48	0.70	0.89	1.08
CO_2 emissions	-5.4	-10.1	-14.3	-18.0	-21.4
Domestic coal	-11.5	-20.7	-28.3	-34.6	-39.9
Imported coal	-6.9	-13.0	-18.4	-23.3	-27.6
Oil	-2.7	-5.3	-7.7	-10.0	-12.2
Natural gas	-3.4	-6.6	-9.6	-12.5	-15.1
Renewable energy	-0.5	-0.9	-1.3	-1.7	-2.2
Share of domestic coal in total energy	-7.5	-13.8	-19.0	-23.5	-27.3
Share of imported coal in total energy	-2.8	-5.4	-7.9	-10.2	-12.4
Share of oil in total energy	1.6	3.0	4.2	5.3	6.2
Share of natural gas in total energy	0.9	1.6	2.1	2.4	2.7
Share of renewable energy in total energy	4.0	7.8	11.4	14.9	18.4

Note: Tax revenue is reported as a percentage of GDP, in percentage points, not as a percentage range from the benchmark.

Table 1 shows the effects of the tax policies on the main variables after the economy completes its transition to the new long-run equilibrium. The values correspond to percentage changes from the business-as-usual path, which is defined as the long-run path associated with the initial equilibrium where key macroeconomic aggregates, such as GDP, consumption, investment, and employment, are assumed to grow regularly following their historical trends. This initial equilibrium defined by historical trends is our benchmark; that is, the business-as-usual case. The results show that all macroeconomic variables decline with the implementation of carbon tax policies and the decline in economic activity gets bigger with the size of the taxes. The decrease in GDP ranges between 0.8 percent in the case of a 10 TL tax per ton of CO_2 and 3.9 percent in the case of a 50 TL tax per ton of CO_2. The decline in employment, on the other hand, ranges between 0.4 percent and 1.8 percent. The reduction in carbon emissions resulting from the analyzed tax policies are between 5.4 percent and 21.4 percent.

As the energy use figures show, the use of all energy types decreases with the implementation of carbon taxes, but the magnitudes are different. The biggest reduction among different energy types is observed in the use of domestic coal, followed by imported coal. The changes in the use of the different energy types depend both on their carbon content and the size of the tax relative to the initial price of that type of energy. The effective tax rates increase as the carbon content of the energy source increases, since the effective tax equals $\tau \times$ carbon content of energy, where τ represents the tax rates per ton of CO_2 that we use in the policy analyses. Hence, more polluting energy types face higher taxes. Another factor is the size of the tax relative to the initial price. If the relative size of the tax is higher, then demand for that type of energy decreases further. For instance, even though the carbon content of oil is higher than that of natural gas (3.07 tons of CO_2 per TOE versus 2.33 tons of CO_2 per TOE), the decline observed for oil use is lower. Even though the effective tax for oil is higher in absolute terms due to its carbon content, the tax is lower in relative terms since the average price of oil is higher than natural gas. As a result, the effect on oil is smaller compared to the effect on natural gas.

Another point to note is that renewable energy use also decreases even though renewable energy is non-polluting and is not affected by carbon taxes. The decline in renewable energy use is due to the decrease in production, which results in lower demand for all energy types, including renewable energy. However, the magnitude of the decline in renewable energy is much smaller than it is for the polluting energy types. This leads to a sizable increase in the share of renewable energy in total energy use, ranging from 4 percent to 18.4 percent increase for the tax rates that we consider. The results for the energy shares also show that the shares of domestic coal and imported coal decline, while oil and natural gas increase.

In Figure 8, we plot the simulation results (percentage changes from the business- as-usual path) for GDP for the different tax policies that we consider. The first panel shows the effects for the case where taxes are implemented starting in the next period and the second panel shows the effects for the case where taxes are implemented starting in five years. In the first panel, GDP starts to deviate from the business- as-usual path with the implementation of the taxes for all tax rates and in roughly 10 years it stabilizes at the new long-run levels. The decline in GDP gets larger as the tax rate increases, as also illustrated in Table 1. In Panel 2, the effect on GDP comes with a lag compared to the figure in Panel 1, since the taxes are implemented in five years. However, because of the anticipated tax increase, GDP starts to decrease earlier than the implementation of the taxes. Again, we see in this figure that the decline in GDP gets bigger as the tax rates increase.

Figure 8 - The effect of carbon taxes on GDP

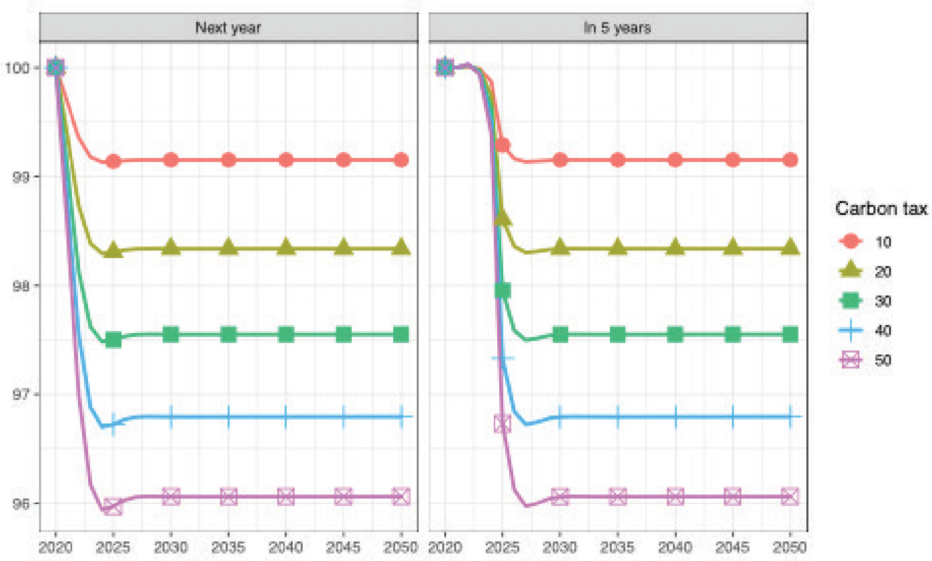
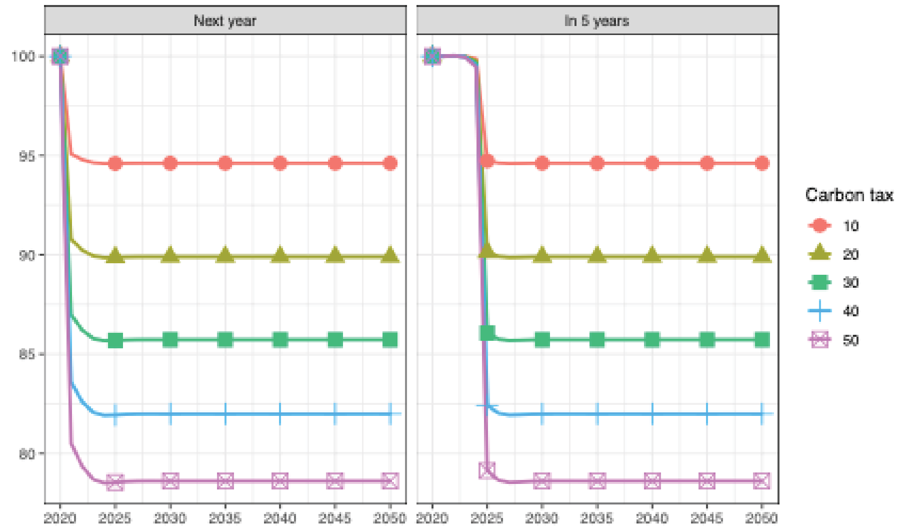


Figure 9 shows the effects of different tax policies on carbon emissions. In the first panel, carbon emissions drop sharply with the implementation of the carbon taxes (compared to the business-as-usual path). For instance, with a 30 TL tax, carbon emissions decrease by about 13 percent during the period in which the taxes become effective and after a while they stabilize at a new level that is 14.3 percent lower than the starting level. With the policy that becomes effective in five years, the emissions decline with a lag, but then we see sharp declines again.

Figure 9 - The effect of carbon taxes on CO_2 emissions



Next, we study the effects of a carbon tax rate that increases over time on GDP, CO_2 emissions and tax revenue as a share of GDP. The tax path that we consider in this part is a tax rate of 7.5 TL per ton of CO_2 between 2021 and 2025, 15 TL between 2026 and 2030, 22.5 TL between 2031 and 2035, and finally 30 TL starting from 2036. For each variable, we compare the increasing tax case with the path under a constant tax rate of 30 TL.

Figure 10 shows the path of GDP for constant and increasing tax rates. GDP starts decreasing (compared to the business-as-usual path) with the implementation of the taxes in both cases, but the decline in the case of an increasing tax schedule is slower and more gradual since the tax rate increases gradually. In the long run, GDP converges to the same level for both tax schedules since the tax rates are equalized.

Figure 10 - The effect of carbon taxes on GDP: Constant vs increasing tax

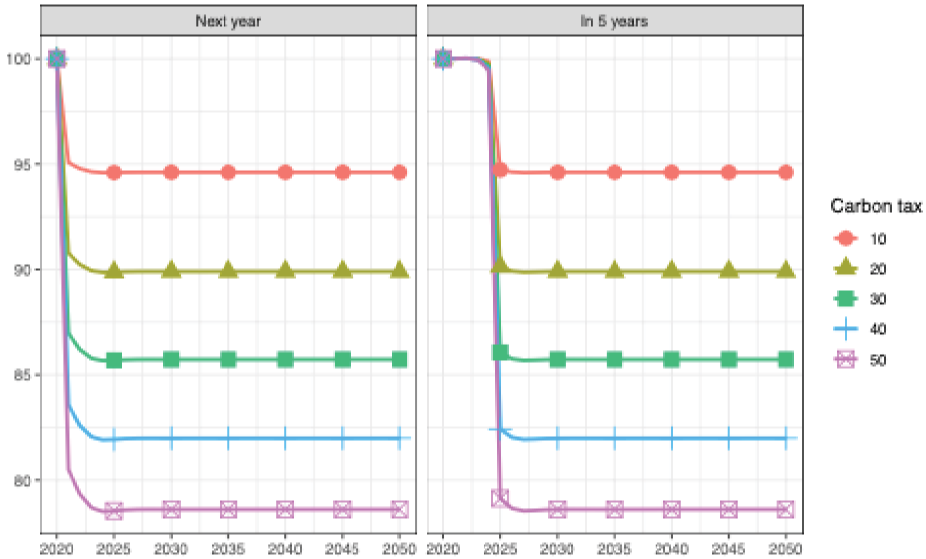
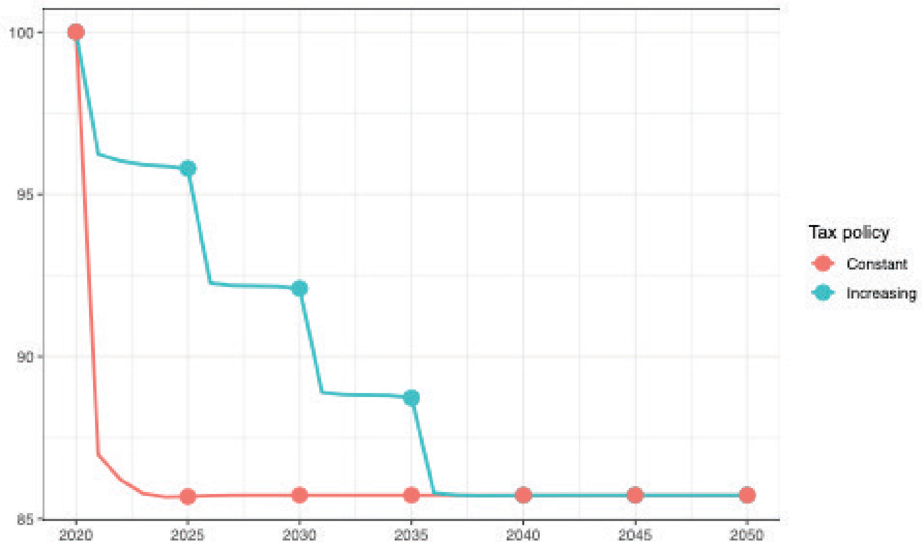


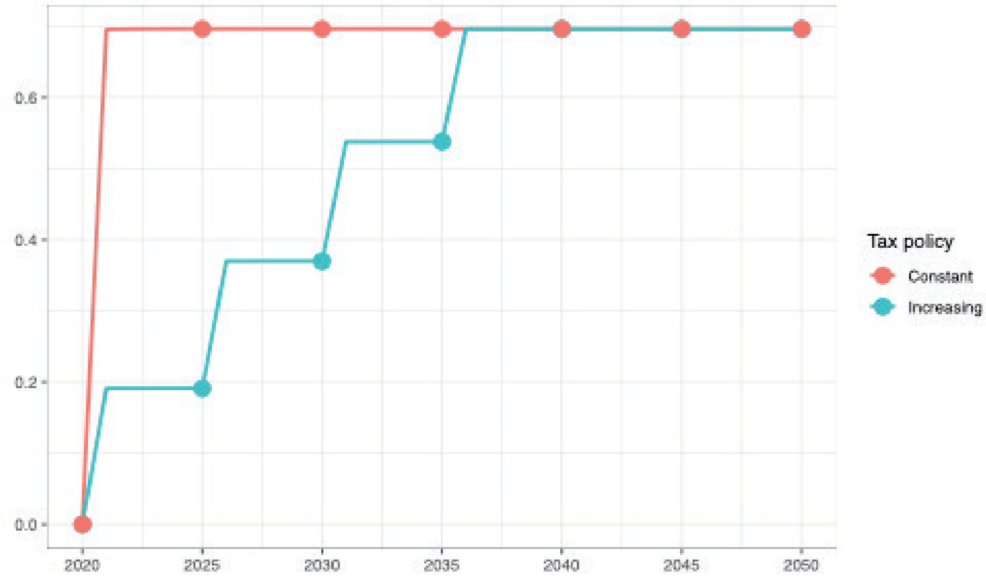
Figure 11 compares the path of CO_2 emissions for constant and increasing tax rates. As in the case of GDP, CO_2 emissions decline (compared to the business-as- usual path) more slowly with the increasing tax rate. Hence, emissions stay higher for a longer time period even though they decline to the same level for both tax schedules in the long run.

Figure 11 - The effect of carbon taxes on CO_2 emissions: Constant vs increasing tax



Finally, we compare the tax revenue as a share of GDP for constant and increasing tax rates in Figure 12. As expected, tax revenue increases gradually in the case of an increasing tax rate and for both tax schedules, the tax revenue from carbon taxes equals 0.7 percent of GDP in the long run.

Figure 12 - Carbon tax revenue as a percentage of GDP: Constant vs increasing tax



6.2. A carbon tax on all polluting energy types and subsidies for renewable energy and employment

We now analyze the effects of subsidies for renewable energy and employment, implemented together with carbon taxes. For all results presented in this section, we assume that there is a carbon tax of 30 TL per ton of CO_2 on all polluting energy types.

For the analysis with a renewable energy subsidy, we use a subsidy level of 92 TL per TOE (equivalently, 7.9 TL per MWh) of renewable energy. We choose this subsidy level using the carbon taxes on oil as a reference point. The 30 TL tax per ton of CO2 implies about a 92 TL tax on one TOE of oil used, considering the carbon content of oil (3.07 × 30 = 92.1). Therefore, we use a subsidy of 92 TL for renewable energy in the simulations. This is about 2 percent of guaranteed prices (assuming 5 cent/kWh and 1 USD = 7.4 TL) in the recent Renewable Energy Resources Zone Areas (YEKA) tenders.

For the case with an employment subsidy, we assume that all of the tax revenue generated by carbon taxes is paid to producers as a subsidy on their wage payments. Specifically, when the producer pays the wage rate *w* to a worker, a certain percentage of this, *s*, is compensated by the government, which is financed by carbon tax revenues. Hence, the cost of labor decreases to *(1-s)w* for the producer. The subsidy rate is calculated such that the total subsidy equals the tax revenue from carbon taxes.

We also analyze a case in which renewable energy subsidy and employment subsidy are implemented together. In that case, the sum of the two subsidies equals the tax revenue from carbon taxes. The renewable energy subsidy still equals 92 TL per TOE of renewable energy. The tax revenue that remains after providing the subsidy for renewable energy is used to finance the subsidy for labor payments.

Table 2 shows the effects of the subsidies on the long-run values of the main variables from the model. The numbers reported in the table correspond to percentage changes compared to the initial long-run path of the economy; that is, the business- as-usual case. The results are presented with a case where there is a 30 TL carbon tax but no subsidy.

Table 3 - The effects of subsidies on long-run equilibrium

	Percentage change compared to benchmark			
	Under a tax of 30 TL per ton of CO_2			
	No subsidy	Renewable subsidy	Employment subsidy	Renewable + Employment subsidies
GDP	-2.5	-2.3	-1.4	-1.4
Consumption	-1.4	-1.2	-0.3	-0.4
Employment	-1.1	-0.9	-0.1	-0.1
Capital	-2.5	-2.3	-1.4	-1.4
CO_2 emissions	-14.3	-14.1	-13.4	-13.4
Domestic coal	-28.3	-28.2	-27.5	-27.6
Imported coal	-18.4	-18.3	-17.6	-17.6
Oil	-7.7	-7.5	-6.7	-6.7
Natural gas	-9.6	-9.4	-8.7	-8.6
Renewable energy	-1.3	6.5	-0.3	7.4
Share of domestic coal in total energy	-19.0	-20.0	-19.0	-20.0
Share of imported coal in total energy	-7.9	-8.9	-7.9	-8.9
Share of oil in total energy	4.2	3.1	4.2	3.1
Share of natural gas in total energy	2.1	1.0	2.1	1.0
Share of renewable energy in total energy	11.4	18.7	11.4	18.7

Note: Renewable subsidy is 92 TL per TOE of renewable energy. The employment subsidy rate is 1.47 percent in the third column and 1.21 percent in the last column.

In the case of a renewable energy subsidy, the decline in main macroeconomic variables observed in the benchmark case with only taxes are reduced slightly. For instance, the decline in GDP is reduced from 2.5 percent to 2.3 percent and the decline in employment is reduced from 1.1 percent to 0.9 percent. The biggest effect of the renewable energy subsidy is observed for the use of renewable energy. With the subsidy, the use of renewable energy increases by 6.5 percent as opposed to a 1.3 percent decline in the case of a 30 TL carbon tax.

The employment subsidy, reported in Column 3, leads to a larger increase in all of the macroeconomic variables compared to the subsidy for renewable energy. In this case, the decline in GDP is reduced from 2.5 percent to 1.4 percent and the decline in employment is almost completely eliminated. CO2 emissions increase compared to the no-subsidy case by about one percentage point since energy use increases with higher production in the economy.

The case where both subsidies are implemented generates effects that are quite similar to the case with only employment subsidy for most variables. Unlike the case with the employment subsidy, the use of renewable energy increases significantly, since renewable energy is also subsidized in this case.

The figures below show the simulation results for the case where both subsidies are implemented starting in the next year jointly with a carbon tax of 30 TL per ton of CO_2 on all polluting energy types. The results are presented with the benchmark case where there is no subsidy, but there is a 30 TL carbon tax, which again starts in the next year.

Figure 13, shows the simulation results for GDP. The use of subsidies reduces the decline in GDP compared to the no-subsidy case.

Figure 13 - The effect of carbon taxes plus both subsidies on GDP

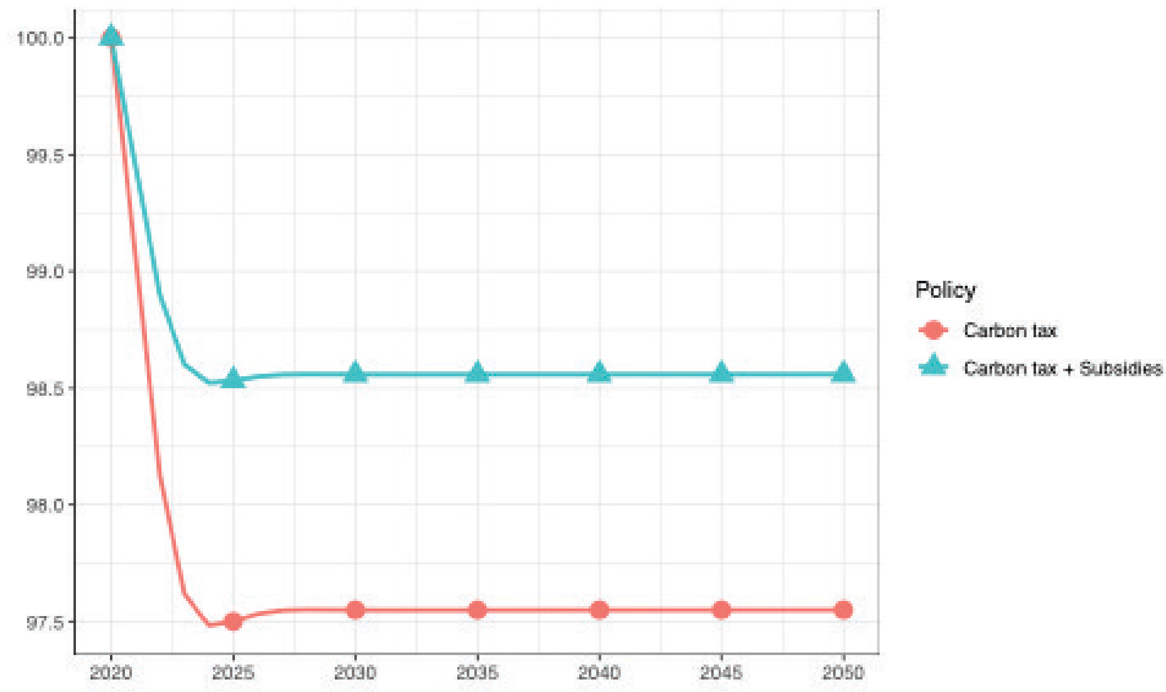


Figure 14 shows the simulation results for employment. In the case with subsidies, the use of employment subsidy initially raises the demand for labor and employment increases. However, this effect soon dissipates since production decreases as shown in the previous figure, which suppresses the demand for labor. Overall, there is a slight decline in employment in the long run (0.1 percent), showing that the subsidy for employment almost completely reverses the effect of the carbon tax on employment.

Figure 14 - The effect of carbon taxes plus both subsidies on employment

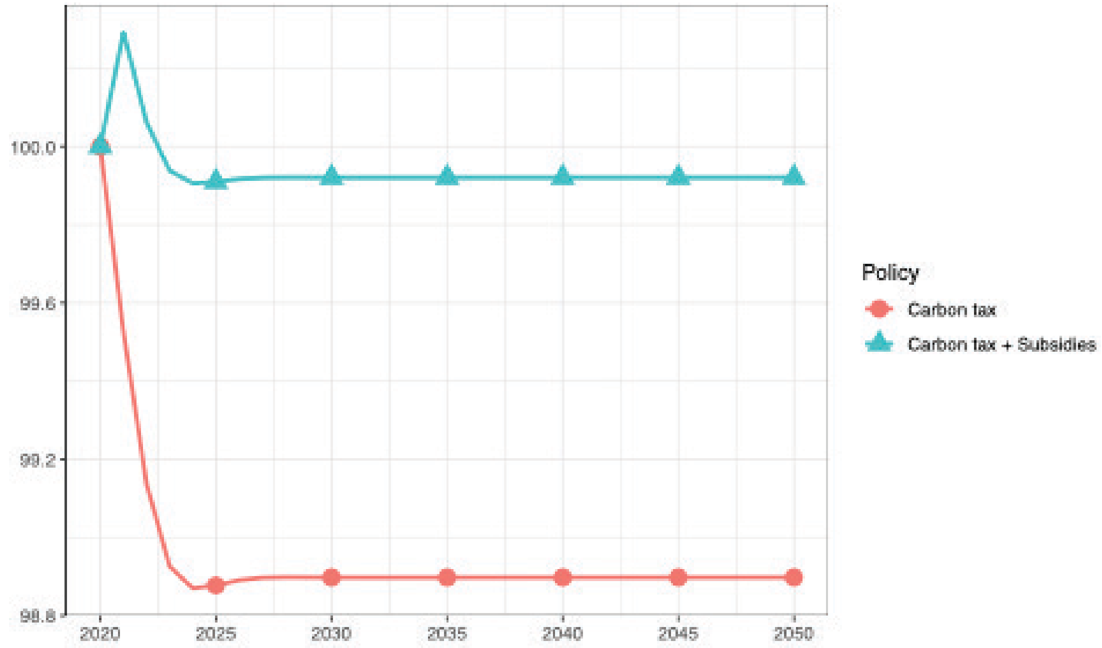
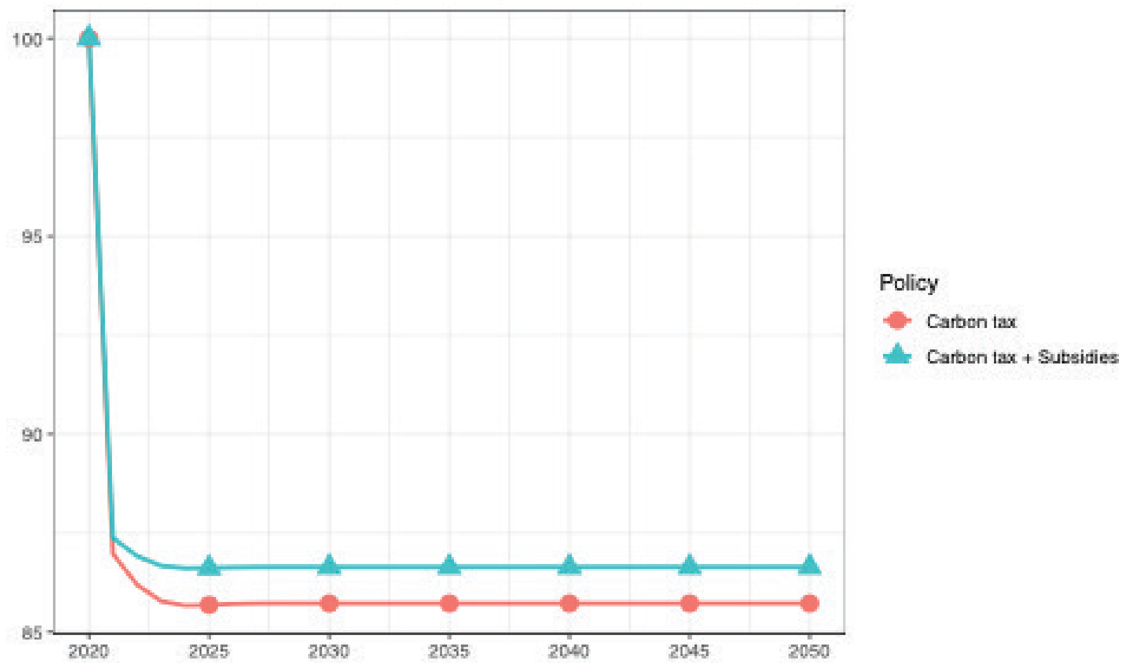


Figure 15 shows the CO_2 emission levels for the case with subsidies and the no- subsidy case. As also illustrated in Table 2, the emission level increases by about one percentage point in the case with subsidies, since higher production in the economy increases the use of energy. However, because of the subsidy for renewable energy, the use of renewable energy increases much more than the polluting energy types, which limits the increase in CO_2 emissions.

Figure 15 - The effect of carbon taxes plus both subsidies on CO_2 emissions



7. Conclusion and Policy Recommendations

The present study has shown that carbon taxes have indeed high social costs. A carbon tax of 30 TL (using 2019 prices) decreases Turkey's GDP by 2.5 percent as compared to a business-as-usual scenario. There are similar adverse effects on consumption (1.4 percent), employment (1.1 percent), and capital (2.5 percent).

Nevertheless, carbon taxes effectively reduce CO2 emissions: a carbon tax of 30 TL (using 2019 prices) decreases CO_2 emissions by 14.3 percent relative to the BAU scenario. If we combine carbon taxes on polluting energy types and subsidies for renewable energy and employment, the reduction in GDP, consumption, employment, capital, and the amount of CO_2 emissions are all smaller. For instance, if we combine a carbon tax of 30 TL (using 2019 prices) per ton of CO_2 and a subsidy of 92 TL (using 2019 prices) per TOE (equivalently, 7.9 TL per MWh) of renewable energy, the drop in GDP is 1.4 percent instead of 2.5 percent. We have similar improvements in consumption, employment, and capital. Another benefit of using renewable energy subsidies is that we have a higher reduction in CO_2 emissions than in the tax only case. For example, with a GDP reduction of 1.4 percent, we would observe a decrease of 8.2 percent in CO2 emissions in a tax-only case. Thanks to subsidies to renewable energy and employment, we have a reduction of 13.4 percent instead of 8.2 percent in CO_2 emissions (a difference of 5.2 percentage points).

Overall, our study shows that Turkey can meet its INDCs, but with high social costs. If the government uses a policy consisting solely of carbon taxes, a 50 TL (using 2019 prices) carbon tax would decrease the carbon emissions by 21.4 percent by 2030 compared to the business-as-usual scenario. However, such a tax level would reduce the GDP by 3.9 percent compared to the business-as-usual scenario, and have adverse effects on consumption, employment, and investment. If the government combines carbon taxes with subsidies to renewable energy and employment, then again a 50 TL (using 2019 prices) carbon tax would again decrease carbon emissions by 20.0 percent by 2030 compared to the business-as-usual scenario. As expected, the welfare costs of this combined policy are lower. For instance, the decline in GDP is only 2.4 percent.1 We have similar effects on other macroeconomic aggregates. Therefore, relying on other countries' experience, relevant literature, and our simulation results, we propose applying a more moderate tax level (30 TL, approximately 4 USD as we write this study) and accompanying subsidies for renewable energy and employment.

Although such a combination reduces the carbon emissions less than Turkey's INDCs, its adverse effects on macroeconomic aggregates remain limited. Turkey could explore other options to reduce GHG emissions. These could include more stringent energy savings measures, the active promotion of carbon capture (natural and technological), or action on the other important greenhouse gases (CH_4 and N_2O). In any case, we recommend developing a comprehensive GHG data inventory and tracking system that could be used, at a later stage, to create or enter into an emissions trading system.

Our study, particularly the model, is designed to simulate the macroeconomic impact of carbon taxes. Although the employment level is simulated under different scenarios, social effects are not examined. Therefore, our study does not provide any direct outcome for sharing the burden of the carbon tax. However, the simulation outputs indicate that the carbon taxes, even when combined with subsidies, hit hard the domestic coal demand, which signifies unignorable job losses in the domestic coal industry. To mitigate the distributional effects of job losses and to increase public acceptability, decision-makers should adopt policy measures that are specific to the domestic coal industry.

Adopting an appropriate climate change mitigation policy is the primary requirement of the Paris Agreement. However, besides the Paris Agreement, the European Green Deal (EGD) is another factor when considering adopting a climate policy. As a complement to EGD, the EU plans to reduce the carbon leakages between the countries with and without decarbonization regulation through a carbon border adjustment mechanism. Turkey may be one of the countries affected by such a mechanism, unless it adopts a proper climate change mitigation policy. Considering the volume of Turkish exports to the EU markets, adopting an appropriate climate policy becomes critical for avoiding the adverse effects of a possible carbon border adjustment mechanism.

References

Acar, S., Voyvoda, E., and Yeldan, E. (2018). Macroeconomics of Climate Change in a Dualistic Economy: A Regional General Equilibrium Analysis. Academic Press.

Büchs, M., Bardsley, N., and Duwe, S. (2011). Who bears the brunt? Distributional effects of climate change mitigation policies. Critical Social Policy, 31(2), 285–307.

Büchs, M., and Schnepf, S. V. (2013). Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. Ecological Economics, 90, 114–123.

Carl, J., and Fedor, D. (2016). Tracking global carbon revenues: A survey of carbon taxes versus cap-and-trade in the real world. Energy Policy, 96, 50–77.

Cherniwchan, J. (2012). Economic growth, industrialization, and the environment. Resource and Energy Economics, 34(4), 442–467.

Conway, D., Richards, K., Richards, S., Keenlyside, P., Mikolajczyk, S., Streck, C., Ross, J., Anthony Liu, A. and Tran, A. (2017). Carbon Tax Guide: A Hand- book for Policy Makers (No. 129668, pp. 1–172). The World Bank.

Ellerman, A., Denny, P., Joskow L., and Harrison, D. (2003). Emissions Trading in the U.S.: Experience, Lessons, and Considerations for Greenhouse Gases. Arlington, Virginia: Pew Center on Global Climate Change.

Fried, S. (2018). Climate policy and innovation: A quantitative macroeconomic analysis. American Economic Journal: Macroeconomics, 10(1), 90–118.

Galinato, G. I., and Yoder, J. K. (2010). An integrated tax-subsidy policy for carbon emission reduction. Resource and Energy Economics, 32(3), 310–326.

Gollier, C., and Tirole, J. (2015). Negotiating effective institutions against cli- mate change. Economics of Energy and Environmental Policy, 4(2).

Goulder, L. H., and Schein, A. R. (2013). Carbon taxes versus cap and trade: a critical review. Climate Change Economics, 4(03), 1350010.

Hassler, J., Krusell, P., and Smith Jr., A. A. (2016). Environmental macroeconomics. In Handbook of macroeconomics (Vol. 2, pp. 1893-2008). Elsevier.

Henriet, F., Maggiar, N., and Schubert, K. (2014). A stylized applied energy- economy model for France. The Energy Journal, 35(4), 1–37.

Heutel, G. (2012). How should environmental policy respond to business cycles? Optimal policy under persistent productivity shocks. Review of Economic Dynamics, 15(2), 244–264.

Hossain, M. S. (2011). Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy, 39(11), 6991–6999.

Keohane, N. O. (2009). Cap and trade, rehabilitated: Using tradable permits to control US greenhouse gases. Review of Environmental Economics and Policy, 3(1), 42–62.

Nordhaus, W. D. (1977). Economic growth and climate: the carbon dioxide problem. The American Economic Review, 67(1), 341–346.

Nordhaus, W. D. (2007). To tax or not to tax: Alternative approaches to slowing global warming. Review of Environmental Economics and Policy, 1(1), 26–44.

Nordhaus, W.D., and Boyer, J. (2000). Warming the World: Economic Modeling of Global Warming. MIT Press, Cambridge, MA.

OECD (2020). Greenhouse Gas Emissions Statistics, OECD Environment Database, available at https://stats.oecd.org/, accessed on 30.10.2020

Popp, A., Lotze-Campen, H., and Bodirsky, B. (2010). Food consumption, diet shifts and associated non-CO2 greenhouse gases from agricultural production. Global Environmental Change, 20(3), 451–462.

Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries?. Energy Economics, 37, 52–59.

Stavins, R. N. (2019). Carbon Taxes vs. Cap and Trade: Theory and Practice. Cambridge, Mass.: Harvard Project on Climate Agreements.

TURKSTAT (2020). Greenhouse Gas Emissions Statistics, 1990–2018, available at https://data.tuik.gov.tr/en/display-bulletin/?bulletin=greenhouse-gas-emissions-statistics-1990-2018-33624, accessed on 30.10.2020

TÜSİAD. (2016). Ekonomi Politikaları Perspektifinden İklim Değişikliği ile Mücadele, available at https://tusiad.org/tr/yayinlar/raporlar/item/download/8413_6162f22e86d7d7c12d-3c5a9a77011c75, accessed on 30.10.2020.

TÜSİAD. (2020). Ekonomik Göstergeler Merceğinden Yeni İklim Rejimi, available at https://tusiad.org/tr/yayinlar/raporlar/item/download/9453_ 0ca8c97b89ad3ec3b9dbd8121174b114, accessed on 30.10.2020.

Vona, F. (2019). Job losses and political acceptability of climate policies: why the ‘job-killing’ argument is so persistent and how to overturn it. Climate Policy, 19(4), 524–532.

Yeldan, E., Voyvoda, E., Berke, Ö., and Şahin, Ü. (2015). Low Carbon Development Pathways and Priorities for Turkey Climate-Friendly Development in Turkey: A Macro Level Evaluation. WWF-Turkey.

for more information
you can visit our website
by using qr code or clicking
ic4r.net