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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

# ENVIRONMENTAL AND ECONOMIC IMPACT ANALYSIS OF REDUCING GREENHOUSE GAS EMISSIONS VIA ENERGY SUBSTITUTION AND CARBON TAX

## ENERJİ İKAMESİ VE KARBON VERGİSİ YOLUYLA SERA GAZI EMİSYONLARI AZALTIMININ ÇEVRESEL VE EKONOMİK ETKİ ANALİZİ

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**Abstract**

Accordingly, with the decisions taken under Paris Conference-2015, Turkey has committed to constraint greenhouse gas emissions. An environmentally efficient way to do this is controlling industrial processes and fossil fuel use. Turkey has also determined her energy use targets as documented in Energy Strategy Document in which partial substitution of natural gas used in electricity production with some other energy sources is suggested as an alternative instrument in reducing greenhouse gas emissions. This study aims at developing a policy package to reduce total greenhouse gas emissions and to carry out the environmental and economic impact analysis of the policy package. Findings suggest that energy substitution will not be enough to achieve the targets proposed under Paris Conference commitments. Carbon taxing should be applied besides energy substitution, but rather on all industries it should be applied on selected polluter industries. In this way, while environmental targets are reached contraction in the economy will be less.

**Keywords:** Greenhouse Gas Emissions, Energy Substitution, Carbon Tax, Input-Output Matrix
**Jel Classification:** C67, H23, Q5, R11

**Öz**

Türkiye, 2015 yılında Paris Konferansı kapsamında alınan kararla sera gazı emisyonlarını sınırlamayı taahhüt etmiştir. Çevresel açıdan bunu yapmanın bir yolu endüstriyel süreçleri ve fosil yakıt kullanımını kontrol etmektir. Türkiye ayrıca Enerji Stratejisi Belgesi'nde sera gazı emisyonlarının azaltılmasında alternatif bir araç olarak elektrik üretiminde kullanılan doğal gazın diğer bazı enerji kaynakları ile kısmen ikamesini önererek enerji hedeflerini belirlemiştir. Bu çalışma, toplam sera gazı emisyonlarını azaltmak için bir politika geliştirmeyi ve bu politika paketinin çevresel ve ekonomik etkilerini analiz

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etmeyi amaçlamaktadır. Bulgular, Paris Konferansı taahhütleri altında önerilen hedeflere ulaşmak için enerji ikamesinin yeterli olmayacağını göstermektedir. Karbon vergisi enerji ikamesi ile birlikte tüm endüstrilerden ziyade seçili endüstrilere uygulanmalıdır. Bu yolla çevresel hedeflere ulaşılırken ekonomideki daralma daha az olacaktır.
**Anahtar Kelimeler:** Sera Gazı Emisyonları, Enerji İkamesi, Karbon Vergisi, Girdi-çıktı Matrisi
**Jel Sınıflandırması:** C67, H23, Q5, R11

## 1. Introduction

The level of greenhouse gas emissions of Turkey was 207.8 $mtCO_2e$ (million tons of carbon dioxide equivalents) in 1990, but reached at 467.6 $mtCO_2e$ in 2014. When the greenhouse gas emissions are evaluated according to industrial distribution, it is observed that the energy sector has the highest share with 72.5%, followed by industrial transactions and product usage with a share of 13.4%. The share of energy sector in annual emissions has increased from 64% to 73% in the 1990-2014 period. It was also found that 80% of the annual increase in emissions was attributable to the energy sector. On the other hand, an increase in per capita emissions also occurred in the 1990-2014 period. Emissions per capita in 1990 were 3.77 tons, rising to 6.08 tons in 2014 (TURKSTAT, 2016).

The high demand for electricity and the share of coal used in electricity generation are remarkable and lie behind the high rate of emission increase in Turkey. Emissions from coal combustion amounted to 62.6 million tons in 1990, rising up by 130% to 144.2 million tons in 2012, and approximately one-third of total emissions in 2012 stemmed from coal consumption. Emissions from coal burned in thermal power plants in the period from 1990 to 2012 increased by 219%, trending above the rate of increase in total emissions (Yeldan et al., 2016: 35).

In accordance with the Paris Agreement adopted at the climate change conference on December 2015 in Paris, it was decided that the increase in global average temperature should be kept well below 2 $^0$C compared to the pre-industrial period, and that the parties should struggle to limit the increase at 1,5 $^0$C (Yeldan et al., 2016: 37). Contrary to the Kyoto Protocol, the Paris Agreement, which entered into force on 4 November 2016, has stipulated for the first time all countries to participate effectively in combating climate change. Therefore, this agreement aims to accelerate the investments and actions required for a sustainable, low-carbon future (UNFCCC, 2016). This method, called 'bottom up' approach, has been added to the Paris Agreement under the name of 'Intended Nationally Determined Contributions' (INDC, 2016). According to the Agreement, the party states are obliged to update the INDCs and give information about their national contributions in the line of achieving the purpose of agreement during the global situation assessment meeting to be held every 5 years (Yeldan et al., 2016: 37-38).

To carry out the National Contribution Statement of Turkey, it is beneficial to examine the issue within the relevant national and industrial plans and policies. In this respect, the targets and policies in Turkey's Tenth Development Plan are of great importance (TCKB, 2014). As a result of policies to be implemented according to the Tenth Development Plan covering the period

2014-2018, the real GDP is projected to increase by an average of 5.5%. Parallel to these targets, the Energy Efficiency Law and relevant regulations that incentive for efficient energy use were enacted and enforced, and it was aimed to reduce energy intensity by at least 20% by 2023 in accordance with the Energy Efficiency Strategy Document published in 2012.

Turkey is a country that stands out with its rapid increase in total greenhouse gas emissions rather than its greenhouse gas emission volume. So now it has to follow a steady path to achieve the environmental targets set to contribute to climate change. The most important issue on this path is that the economic policies to be implemented for emission reduction should not contradict the growth targets of the economy. In other words, it will not be reasonable and meaningful to reach environmental targets only by complying with economic goals.

In this study, the environmental and economic impacts of carbon taxing and energy substitution policies were analysed. Policies were applied in accordance with the targets set out in the current economic plan and environmental commitments to reduce greenhouse gas emissions. The main argument of the study is that the economic policies, which could be implemented to meet the greenhouse gas emission targets, conflict with the growth targets of the economy. In other words, if a different policy package is not implemented, the declared emission (growth) targets are an obstacle to the targeted economic growth (emission reduction). The second part of the paper provides a review of the relevant domestic and international literature. Third part presents methodology together with empirical analyses. In section four the study concludes.

## 2. Review of Empirical Literature

The first part of this review focuses on the studies that analyse environmental and economic impacts of carbon tax policy used as an instrument to reduce greenhouse gas emissions. We prefer to provide common features of these studies in the text and a list of literature categorized with respect to focused country and to specific policy instrument [1] is given in the appendix. The second part will review the studies that focus on the same subject particularly in Turkey.

Carbon tax is a widely used policy tool to reduce greenhouse gas emissions, and there are numerous studies in the international literature that discuss the environmental and economic consequences of carbon taxation. The common emphasis of these studies is that carbon tax is effective in reducing emissions, but it is likely to cause a significant contraction in economic activity in which the expected effects of Pigouivan taxation [2] will appear. In preventing or reducing this economic contraction, it becomes important to return the carbon tax revenues to the economy, and to know in what channels these revenues are returned. In addition, neutral taxes come into prominence to avoid the economic contraction against environmental gains. In other words "double dividend theory" at this point can be a solution to the economic contraction

1 Neutral tax: terminology used to name policies implemented to offset/reduce contractionary economic impacts of carbon taxing.

2 Krugman and Wells, 2009: 445-450.

problem either through reduction of other taxes on economic agents or through transferring the collected carbon tax back to the agents in some sort of a subsidy or direct income. [3] The studies in question, generally, have applied a computable general equilibrium model and evaluated the effects of carbon tax and various energy taxes on the environment and economy. In addition, they have emphasized through which channels to return revenues from carbon tax and other energy taxes to the economy in order to prevent or optimally reduce their negative effects on the economy. The studies cover a large set of countries and their industrial and time focus also differs.

In the studies, neutral taxing is applied through reductions in other either direct or indirect taxes. Mostly personal income and/or corporate tax rates are utilized and in some studies reductions in taxes regarding employment/labour market and capital taxation is also used. There are some studies that employ industry specific tax reductions and some decreases the tax rate on consumption. Returning collected carbon tax revenue back to the economic activity is another channel to overcome the adverse impact of carbon taxes on economy. Transferring the tax revenue to households to trigger final consumption expenditure in economy is one channel while providing those resources to firms to create incentive for production is another. Transfer to firms either aim at reducing intermediate input cost or cost of labour to the firm.

There are only limited number of studies on environmental and economic effects of carbon taxation in Turkey. The earliest is Telli et al. (2008) in which a computable general equilibrium model is used to analyse 2006-2020 economic effects of emission reduction policies applied in accordance with Kyoto Protocol. The economy is aggregated into 10 industries that specifically focus on main energy and mining industries. Carbon emission quotas and carbon taxes are used as alternative policy instruments. The latter was found to be more effective in terms of reducing gas emissions. Both instruments create a contraction in the economy however since carbon taxing is more effective, adverse economic effects of this policy is not as high as of carbon quotas.

Another CGE work was carried out by Bouzaher et al. (2015) to evaluate the effects of emissions and waste generation over the period of 2010-2030. They aggregated the economy into 12 industries by focusing more on manufacturing and energy. While they applied emission tax on urban households, they also used tax against industrial and household solid and liquid wastes. Tax revenues were transferred back into green professions and also used to lower employment taxes. In the rural areas tax revenues were used to lower costs of water use efficiency, to improve management and conditions of meadows and to protect agricultural lands. They conclude that to use any environmental policy to reduce wastes and emissions some recovery policies to overcome the adverse economic impacts should definitely be used.

Yeldan and Voyvoda (2015) analysed impacts of commitments given by Turkey accordingly with decision taken in 2015 Paris Congress. They also simulated effects of transferring carbon tax revenues to renewable investment funds. Findings from CGE modelling suggest that in 2030

3 Jaeger, 2013: 2-16.

emission targets will be reached however at the cost of contracting economy until after 2020. Once renewable investments are used in economic activities the economic recovery will start in 2030.

Lastly Yeldan et al. (2016) has simulated economic effects of fossil-fuel taxes to reach %21 reduction in emissions by using a CGE model. Tax revenues were injected back to the economy by lowering taxes on employment. According to their findings sole taxation will result in less emissions at the cost of slower economic growth rates and lower employment. Therefore, tax revenues have to be used to lower employment costs in order to overcome the adverse impacts.

Two more studies, Bhutto and Çağatay (2010); Özeş and Çağatay (2015), are worth to mention here due to the methodology they used for energy substitution. While the former simulates impacts of substituting fuel oil used by households and in industrial production with natural gas, the latter focuses on the substitution of natural gas and with bio-ethanol. Both studies target the impacts in Turkish economy by employing an input-output matrix of the country.

This study shares common grounds with Bhutto and Çağatay (2010); Özeş and Çağatay (2015) in terms of the methodology used for energy substitution. On the other hand, carbon taxation is another common policy instrument used both in this study and in large number of studies in international literature. As a difference, in this study energy substitution and carbon taxation are used together to reach emission targets without creating too big adverse impacts on the economy.

## 3. Methodology and Empirical Analysis

Turkey has announced its national target for greenhouse gas emission reduction through the Intended Nationally Determined Contribution (INDC, 2016) in the 21$^{st}$ Conference of the Parties held in December 2015, before the Paris Agreement, which was adopted with the participation of 195 countries and entered into force on 4 November 2016 (Yeldan et al., 2016: 19). This document explains that in the case of current economic growth targets and assumptions about the amount of energy use, it is aimed to reduce the greenhouse gas emission of 1,175 million tons of $CO_2$ equivalents to be released in 2030 by 21% to 929 million tons of $CO_2$ equivalents. Thus, Turkey aims to keep the target of global warming up to 2 $^0$C by 2030, as envisaged in the Paris Conference. Turkey should also take into account economic growth targets and policies while achieving the greenhouse gas emission targets set out in its National Contribution Statement. An important economic objective to be taken into account in this respect is the general economic growth target set out in the Tenth Development Plan for the period 2014-2018. The average real GDP growth is projected to be 5.5% and 5.9% for the periods of 2014-2018 and 2017-2018, respectively. Another target to be considered is determined in the Energy Efficiency Strategy Document, which aims to reduce energy intensity by at least 20% by 2023 (Energy Efficiency Strategy Document, 2012). By 2018, the targets of primary energy and electricity demands were set at 154,000 BTEPs and 341,000 GWH, respectively, while the share of natural gas and renewable resources in electricity generation was targeted at 41% and 29%, respectively.

A contradictory situation arises when the various commitments and targets mentioned above are evaluated together. This contradiction arises from the energy use consistent with economic growth targets making it difficult for Turkey to fulfil the Paris Conference commitments, in other words, the energy use fulfilling the Paris Conference commitments makes it difficult to achieve economic growth targets. The focal point of the empirical analysis carried out in the present study shows the presence/absence of this contradiction. The hypothesis to be tested through analyses is that Turkey cannot achieve its goal of economic growth in case of fulfilling the Paris Conference commitments. This hypothesis is tested for the year 2018, the last year of the Tenth Development Plan. The proposed policy change under which the study is going to test the hypothesis is carbon tax application and energy substitution.

For calculating economic effects Turkey's year 2012 input-output matrix is used, in which 65 industries are aggregated into 15 industries. By using the well-known Leontief inverse, demand side shocks were introduced and employment multipliers were also calculated. Calculations regarding energy substitution are carried out exogenously and explained in the following sub-sections.

## 4. Emission Reduction Through Energy Substitution

Turkey's National Contribution Statement aimed at reducing the greenhouse gas emission of 1,175 million tons of $CO_2$ equivalents to be released in 2030 by 21% to 929 million tons of $CO_2$ equivalent. The Declaration predicts an annual average increase of 6.3% on total greenhouse gas emissions. Based on this information and the total greenhouse gas emission volume realized in Turkey in 2014, firstly greenhouse gas emissions were calculated for the cases with and without a greenhouse gas reduction commitment in 2018 (Table 1: 581.7 and 535.5 million tons $CO_{2e}$, respectively)

**Table 1:** Total Greenhouse Gas Emission Target Values

| (mn. Tons $CO_{2e}$) | 2018 | 2030 |
|---|---|---|
| **Base scenario** | 581,7 | 1.175,0 |
| **Paris Conference Target** | 535,5 | 928,3 |
| **Reduction Target** | 46,7 | 246,7 |

**Source:** Author calculations.

First part of the scenario analysis reveals the greenhouse gas emissions and economic changes that can meet the changing energy demand when a certain proportion of the total amount of natural gas used in electricity generation is substituted by bio-ethanol [4]. In the scenario, the share of natural gas usage in electricity generation (48.1%) is targeted to reduce the level of natural gas usage (41%) in electricity generation for 2018, which was determined in the Energy Strategy

4 In their empirical analyses, previously Çağatay et al. (2017: p. 222) has concluded the feasibility of using wheat, maize and sugar beet production in Turkey in production of bio-ethanol and hence in reduction of $CO_2$ emissions.

Document. For this purpose, the total amount of natural gas used in electricity generation in 2014 was reduced by 7.1% and the resultant energy deficit was met by increasing the bio-ethanol demand through bio-ethanol net calorie value. This reduction in natural gas usage was reduced from the total emission volume using emission factors, and the increase in bio-ethanol consumption was added to the total emission again using the emission factor (Table 2).

**Table 2:** Results of Energy Substitution

| | | | | | | **Calorie Value in Case of 7.1% Reduction in Natural Gas Consumption (Tj)*** | |
|---|---|---|---|---|---|---|---|
| | **Natural Gas Amount Used for 2014 Year Electricity Production (thousand TEP) (A)** | **Net Calorific Value (Tj / 1000 tons) (B)** | **Total Calories (Tj) (A * B)** | **Emission Factor (Kg/Tj)** | **Total Greenhouse Gas Emission (Kg)** | **Natural Gas Total Calorie Value (Tj)** | **Bio-ethanol Increase to Close Calorie Deficit (TEP)** |
| **Natural Gas** | 10.384,7* | 48** | 498.463 | 56.100 | 27.963.785.520 | 463.072 | 1.291,6 |
| **Bio-ethanol** | | 27,4** | | 79.600 | | | |

**Source:** * Electricity Production Sector Report, 2015.

** IPCC, 2006.

*** The total calorific value of natural gas was calculated by multiplying the value that was obtained when natural gas usage is reduced by 7.1%, with the net natural gas calorific value. The bio-ethanol increase to close the calorie deficit was achieved by dividing the calorie deficit resulting from the reduction of natural gas demand to the bioethanol net calorie value

As a result of the analysis, the total emission of greenhouse gases (24.9 million tons) was found to be less than the target emission (46.7 million tons – Table 1) determined in the Paris Conference.

## 5. Emission Reduction Through Energy Substitution and Carbon Tax

In the second part of the scenario analysis carbon taxation has been introduced in addition to energy substitution as emission reduction after energy substitution was enough to meet the target. Prior to the application of carbon taxation, the industries to which the tax would be applied to achieve the targeted emission reduction were identified. The selection of industries to be focused in this scenario was based on their shares in total emissions. Two industries from them, namely 'electricity, gas, water, treatment, infrastructure' and 'chemicals, plastic products, non-metallic minerals', are the ones with highest emissions share in total emission. The third industry, 'coke and refined petroleum products,' is also important as it is the primary energy industry with a high share of emissions. In this scenario, the amount of total emissions to be reduced is shared only among these three industries.

The amount of emission reduction for 2018, shown in Table 1, was distributed to the industries using the total greenhouse gas emissions of the industries [5]. The drop in production, which

5 The industrial emission shares are multiplied by the target emission amount. Industrial emission data from the WIOD tables were used when calculating industrial emission shares (WIOD, 2017)

will provide the projected emission reductions for each industry, is then calculated by using greenhouse gas emission coefficients per unit production value in these industries. In the next stage, the amount of carbon taxation that would give the necessary production reduction was found by using the industry-based reduction of production value and the tax-production value elasticity coefficients [6] calculated for each industry (Table 3).

**Table 3:** Emission Shares, Carbon Tax Amount and Production Decrease by Industry

| | Industrial Distribution of 21.8 million tons of Emission Reduction (%) | Required Production Decrease (million TL) | Carbon Tax Amounts (million TL) | Share of Industrial Carbon Tax Amount in Industrial Tax Burden (%) (tax on product + production) | Share of Industrial Carbon Tax Amount in Total Carbon Tax (%) |
|---|---|---|---|---|---|
| **Coke and Refined Petroleum Products** | 1,42 | 476 | 63,06 | 0,001 | 4,93 |
| **Chemicals, Plastic Products and Non-Metallic Minerals** | 6,55 | 8.35 | 412,57 | 0,007 | 32,25 |
| **Electricity, Gas, Water, Treatment, Infrastructure** | 13,83 | 10.89 | 803,68 | 0,013 | 62,82 |
| **Total** | 21,80 | 19.71 | 1279,32 | 0,021 | 100,00 |

**Source:** Author calculations.

The results of the inter-industry interaction (indirect effects) caused by the production decrease (direct effects) on the industrial basis and the resultant economic downsizing effect were determined by the demand-side input-output matrix simulations. In addition, an industrial employment decline was determined after economic contraction by using employment multipliers. Direct and indirect production effects are given in Table 4.

First column in Table 4 gives the increase in value of industrial production in case if there were no carbon taxing. Second column presents the decrease in production with respect to required emission reduction in the selected three industries. Third column gives the inter-industry impacts arose due to the fall in production value. The last column provides the decrease in payments to employees which proxies the fall in employment. In the base scenario in case if there was no carbon taxing the overall growth of the economy would be about %4,4 which was still lower than the targeted rate of %5,5. After energy substitution, carbon taxing created a fall in overall growth,

6 Calculation of carbon tax elasticity: Both year's 2002 and 2012 input-output tables were aggregated for 15 sectors, and then elasticity coefficients between tax and supply data for these years were found.

2012 net taxes and subsidies ($Y_{1)}$

2002 net taxes and subsidies ($Y_2$)

2012 value of production ($X_1$)

2002 value of production ($X_2$)

Tax-production value elasticity coefficient: $\epsilon_{\nu\ddot{u}} = \frac{\%\Delta(X_1 - X_2)}{\%\Delta(Y_1 - Y_2)} * \frac{(Y_1 - Y_2)/2}{(X_1 - X_2)/2}$

in other words the economy contracted about %0,4 which meant a fall in growth about %4 with respect to base scenario and a fall about %5 with respect to target growth rate.

**Table 4:** Economic Contraction as a Result of Inter-Industry Interactions

| Thousand TL | Base Scenario* | Industrial Production Decrease (direct effect) | Industrial Production Decrease (indirect effects) | Decrease in payments to Employees |
|---|---|---|---|---|
| **Agriculture, Forestry and Fishery** | 4.759.580 | – | 98.113 | 1.416 |
| **Mining and Quarrying** | 5.392.303 | – | 4.014.356 | 4.300 |
| **Food, Beverages and Tobacco Products** | 6.839.937 | – | 80.013 | 4.475 |
| **Textile, Garment, Leather and Related Products** | 6.248.774 | – | 99.098 | 4.475 |
| **Coke and Refined Petroleum Products** | 3.506.375 | 476.324 | 908.344 | 2.117 |
| **Chemicals, Plastic Products and Non-metallic Minerals** | 8.991.670 | 8.346.376 | 11.198.748 | 5.256 |
| **Basic Metals** | 5.913.483 | – | 224.028 | 10.644 |
| **Motor and Vehicle Production** | 3.673.781 | – | 17.313 | 5.818 |
| **Forest Products, Paper & Furniture** | 3.508.449 | – | 168.044 | 4.475 |
| **Metal, Electronics, Optical and other Manufacturing** | 9.220.704 | – | 379.710 | 8.231 |
| **Electricity, Gas, Water, Treatment, Infrastructure** | 8.517.048 | 10.890.992 | 18.371.799 | 2.117 |
| **Construction and Construction Works** | 15.671.953 | – | 389.508 | 10.761 |
| **Transportation and Storage** | 12.803.013 | – | 794.155 | 3.534 |
| **Wholesale, Retail Trade, Accommodation** | 16.432.551 | – | 780.686 | 6.285 |
| **Service** | 38.967.499 | – | 1.647.416 | 5.491 |
| **Economy-wide average growth / contraction (%)** | 4,4 | | 0,4 | |
| **Economy-wide growth target in 2018 (%)** | 5,9 | | | |
| **Growth target for 2014-2018 period (%)** | 5,5 | | | |

**Source:** Author calculations.

* The base scenario values are calculated using the average real growth rates of the 15 sectors obtained from the WIOD.

Industries with the highest production decline (direct impact) are the industries of 'electricity, gas, water, treatment and infrastructure', 'chemistry, plastic products and non-metallic minerals' and 'coke and refined petroleum products', respectively. Furthermore, industries with the highest industrial economic contraction (indirect impact) are the industries of 'electricity, gas, water, treatment and infrastructure', 'chemistry, plastic products and non-metallic minerals' and 'mining and quarrying', respectively. Industries with the lowest industrial economic contraction

are the industries of 'motor land vehicle production' and 'food, beverages and tobacco products' industries, respectively. Industries with the highest employment decline are the industries of 'constructions and construction works' and 'basic metals', respectively. Industries with the lowest employment decline are the industries of 'agriculture, forestry and fishery', 'coke and refined petroleum products' and 'electricity, gas, water, treatment and infrastructure', respectively.

## 6. Conclusion

In this study, the environmental and economic impacts of greenhouse gas emissions were analysed in accordance with the targets set out in the current economic plan and environmental commitments of Turkey. The economy was aggregated into 15 industries and the environmental and economic impacts of energy substitution and carbon tax applied to the selected industries were evaluated. In the analysis, first a certain proportion of the total amount of natural gas used for electricity generation was replaced by bio-ethanol. However, it was found that environmental targets were not met by sole energy substitution, although there were no adverse impacts on economy. Then, carbon taxation was introduced on most polluting three industries in addition to energy substitution.

Taking into account the main argument discussed in the present study, the application of carbon taxation to reduce greenhouse gas emissions could be an important and effective policy tool for attaining environmental targets. However, according to the research results, achieving environmental targets pushes the economy away from attaining growth targets. Therefore, the issue that needs to be emphasized here is to ensure harmony and balance between environmental and economic targets so that the possible impacts of Pigouvan taxation on the economy is reduced. To achieve this balance, it seems inevitable to implement an additional policy package compatible. In this case, injecting carbon tax revenues back to the economy might be an efficient alternative, as suggested by "double dividend theory" and strongly advised by the empirical literature.

In parallel with our findings, various studies (Conefrey et al., 2008; Estrada and Santabarbara, 2021; Bourgeois et al., 2021; Liu et al., 2021) that examine the recycling of carbon tax revenues to the economy have found that if carbon tax revenues are transferred back to the economy it will create a double dividend effect and have a positive effect on economic growth.

According to the findings, a substitution between the consumption amounts of existing types of energy used in industrial production, in other words, an orientation toward cleaner energy, directly facilitates to achieve environmental targets and hence energy substitution arises as another alternative to reach both economic and environmental targets.

Sole carbon taxation would not be enough to meet environmental targets without contracting the economy. Injection of carbon tax revenue back to the economy might be a solution however we see this as a short-sighted alternative. Because boosting demand will trigger the production

inevitably however production will continue with the existing dirty technology. Therefore, main message would be the country should target clean production technologies and it is obviously and mostly related to type of energy used in production.

We could expect a fall both in production cost and emissions due to the inter-industry interactions if substitution between natural gas and bio-ethanol is realized for electricity production. Therefore, in the medium term Turkey should search for the ways to substitute natural gas with bio-ethanol. However, in the short run; carbon taxing policy implemented with energy substitution would create the opportunity to reduce emissions in a shorter period and with less economic costs.

## Appendix

| A-Studies that emphasize utilization of neutral taxation to overcome adverse impacts of carbon taxation | | |
|---|---|---|
| **Country** | **Authors** | **Policy instrument** |
| China | Li and Lin (2013; 2015) | reductions in value added taxes and in indirect consumption/ direct production taxes |
| | Zhang et al. (2016) | reductions in indirect taxes |
| USA | Glomm et al. (2008), Roson (2003) and Williams et al. (2014) | reductions in capital taxation |
| | Goulder and Hafstead (2013), Rausch and Reilly (2012) | decrease in corporate taxes |
| | Rausch and Reilly (2012), Roson (2003) and Williams et al. (2014) | reduction in taxes in labour market |
| | Gonzalez (2012) | decrease in tax rates regarding manufacturing industries |
| The EU and other Europe | Allan et al. (2014) | income tax reduction |
| | Gemechu et al. (2014) | reductions in income and corporate tax |
| | Combet et al. (2010), Faehn et al. (2009), Manresa and Sancho (2005), Vandyck and Regemorter (2014), Bosello and Carraro (2001), Majocchi et al. (2002) | reductions in taxes regarding labour market |
| South Africa | Alton et al. (2014) | reductions in indirect sales taxes |
| | Heerden et al. (2006) | reductions in direct income tax and in taxes on food consumption |
| Brazil | Grottera et al. (2015) | reduction in labour cost |
| Russia | Orlov et al. (2013) | reductions in tax on qualified and unqualified labour |
| Thailand | Timilsina and Shrestha (2007) | reductions in tax on labour and in indirect taxes on consumption of non-energy goods |

| B-Studies that emphasize redistribution of income to overcome adverse impacts of carbon taxation | | |
|---|---|---|
| **Country** | **Authors** | **Policy instrument** |
| The EU and other Europe | Allan et al. (2014) | increase in public spending |
| | Bureau (2011), Combet et al. (2010), Faehn et al. (2009), Vandyck et al. (2014) | direct transfer to households |
| | Majocchi et al. (2002) | subsidizing exports |
| China | Brenner et al. (2005), Zhou et al. (2011) | direct transfer to households |
| | Liang et al. (2007) | subsidizing production |
| | Lu et al. (2010) | direct transfers to firms and households |
| | Zhang et al. (2016) | various subsidies to households |
| USA | Gonzalez (2012); food aid. Rausch and Reilly (2012) | various transfers to households |
| | Williams et al. (2014) | direct transfer to households |
| Canada | Beck et al. (2015) | direct transfer to households |
| | Dissou and Eyland (2011) | subsidizing production and exports |

| | | |
|---|---|---|
| South Africa | Alton et al. (2014) | social transfers to households |
| Indonesia | Yusuf and Resosudarmo (2007) | direct transfer to households |
| Brazil | Grottera et al. (2015) | direct transfers to lower income group |
| Australia | Meng (2014) | direct transfers to poorest group |
| Thailand | Timilsina and Shrestha (2007) | direct transfer to households |
| **C-Other studies** | | |
| **Country** | **Authors** | **Policy instrument** |
| 25 Developed Economies | Timilsina et al. (2011) | subsidizing use of biofuels |
| China | Sun and Ueta (2011) | reducing electricity price for household use |

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