İstanbul İktisat Dergisi - Istanbul Journal of Economics
73, 2023/1, s. 419-452
ISSN: 2602-4152
E-ISSN: 2602-3954

RESEARCH ARTICLE

The Economic Impact of the Paris Agreement on Sectoral Outputs in Türkiye: An Input-Output Approach

Paris Anlaşması'nın Türkiye'de Sektörel Üretim Üzerine Etkileri: Bir Girdi-Çıktı Yaklaşımı

Mustafa BORAN[1], Bekir KAYACAN[2]

ABSTRACT

This study analyzes the economic impact of the Paris Agreement on sectoral outputs in Türkiye. All member countries are required to reduce their greenhouse gas emissions by the Agreement according to their responsibilities and capabilities. In this regard, developed countries are subject to absolute emission reduction. Türkiye ratified the Agreement in 2021 as a developing country and started implementation in 2022 as stated in the Nationally Determined Contributions. Regarding implementation of the Agreement, three scenarios are analyzed: the business-as-usual (as a developing country), the absolute emission reduction (as a developed country), and the exit (exiting the Agreement). Emission pathways and reduction amounts for each scenario are estimated accordingly. An input-output model is used based on 2018 tables for 45 sectors. Five policy options are analyzed regarding how to distribute the emission reduction burden among sectors: all sectors according to their shares in 2018 emissions (option 1); the top 9 sectors whose emission coefficients are above average (option 2); the top 6 sectors whose emission multipliers are high (option 3); the top 11 sectors whose emission multipliers are above average (option 4); the top 12 sectors which are the top 11 in option 4 plus the construction sector (option 5). Reducing emissions significantly reduces sectoral output in all scenarios and policy options. However, the impact of the business-as-usual is less than absolute emission reduction. Targeting only a few sectors in emission reduction results in a lower impact. If policy options are sorted by their total cost from smallest to largest, the order would be 3, 2, 4, 5, and 1.

Keywords: Emission reduction, The Paris Agreement, Economic impact analysis, Input-output model
JEL Classification: C67, Q58

ÖZ

Bu çalışmanın amacı Paris iklim Anlaşması'nın Türkiye'de sektörel üretim üzerine etkilerini analiz etmektir. Anlaşma ile

DOI: 10.26650/ISTJECON2022-1211511

[1]PhD Student, Graduate School of Social Sciences, Istanbul University, Istanbul, Turkiye
[2]Prof. Dr., Faculty of Economics, Istanbul University, Istanbul, Turkiye

ORCID: M.B. 0000-0002-7849-0623; B.K. 0000-0002-6569-8054

Corresponding author:
Mustafa Boran,
Graduate School of Social Sciences, Istanbul University, Istanbul, Turkiye
E-mail: boranm@yahoo.com

Submitted: 29.11.2022
Accepted: 18.04.2023

Citation: Boran, M., & Kayacan, B. (2023). The economic impact of the Paris agreement on sectoral outputs in Turkiye: an input-output approach. *İstanbul İktisat Dergisi - Istanbul Journal of Economics*, *73*(1), 419-452. https://doi.org/10.26650/ISTJECON2022-1211511

tüm taraflardan, sorumluluk ve imkanları nispetinde, sera gazı salınımlarını azaltmaları beklenmektedir. Bu anlamda, gelişmiş ülkelerden mutlak azaltım yapmaları beklenmektedir. Türkiye Anlaşmayı gelişmekte olan bir ülke olarak onaylamış ve uygulamasına Ulusal Katkı Beyanı çerçevesinde 2022 yılında başlamıştır. Anlaşma'nın uygulaması anlamında üç senaryo çalışılmıştır: referans senaryo (gelişmekte olan ülke gibi), mutlak azaltım senaryosu (gelişmiş ülke gibi) ve çıkış senaryosu (Anlaşma'dan çıkılması). Emisyon ve azaltım miktarları herbir senaryo için ayrı ayrı tahmin edilmiştir. Çalışmada 45 sektör bazında yayımlanmış 2018 verilerine dayalı bir girdi-çıktı modeli kullanılmıştır. Emisyon azaltımının hangi sektörlerde yapılacağına ilişkin 5 politika seçeneği analiz edilmiştir: 2018 emisyon paylarına göre tüm sektörlerde (seçenek 1); emisyon katsayısı ortalamanın üzerinde olan en büyük 9 sektörde (seçenek 2); emisyon çarpanı yüksek olan en büyük 6 sektörde (seçenek 3); emisyon çarpanı ortalamanın üzerinde olan en büyük 11 sektörde (seçenek 4); seçenek 4'deki 11 sektör ve inşaatla birlikte 12 sektörde (seçenek 5). Emisyon azaltımının sektörel üretim üzerindeki olumsuz etkileri, tüm senaryo ve politika seçenekleri için yüksek bulunmuştur. Ancak, referans senaryonun etkisi mutlak azaltım senaryosuna göre daha azdır. Emisyon azaltımının az sayıda sektörde yapıldığı politika seçeneklerinin üretim üzerindeki etkisi, diğerlerine göre daha azdır. Politika seçenekleri toplam maliyetleri anlamında en düşük maliyetliden en yükseğe sıralanacak olursa, sıra 3, 2, 4, 5 ve 1 şeklinde olurdu.

Anahtar kelimeler: Emisyon azaltımı, Paris Anlaşması, Ekonomik etki analizi, Girdi-çıktı modeli
JEL Sınıflaması: C67, Q58

1. Introduction

The Paris Agreement on climate change was adopted in 2015 by the United Nations and implementation period started in 2020 regarding emission reduction responsibilities. One hundred and ninety-four parties out of 198 Parties from the United Nations Framework Convention on Climate Change (UNFCCC) are signed up to the Paris Agreement as of November 9th, 2022 (UNFCCC, 2022a). According to the Agreement, all countries are subject to emission mitigation responsibility and should prepare nationally determined contributions (NDCs) which contain emission reduction targets and measures to achieve them. Developed countries are further subject to absolute emission targets and are to cap their greenhouse gas (GHG) emissions as soon as possible. On the other hand, the Agreement recognized that the capping of GHG emissions will take longer time for developing countries. In this regard, it may be argued that other developmental needs and objectives of developing countries are recognized by the Agreement.

Türkiye ratified the Agreement in 2021 with the reservation of implementing the Agreement as a developing country in the scope of her NDC (UNFCCC, 2022b). Türkiye has two major concerns regarding the Paris Agreement. These concerns are the possibility of an absolute emission reduction burden and the non-provision of support. Both of these concerns stem from Turkey's status before the Agreement. Türkiye was included in Annex I and Annex II of the UNFCCC in 1994. Annex I countries are subject to emission reduction whereas Annex II countries are subject to provision of finance to developing countries. Being a developing country, Türkiye did not ratify the UNFCCC until 2004, until being excluded from Annex II. Although there is no reference to the annex system of the Convention in the Paris Agreement, being an Annex I country in the Convention, Türkiye is sometimes perceived as a "developed country" before the Agreement. Thus, there is a risk that the absolute emission reduction responsibility of developed countries may be applied to Türkiye. In addition, support measures which are designed for developing countries may not be provided to Türkiye. These concerns are clearly mentioned in Turkey's NDC. Türkiye submitted her NDC back in 2016 as a developing country and annual GHG emissions are projected to be reduced up to 21% until 2030 accordingly.

The status of the country parties before the Paris Agreement have an important impact on the amount of emission reduction burden. Developed country parties are subject to absolute emission reduction whereas developing countries are required to reduce emissions taking into account their developmental needs. This means that the emission reduction burden of developed countries is much more than developing countries. A higher emission reduction burden results in having a greater impact on economies since it requires additional investment and/or output reductions.

In addition, the distribution of the emission reduction burden among economic sectors has different effects on economies as well. As some studies suggest, targeting just a few sectors in emission reduction may be cost effective for the economies.

In this paper, we analyzed various emission reduction scenarios for Türkiye taking into account her development status before the Paris Agreement. In addition, various policy options are analyzed regarding the distribution of the emission reduction burden among different sectors in Türkiye. However, our analyzes are limited to the impact of emission reduction on the output of different economic sectors.

2. Literature Review

Studies on the economic effects of the Paris Agreement focus usually on the energy sector. Among others, a recent book edited by Dejuan, Lenzen, & Cadarso (2018) consists of 17 papers, 8 of which contain an impact analysis on the energy sector. Altieri et al. (2016) focused on coal-fired power plants and their replacement with renewable power plants to reduce GHG emissions. Kratena and Schleicher's (1999) study on the Austrian economy divided commodities into two groups: energy and non-energy commodities. As energy is responsible for most of the GHG emissions in many economies, this seems logical. Besides, the availability of data and a rather limited number of production technologies help model construction and the estimation of variables.

Studies by Marcucci and Zhang (2019), la Rovere, Wills, Grottera, Dubeuxc, & Gesteira (2018), Jorgenson and Wilcoxen (1989), and Blitzer, Eckaus, Lahiri, & Meeraus (1990) are examples of impact analysis of emission reduction in the whole economy. As emission reduction policies are applied to all sectors, their models may be claimed as more realistic.

The majority of studies in the literature claim that emission reduction policies have negative economic effects. However, Marcucci and Zhang (2019) found that emission reductions of 72% and 80% compared to 1990 levels in the Swiss economy resulted in a slight decrease in utility and an increase in investments through a shift of labor from manufacturing to research. Altieri et al. (2016) claims that South Africa could achieve decreasing unemployment and poverty if emission abatement policies are implemented in such a way that coal-fired power plants are replaced with solar and wind power, and energy intensity is reduced via fuel switching and efficiency improvements.

Most of the studies on the economic impact of climate agreements are based on computable general equilibrium models (CGE) whereas input-output models are limited in number (Babatunde, Begum, & Saida, 2017). A recent example on input-output models is papers in Dejuan, Lenzen, & Cadarso's book (2018). However, they focus on either energy or household consumption sectors. Study of Lixon, Thomassin, & Hamaide (2008), on the contrary, analyzed the impact of emission reduction on the whole Canadian economy based on an input-output model.

Regarding the impact of climate agreements on the Turkish economy, studies are limited in number. Telli, Voyvoda, & Yeldan (2007) applied a CGE model to estimate the impact of emission reduction in all sectors versus the energy sector in 2006-2020 periods. Their study reveals the importance of external financing for Türkiye. If emissions are reduced by abatement investments and these investments are financed by external financing as suggested by the Kyoto Protocol, there will be no GDP losses. If emissions are reduced through the taxation of energy input use, there will be significant GDP growth losses. If emissions are reduced through by quotas with a similar emission reduction effect of taxation, GDP growth losses will almost double. Bouzaher, Sahin, & Yeldan (2014) studied the impact of an emission tax and emission tax revenues which were earmarked for investments in green jobs and R&D. They found a significant negative impact on GDP growth for both scenarios. Kolsuz and Yeldan (2017) studied similar taxation of emissions revenues which were earmarked for green jobs (the first scenario) and also for labor market reform (the second scenario). They found a negative impact on GDP in the first scenario and a positive impact in the second scenario.

This study analyzes the economic impact of emission reduction on the Turkish economy at large. Annual emissions in the economy in 2022-2030 periods are estimated according to the available emission data and assumptions in the NDC. In addition, sector specific emission reduction policies are suggested as alternative policies and the impact on sectoral output is estimated. The study shows that reducing emissions results in significant output losses to the Turkish economy. The magnitude of economic losses depends on the amount of annual emissions reduced and on the sectors targeted for emission reduction.

3. Data and Method

2018 input-output data obtained from the OECD (2021a) is used in the study. The input-output tables are the most recent data available for Türkiye and provided on the basis of an industry by industry (IxI) approach and consist of 45 sectors. The tables are originally provided in USD Dollars and converted to Turkish Liras at OECD annual average buying exchange rate for 2018 (TL/USD=4.82837). The IxI input-output table used in this study has an interindustry transactions matrix, nine final demand column vectors, and four row vectors. Interindustry transactions matrix (Z matrix) is symmetric matrix and has 45*45 dimensions corresponding to 45 sectors based on ISIC Rev. 4 classification.

The final demand is composed of 9 column vectors each of which has 45*1 dimensions. Each of these vectors represent different final demand components: the final consumption expenditure of households (HFCE), the final consumption expenditure of non-profit institutions serving households (NPISH), the final consumption expenditure of general government (GGFC), gross fixed capital formation (GFCF), changes in inventories (INVNT), cross border exports (EXPO), direct purchases by non-residents (exports) (CONS_NONRES), cross border imports (IMPO), and direct purchases abroad by residents (imports) (CONS_ABR).

There are two row vectors regarding taxes less subsidies on production each of which has 1*54 dimensions, 45 industrial sectors plus 9 final demand sectors: taxes less subsidies on intermediate and final products (paid in foreign countries) (TXS_IMP_FNL) and taxes less subsidies on intermediate and final products (paid in domestic agencies, includes duty on imported products) (TXS_INT_FNL). Data on primary inputs (VALU: value added at basic prices) is provided via a row vector of 1*45 dimension. OUTPUT is a row vector of 1*45 dimensions and represents output at basic prices. OUTPUT vector is used in calculating sectoral emission intensities (emission coefficients).

A summary of the input-output table used in this study is prepared similar to Kayacan's (2020) example and provided in Table 1.

Table 1: Summary of 2018 Industry by Industry Input-Output Table for Türkiye (mn TL)

		Buying Sectors / Industries	Final Demand (F) = C (HFCE+NPISH) + G (GGFC) + I (GFCF+INVNT) + X (CONS_NONRES+EXPO) - M (CONS_ABR+IMPO)	Output (X) at Basic Prices

Selling Sectors / Industries		1....45	HFCE (C) NPISH (C) GGFC (G) GFCF (I) INVNT (I) CONS_NONRES (X) EXPO (X) CONS_ABR (M) IMPO (M) Final Demand at Purchasers' Prices TXS_IMP_FNL TXS_INT_FNL	2,088,964 10,556 551,638 1,108,907 -3,343 103,463 931,982 13,886 -1,082,858 3,723,197 0 175,105	
	1 45	Interindustrial Production = Interindustrial Sales = Domestic Intermediate Inputs of Industries (at Basic Prices)			
		3,577,129	Final Demand at Basic Prices	3,548,092	7,125,221
TXS_IMP_FNL		0			
TXS_INT_FNL		212,878			
TTL_INT_FNL		3,790,006			
Value Added at Basic Prices		3,335,215			
Output (X) at Basic Prices		7,125,221			

Source: Own elaboration based on OECD data (2021a)

F Final Demand (F) = final demand expenditures are composed of consumption (C) plus government (G) plus investment (I) plus exports (X) minus imports (M)

HFCE = final consumption expenditure of households

NPISH = final consumption expenditure of non-profit institutions serving households

GGFC = final consumption expenditure of general government

GFCF = gross fixed capital formation

INVNT = changes in inventories

EXPO = cross border exports

CONS_NONRES = direct purchases by non-residents

IMPO = cross border imports

CONS_ABR = direct purchases abroad by residents

TXS_ IMP_FNL = taxes less subsidies on intermediate and final products (paid in foreign countries)

TXS_ INT_FNL = taxes less subsidies on intermediate and final products (paid in domestic agencies, includes duty on imported products)

TTL_INT_FNL = total intermediate consumption at purchasers' prices.

The GHG emissions data is obtained from the EUROSTAT (2021) for 1995-2019 periods. The data is provided for 64 sectors based on NACE Rev. 2 classification and, then, aggregated to 45 sectors based on ISIC Rev. 4 classification in line with the input-output data.

This paper analyzes the possible economic impacts of the Paris Agreement on sectoral outputs in the Turkish economy when GHG emissions are reduced as much as a developing or a developed country. Based on 2018 industry by industry input-output tables for Türkiye provided by the OECD (2021a), the impact of emission reduction on sectoral outputs are estimated to analyze the economic impact. Three scenarios are studied in this regard. Business as usual (BAU) scenario assumes that emissions are reduced as a developing country in line with the NDC. Absolute emission reduction (AER) scenario assumes that emission reduction is done as a developed country. EXIT scenario assumes that if Türkiye exists the Agreement in case her developing country status is not recognized and absolute emission reduction is required. This is a no emission reduction scenario. Thus, the impact of emission reduction on output is not estimated for the EXIT scenario.

Regarding the implementation period of the Paris Agreement in Türkiye (i.e. 2022-2030), total emissions are estimated for each of three scenarios, the EXIT, the BAU, and the AER.

In addition, five policy options are analyzed as alternative policies in which sectors reduce emissions. Policy option 1 suggests all sectors to be subject to emission reduction according to their share in 2018 emissions. In policy options 2, 3, 4, and 5, emissions are to be reduced in only 9, 6, 11, and 12 sectors, respectively.

Finally, the impact of sectoral emission reductions on sectoral output is estimated.

3.1. Estimation of total annual emissions for 2022-2030 periods

As Türkiye ratified the Agreement in 2021, the implementation period started in 2022 through to 2030 in line with the NDC. Annual GHG emissions for this period are estimated according to assumptions and available data in the NDC for each of three scenarios, the EXIT, the BAU, and the AER. Data for the EXIT and BAU scenarios for years 2020, 2023, 2025, and 2030 are available in the NDC. Data for remaining years are extrapolated using econometric software, Eviews, using a cubic function process. Data for the AER scenario is estimated based on the assumption that implementation starts in 2022 according to the BAU scenario as a developing country and, in case this is not welcomed, the AER scenario starts in 2023. In addition, emission reductions in the AER scenario will be one million tons each year compared to the BAU scenario.

As emission figures for the years 2018, 2019, and 2020 are already realized and different from data provided in the NDC, emission estimations are updated accordingly based on the same assumptions used in the NDC. In addition, technological improvements are reflected in emission estimations. As technology is improving and thus, emission intensities are decreasing, emission projections should be updated accordingly. In this regard, changes in the sectoral emission intensity rate is used in estimating the technological improvement rate according to Equation 1 and 2.

$$G_{jt}=GHG_{jt}/X_{jt} \tag{1}$$

$$\Delta G_{jt}=(G_{jt}-G_{jt-1})/G_{jt-1} \tag{2}$$

where, for any specific sector j, G is emission intensity rate or emission coefficient at time t, GHG is annual CO2e emissions, X is total output of sector j, and ΔG is changes (or growth) in emission intensity rate or emission coefficient. Regarding sectoral outputs, data on sectoral outputs at 2015 constant TL prices is used as it better reflects real changes in output. In addition, real output data for 2001-2019 periods is used as it is the most available (OECD, 2021b). Sectoral emission intensities are calculated for 11 aggregated sectors according to ISIC Rev.4

classification because data on both sectoral real output and emissions are provided in these 11 sector groups.

Finally, the following equations are formulated to estimate the annual average changes in emission intensities weighted for emission shares as a measure of an annual technological improvement rate:

$$G_{jtw} = G_{jt} * (GHG_{jt} / \sum_{j=1}^{n} GHG_{jt}) \quad (3)$$

$$G_{tw} = \sum_{j=1}^{n} G_{jtw} \quad (4)$$

$$\Delta G_{tw} = (G_{tw} - G_{t-1w}) / G_{t-1w} \; \Delta G_{tw} = (G_{tw} - G_{t-1w}) / G_{t-1w} \quad (5)$$

$$G_{tech} = (\sum_{t=1}^{T} \Delta G_{tw}) / T \quad (6)$$

$$GHGU_t = GHG_t \, (1 - G_{tech}) \quad (7)$$

where, G_{jtw} is emission intensity rate weighted for emission shares for any specific sector j at time t, G_{tw} is total emission intensity at time t, ΔG_{tw} is change in total emission intensity at time t, G_{tech} is the rate of technological improvements, and GHGU is annual emissions updated for technology.

Based on Equations 1 - 7, the annual technological improvement rate is estimated as 2%. Estimated emissions and emission reductions are provided in Table 3 and Table 4.

3.2. Estimation of sectoral annual emission reductions for 2022-2030 periods

Sectoral annual emissions are estimated according to total annual emissions estimated in the above section and five policy options. Each policy option targets a different sector in emission reduction. According to policy option 1, all 45 sectors are targeted for emission reduction whereas in policy options 2, 3, 4, and 5, emissions are to be reduced in only 9, 6, 11, and 12 sectors, respectively. The following Equations 8 and 9, are formulated for the estimation of sectoral emission reductions.

$$SERB_{jt} = TERB_t * GHGS_{jr} \quad (8)$$

where, for any specific sector j, $SERB_{jt}$ is sectoral annual emission reduction burden at time t, $TERB_t$ is total annual emission reduction burden for the whole economy at time t. Time t varies between 2022 and 2030. $GHGS_{jr}$ is emission shares of all sectors in the reference year r (i.e. 2018). In matrix notation:

$$s = [h\,(i'h)^{-1}]\,TERB \qquad (9)$$

where, s is the column vector of sectoral annual emission reduction burden in the 2022-2030 period, h is a column vector of sectoral annual CO_2 equivalent GHG emissions in the reference year (i.e. 2018), i is the summation row vector of 1's and TERB is a scalar of total annual emission reduction burden for the whole economy in the 2022-2030 period.

3.2.1. Policy option 1

The first policy option is that emission reduction burden is distributed to each sector according to their emission shares in 2018 total emissions (Table 2) In other words, the more a sector polluted the environment in 2018, the more it will undertake the emission reduction burden in 2022-2030 period.

Table 2: Sectoral GHG CO2e Emissions in Türkiye in 2018

NACE Rev.2 Codes	NACE Rev.2 Labels	GHG CO2e Emissions (ton)	Share (%)
A01_A02	Crop and animal production, hunting and related service activities; Forestry and logging	76,034,257	16.3
A03	Fishing and aquaculture	62,010	0
B05_B06	Mining and quarrying, energy producing products	4,380,391	0.9
B07_B08	Mining and quarrying, non-energy producing products	349,842	0.1
B09	Mining support service activities	1,036,276	0.2
C10-C12	Manufacture of food products; beverages and tobacco products	7,311,944	1.6
C13-C15	Manufacture of textiles, wearing apparel, leather and related products	3,459,324	0.7
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	473,124	0.1

C17_C18	Manufacture of paper and paper products; Printing and reproduction of recorded media	1,548,689	0.3
C19	Manufacture of coke and refined petroleum products	6,941,266	1.5
C20	Manufacture of chemicals and chemical products	10,678,955	2.3
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	285,874	0.1
C22	Manufacture of rubber and plastic products	880,503	0.2
C23	Manufacture of other non-metallic mineral products	75,087,229	16.1
C24	Manufacture of basic metals	18,097,005	3.9
C25	Manufacture of fabricated metal products, except machinery and equipment	1,619,505	0.3
C26	Manufacture of computer, electronic and optical products	142,332	0
C27	Manufacture of electrical equipment	720,394	0.2
C28	Manufacture of machinery and equipment n.e.c.	6,468,936	1.4
C29	Manufacture of motor vehicles, trailers and semi-trailers	665,996	0.1
C30	Manufacture of other transport equipment	181,642	0
C31-C33	Manufacture of furniture; other manufacturing; Repair and installation of machinery and equipment	741,138	0.2
D	Electricity, gas, steam and air conditioning supply	153,538,204	32.9
E	Water supply; sewerage, waste management and remediation activities	17,623,508	3.8
F	Construction	6,132,303	1.3
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	15,819,422	3.4
H49	Land transport and transport via pipelines	25,339,454	5.4
H50	Water transport	1,042,205	0.2
H51	Air transport	3,737,473	0.8
H52	Warehousing and support activities for transportation	853,829	0.2
H53	Postal and courier activities	256,518	0.1
I	Accommodation and food service activities	3,710,394	0.8
J58-J60	Publishing activities; Motion picture, video, television programme production; programming and broadcasting activities	591,724	0.1
J61	Telecommunications	208,900	0.0
J62_J63	Computer programming, consultancy, and information service activities	326,601	0.1
K	Financial and insurance activities	1,453,503	0.3
L	Real estate activities	2,968,951	0.6
M	Professional, scientific and technical activities	2,626,147	0.6
N	Administrative and support service activities	1,793,323	0.4
O	Public administration and defense; compulsory social security	6,348,268	1.4
P	Education	1,529,244	0.3
Q	Human health and social work activities	1,384,164	0.3
R	Arts, entertainment and recreation	354,854	0.1
S	Other service activities	1,367,998	0.3

T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	123,978	0
Total	All NACE Activities	466,297,592	100
Total	All NACE Activities Plus Households	522,739,716	-

Source: EUROSTAT (2021).

Data for mining activities at sub-sectoral level (B05_B06, B07_B08 and B09) are calculated from Turkey's national inventory submission to the UNFCCC for 2018 (Turkish Ministry of Environment, Urbanization and Climate Change, 2021).

3.2.2. Policy Option 2

According to the second policy option, the emission reduction burden is distributed to emission intensive sectors whose direct emission coefficients (g) are above average. Emission coefficients are estimated according to Equation 10 and Equation 11. Estimated coefficients are provided in Table 5. There are nine sectors whose direct emission coefficients are above average (i.e. higher than 69 tons/mn TL) in 2018. Based on NACE Rev.2 classification, these nine sectors are, from the highest emission intensive to the lowest, manufacturing of other non-metallic minerals (C23), electricity, gas, etc. (D35), mining support service activities (B09), water supply, waste, etc. (E36_E39), mining, energy producing products (B05_B06), agriculture (A01_A02), manufacturing of chemicals (C20) and of basic metals (C24) and of machinery and equipment (C28). Emissions of these nine sectors represented 78% of total emissions in 2018. The emission burden is distributed to these nine sectors according to their emission shares in the 2018 total GHG emissions.

$$g' = h'\hat{x}^{-1} \tag{10}$$

$$k' = g'L = h'\hat{x}^{-1}L \tag{11}$$

where, g is row vector of sectoral direct emission coefficients, $\hat{x}^{-1}$ is inverse of total industrial output diagonal matrix, k is row vector of sectoral direct plus indirect emission coefficients (or simple emission multipliers), and L is Leontief inverse matrix or industry by industry total requirements matrix.

3.2.3. Policy option 3

The third policy option is that the emission reduction burden is distributed only to the top six emission intensive sectors in 2018. The top six emission intensive sectors are selected according to direct plus indirect emission coefficients (simple emission multiplier, k) (Table 5). This option with the top six most emission intensive sectors is selected because it is the least cost case among our alternative trials. These sectors are the first six sectors mentioned in option ii above. These six sectors represent 70% of total emissions in 2018. The emission burden is distributed to these six sectors according to their emission shares in 2018.

3.2.4. Policy option 4

According to the fourth policy option, the emission reduction burden is distributed to emission intensive sectors whose simple emission multipliers (direct plus indirect emission coefficients, k) are above average. There are eleven sectors whose simple emission multipliers are above average (i.e. higher than 170.6 tons/mn TL) in 2018. These sectors are, in addition to the nine sectors mentioned in option ii above, manufacturing of coke and refined petroleum products (C19) and of food, beverages and tobacco products (C10_12). These sectors represented 81% of total emissions in 2018. The emission burden is distributed to these eleven sectors according to their emission shares in 2018.

3.2.5. Policy option 5

The fifth policy option focuses on the top twelve most emission intensive sectors according to a simple emission multiplier (k). These sectors are the eleven sectors mentioned in option iv above, plus the construction sector (F41_43). The construction sector is included as a policy option because, it is considered to be a strategic sector in Türkiye. As an urban transformation process has been continuing for some time in Türkiye, the construction sector plays an important role in the economy and this seems to continue in the future as well. As mentioned in Kayacan's study (2020), construction is a leading sector with its backward linkages and its inducing impact on other sectors in Türkiye. Thus, it is an important sector politically and should be taken into account in the decision making process. In addition, the construction sector's emission multiplier is also high, right below the average (i.e. 160.6 tons/mn TL). These twelve sectors represent 82% of total emissions in 2018. The emission burden is distributed to these twelve sectors according to their emission shares in 2018.

3.3. Estimation of the Impact of Sectoral Emission Reductions on Output

The impact of emission reduction on sectoral output is estimated according to an input-output model. We used industry by industry input-output tables in the study. Total output is formulated as follows in matrix notation (Miller and Blair, 2009):

$$x = (I\text{-}A)^{-1} f = Lf \qquad (12)$$

where, x is column vector of total industrial output, I is identity matrix, A is matrix of technical coefficients each element of which means that how much commodity of industry i is needed to produce one unit of commodity of each industry j; f is total final demand vector, L is called as Leontief inverse or total requirements matrix. L can be read as how much of total output of each sector is needed to increase or decrease in order to satisfy an increase or decrease in the final demand. This change in total output contains change in the final demand as well as a change in primary inputs (or value added components).

I-O models are demand driven models and estimate the impact of changes in the final demand (an autonomous impact) on total output (x). Total output is composed of matrices of interindustrial transactions and final demand and/or interindustrial transactions and industry primary inputs. Any increase/decrease in the final demand for any commodity of any sector will result in some amount of increase/decrease in interindustrial output and some amount of increase/decrease in the primary inputs of production. Amount of increase/decrease in total industrial output (x) is based on the amount of final demand change (f) and the Leontief Matrix (L). This relationship is formulized in matrix notation in Equation 12 above.

Similarly, in our study, we tried to estimate the impact of an increase/decrease in industrial output in any sector/s (an autonomous impact) on total industrial output (x). An increase/decrease in industrial output in our model is autonomous because it occurred independently (i.e. based on an emission reduction policy, government imposes output reductions in any sector/s). This is an autonomous impact similar to the impact of a change in final demand on industrial output in standard input-output analysis.

For example, any increase in output of any sector requires more inputs of production like goods and services used in production, labor, capital, etc. More goods and services used in production means an increase in outputs of all relevant sectors as formulated in Leontief inverse (L).

On the contrary, as output decreases, say in sector 1, outputs of all relevant sectors which provide input to sector 1 decrease according to technical coefficients (A matrix). At an initial level, industrial outputs in all input providing sectors, including sector 1 (as input provider), will decrease as a result of an initial decrease in output of sector 1. This may be called first "round-by-round effect" as mentioned in Miller & Blair (2009, p.27). In the second round, industrial outputs further decrease according to decreased industrial outputs in the first round multiplied by relevant technical coefficients (A Matrix). These round-by-round effects continue forever in decreasing amounts that eventually become so small and negligible. The sum of these round-by-round effects including initial effects is equal to the total impact.

We checked this "round-by-round effects" for 17 rounds in our model. At the end of the process, an initial decrease in industrial output (x_0) in any sector results in a greater amount of total industrial output decreases (x), based on the Leontief inverse or total requirements matrix (L). Thus, in our view, Equation 12 can also be read as a change in total output as a result of change in output in any sector. Similar to the impact of a change in final demand, an autonomous change in industrial output will result in changes in total output.

In order to better formulize our model, we decomposed the effects on industrial output into two components: initial impact and induced effects. The impact on industrial output occurs *initially* only in those sectors where the government imposes GHG emission reductions. This can be called the "initial impact" or "initial effect". At the initial stage, emission reduction should be less than the total targeted amount. The reason is that, initial emission reduction and the resulting initial output decreases, will induce additional output and emission decreases through by Leontief multipliers (L). Total emission reductions will be the sum of emission reductions at the initial stage and at the "induced" stages. Thus, as the government does not want to exceed targeted emission reductions, it will reduce emissions at the initial stage less than the targeted total amount. Industrial output at the initial stage will decrease depending on emission reduction amounts and direct emission coefficients. This is what we called "initial industrial output reduction (or change)" (x_0):

$$x_0 = (I-A)\, \hat{G}^{-1}\, s \tag{13}$$

where, x_0 is vector of initial decreases (changes) in annual industrial output, I is identity matrix, A is technical coefficients matrix, $\hat{G}^{-1}$ is inverse of diagonal matrix of direct emission coefficients, s is vector of sectoral annual emission reduction burdens, s_0 is vector of initial emission reductions.

The induced impact on industrial output is triggered by the initial impact. The amount of induced effects on industrial output is the sum of round-by-round effects on industrial output after the first round. The sum of all the round-by-round effects including the initial impact can be called "total effects". Industrial output decreased as a result of initial reduction can be called total industrial output decrease (or change) (x) and contains initial reduction as well:

$$x = Lx_0 \tag{14}$$

where, x_0 is vector of initial decreases (changes) in annual industrial output, x is vector of total changes in annual industrial output, L is Leontief inverse matrix.
The estimation results are provided in Table 6 and Table 7.

3.4. Estimation of the Impact on GHG Emissions

The impacts on GHG emissions is estimated in two steps. Initial industrial GHG emission reduction (s_0) is estimated based on the estimated initial industrial output decrease and direct emission coefficients (Equation 15). This emission reduction is done autonomously by the government as a policy instrument to meet the Paris Agreement obligations. If the government imposes a GHG emission reduction at an amount of s_0, industrial output decreases at an amount of x_0 at initial level. As initial industrial output decreases at an amount of x_0, induced (or total) industrial output decreases at an amount of x. A decrease in total industrial output (x) results in a decrease in total GHG emissions at an amount of s which is exactly the amount needed by the Paris Agreement. The estimated initial reductions for each policy option are provided in Table 8 and Table 9.
Induced or total effects on emissions are estimated according to Equation 16. The magnitude of the impact is based on the magnitude of output reduced/changed and the direct emission coefficient of each sector. The higher the reduced amount of output and emission coefficient, the higher the total reduction in GHG emissions. Estimates of induced/total emission reductions are provided in Table 10 and Table 11.

$$s_0 = \hat{X}_0 g \tag{15}$$

$$s = \hat{X} g \tag{16}$$

where, s_0 is vector of initial emission reductions, $\hat{X}_0$ is diagonal matrix of initial decreases in annual industrial output, g is vector of direct emission coefficients, s is vector of sectoral annual emission reduction burdens, and $\hat{X}$ is a diagonal matrix of total annual industrial output decreases.

4. Findings

GHG emissions for the implementation period are estimated according to available figures and assumptions in the NDC. Taking into account realizations in 2018, 2019, and 2020, emissions in the remaining years have been updated assuming the same growth rates in emissions and the same emission reductions rates in the NDC. Finally, annual emissions are further reduced by an annual technological improvement rate of 2% as estimated in section 3.1 above. These updates result in 428, 338, and 171 million tons of less emissions compared to the NDC figures in 2030 in EXIT, BAU, and AER scenarios, respectively. This means 36.4%, 36.4%, and 25.5% less emissions compared to the NDC in 2030. Similarly, compared to the NDC, emission reductions are decreased by 90 and 257 million tons or 36.6% and 50.8% in 2030 in BAU and AER scenarios.

Table 3: Estimated GHG Emissions

CO_2e, Million tons	NDC Figures			Updated for Realizations			Updated for Technological Improvements		
	EXIT	BAU	AER	EXIT	BAU	AER	EXIT	BAU	AER
2018	**572**	**535**		**523**					
2019	623	566		**506**					
2020	**673**	**599**		**524**					
2021	730	636		568			557		
2022	786	677		612	527		588	506	
2023	**843**	**717**	676	656	558	526	618	525	505
2024	889	755	675	692	588	525	638	542	504
2025	**934**	**790**	674	727	615	524	657	556	503
2026	982	822	673	765	640	523	677	567	502
2027	1030	851	672	802	662	522	696	575	501
2028	1079	878	671	840	684	521	714	582	500
2029	1127	904	670	877	704	520	731	587	499
2030	**1175**	**929**	669	915	723	519	747	591	498
Total (2022-2030)	8845	7322	5377	6885	5700	4178	6067	5030	4011

Source: The bold figures in NDC EXIT and BAU scenario columns are obtained from the NDC document as BAU and Mitigation scenarios. Remaining figures are estimated.

Table 4: Estimated GHG Emission Reductions Compared to EXIT Scenario

CO_2e, Million tons	NDC Figures		Updated for Realizations		Updated for Technological Improvements	
	BAU	AER	BAU	AER	BAU	AER
2022	110		85		82	
2023	126	167	98	131	92	113
2024	133	214	104	167	96	134
2025	144	260	112	203	101	154
2026	160	310	125	242	111	175
2027	179	359	140	280	121	195
2028	201	408	156	319	133	214
2029	223	457	174	357	145	232
2030	246	506	191	396	156	249
Total	1523	2681	1185	2095	1037	1469

Table 5: Estimated GHG Emission Coefficients for 2018

NACE Rev.2 Labels	Direct Emission Coefficients	Direct plus Indirect Emission Coefficients (Simple Emission Multipliers)
	(CO2e ton/mn TL output)	
Crop and animal prod., hunting and related service activities Forestry and logging	166.6	285.4
Fishing and aquaculture	6.7	61.3
Mining and quarrying, energy producing products	186.5	299.7
Mining and quarrying, non-energy producing products	7.8	76.6
Mining support service activities	449.9	508.6
Manufacture of food products; beverages and tobacco products	19.9	175.9
Manufacture of textiles, wearing apparel, leather and related products	9.6	90.9
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	16.7	157.7
Man. of paper and paper products Printing and reproduction of recorded media	23.2	120.0
Manufacture of coke and refined petroleum products	65.3	268.3
Manufacture of chemicals and chemical products	106.8	213.4
Manufacture of basic pharmaceutical products and pharmaceutical preparations	13.3	97.2

Manufacture of rubber and plastic products	8.6	137.1
Manufacture of other non-metallic mineral products	614.8	856.1
Manufacture of basic metals	78.9	277.4
Manufacture of fabricated metal products, except machinery and equipment	13.6	133.5
Manufacture of computer, electronic and optical products	6.1	48.9
Manufacture of electrical equipment	7.5	144.6
Manufacture of machinery and equipment n.e.c.	76.6	193.2
Manufacture of motor vehicles, trailers and semi-trailers	4.7	105.3
Manufacture of other transport equipment	8.3	44.1
Man. of furniture, other man. repair and installation of machinery & equipment	5.8	96.8
Electricity, gas, steam and air conditioning supply	529.8	1335.2
Water supply; sewerage, waste management and remediation activities	251.1	393.9
Construction	8.3	160.6
Wholesale and retail trade; repair of motor vehicles and motorcycles	22.4	72.7
Land transport and transport via pipelines	53.7	131.3
Water transport	28.7	65.9
Air transport	66.9	127.8
Warehousing and support activities for transportation	9.7	37.4
Postal and courier activities	13.5	69.2
Accommodation and food service activities	18.5	98.0
Publishing activities; Motion picture, video, television programme production; programming and broadcasting activities	16.2	71.6
Telecommunications	2.6	60.0
Computer programming, consultancy, and information service activities	7.0	15.8
Financial and insurance activities	8.2	37.1
Real estate activities	7.4	108.1
Professional, scientific and technical activities	18.6	60.2
Administrative and support service activities	10.8	43.9
Public administration and defence; compulsory social security	23.6	84.0
Education	8.7	35.1
Human health and social work activities	8.1	68.4
Arts, entertainment and recreation	6.1	56.7
Other service activities	18.1	84.1
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	68.9	68.9
All NACE Activities	3104.2	7677.5
Average	69.0	170.6

Effects on industrial output is estimated according to Equation 13 and Equation 14 as explained in section 3.3. The effects on industrial (total) output are very significant and are increasing continuously. This is simply because emission reductions are increasing continuously in the same periods. The impact of the AER scenario on industrial output are greater than the BAU scenario in all policy options since emission reduction amounts are much higher in the AER scenario than in the BAU scenario.

The effects of policy options are increasing with the number of sectors included in implementation: the higher the number of sectors subject to emission reduction burden, the higher the impact on industrial output (Table 6 and Table 7). If policy options are sorted by their total cost from smallest to largest, order would be 3, 2, 4, 5, and 1. If they are sorted by number of targeted sectors again from smallest to largest, order would be the same (i.e. 3, 2, 4, 5, and 1). There is a political dilemma in this policy result: the smaller the number of targeted sectors means the less the total burden for the economy but, the less fair or unfair the distribution of burden among the sectors; the higher the number of targeted sectors means the higher the total burden for the economy but, the better or the fairer distribution of burden among the sectors. This result is consistent with the results of Lixon et al. paper (2018).

Table 6: Total Output Decrease (% of 2018 Total Output)

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 (all 45 sectors. emission share)									
BAU	17.6	19.8	20.6	21.7	23.7	26.0	28.5	31.0	33.6
AER	-	24.2	28.8	33.1	37.6	41.9	46.0	49.9	53.5
Option 2 (9 sectors with g > average)									
BAU	4.4	4.9	5.1	5.4	5.9	6.5	7.1	7.7	8.3
AER	-	6.0	7.1	8.2	9.3	10.4	11.4	12.4	13.3
Option 3 (top 6 k sectors)									
BAU	3.4	3.8	4.0	4.2	4.6	5.0	5.5	6.0	6.5
AER	-	4.7	5.5	6.4	7.2	8.1	8.9	9.6	10.3
Option 4 (11 sectors with k > average)									
BAU	5.7	6.4	6.6	7.0	7.6	8.4	9.2	10.0	10.8
AER	-	7.8	9.2	10.6	12.1	13.5	14.8	16.0	17.2
Option 5 (12 sectors. option 4 + construction sector)									
BAU	7.8	8.7	9.1	9.6	10.5	11.5	12.6	13.7	14.8
AER	-	10.7	12.7	14.6	16.6	18.5	20.3	22.0	23.6

Table 7: Total Output Decrease (mn TL)

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 (all 45 sectors, emission share)									
BAU	1,253,169	,410,643	,464,448	,548,322	,690,161	,853,247	2,029,376	2,210,943	2,390,915
AER	-	,723,203	2,048,937	,358,478	2,680,799	,986,821	,277,074	,552,072	,812,315
Option 2 (9 sectors with g > average)									
BAU	311,378	50,506	63,875	384,716	419,959	460,481	04,244	49,359	594,077
AER	-	28,169	09,105	586,017	666,105	742,143	14,263	82,593	947,256
Option 3 (top 6 k sectors)									
BAU	241,321	271,645	282,006	298,157	325,471	356,877	90,793	425,757	60,414
AER	-	31,834	394,560	454,168	516,237	575,167	31,060	84,016	734,131
Option 4 (11 sectors with k > average)									
BAU	02,644	53,240	70,528	497,476	543,050	595,449	52,039	710,377	68,202
AER	-	53,666	58,324	757,780	861,342	959,667	,052,925	1,141,282	1,224,899
Option 5 (12 sectors. option 4 + construction sector)									
BAU	553,518	23,073	646,839	83,885	746,535	818,569	96,364	976,561	1,056,054
AER	-	761,129	905,004	,041,726	1,184,094	1,319,262	,447,465	,568,930	,683,878

Emissions will be reduced in targeted sectors initially according to policy options. Emission reduction at this stage is less than total targeted amounts. The reason is that based on input-output relations and the Leontief multiplier (L), any emission reduction and resulting industrial output decrease will trigger other sectors' production to decrease. As such inter-industrial transactions spread to the whole economy, we will end up with higher amounts of industrial output decreases and, thus, resulting emission decreases. Thus, in order to end up with achieving a targeted reduction, a lesser amount of emission reduction should be imposed. In addition, as the number of targeted sectors increases, the percentage of initial emission reduction to total reduction decreases. At the initial stage, other sectors who are not targeted for emission reduction will either decrease or increase their emissions and output according to input-output relations and the Leontief multiplier. However *eventually*, targeted sectors will undertake most of the emission reduction burden targeted by the government. The estimated reduction rates shown in Table 8 , Table 9 , Table 10 , and Table 11 are the same for all years in 2022-2030 periods and the same for both emission reduction scenarios, BAU and AER.

Table 8: Estimated Initial Emission Reductions in Policy Option 1 in 2022-2030 Periods

NACE Rev.2 Code	NACE Rev.2 Labels	Emission Reductions (% of Total Reductions in Relevant Year)
A01_A02	Crop and animal production, hunting and related service activities; Forestry and logging	6.3
A03	Fishing and aquaculture	0.0
B05_B06	Mining and quarrying, energy producing products	-3.0
B07_B08	Mining and quarrying, non-energy producing products	0.0
B09	Mining support service activities	0.0
C10-C12	Manufacture of food products; beverages and tobacco products	1.1
C13-C15	Manufacture of textiles, wearing apparel, leather and related products	0.5
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.0
C17_C18	Manufacture of paper and paper products; Printing and reproduction of recorded media	0.0
C19	Manufacture of coke and refined petroleum products	-0.6
C20	Manufacture of chemicals and chemical products	-1.3
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.0
C22	Manufacture of rubber and plastic products	0.0
C23	Manufacture of other non-metallic mineral products	2.7
C24	Manufacture of basic metals	0.4
C25	Manufacture of fabricated metal products, except machinery and equipment	0.2
C26	Manufacture of computer, electronic and optical products	0.0
C27	Manufacture of electrical equipment	0.1
C28	Manufacture of machinery and equipment n.e.c.	0.8
C29	Manufacture of motor vehicles, trailers and semi-trailers	0.1
C30	Manufacture of other transport equipment	0.0
C31-C33	Manufacture of furniture; other manufacturing; Repair and installation of machinery and equipment	0.1
D35	Electricity, gas, steam and air conditioning supply	5.5
E36-E39	Water supply; sewerage, waste management and remediation activities	1.0
F41-F43	Construction	1.0
G45-G47	Wholesale and retail trade; repair of motor vehicles and motorcycles	1.7
H49	Land transport and transport via pipelines	2.5
H50	Water transport	0.1
H51	Air transport	0.7
H52	Warehousing and support activities for transportation	0.1

H53	Postal and courier activities	0.0
I55_I56	Accommodation and food service activities	0.7
J58-J60	Publishing activities; Motion picture, video. television programme production; programming and broadcasting activities	0.0
J61	Telecommunications	0.0
J62_J63	Computer programming, consultancy, and information service activities	0.0
K64-K66	Financial and insurance activities	0.1
L68	Real estate activities	0.5
M69-M75	Professional, scientific and technical activities	0.1
N77-N82	Administrative and support service activities	0.1
O84	Public administration and defense; compulsory social security	1.2
P85	Education	0.3
Q86-Q88	Human health and social work activities	0.3
R90-R93	Arts, entertainment and recreation	0.1
S94-S96	Other service activities	0.3
T97_T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	0.0
TOTAL (% of Relevant Years' Total Reduction)		23.4

Table 9: Estimated Initial Emission Reductions in Policy Options 2, 3, 4, and 5 in 2022-2030 Periods

NACE Rev.2 Code	NACE Rev.2 Labels	Emission Reductions (% of Total Reductions in Relevant Year)			
		Option 2 (9 sectors)	Option 3 (6 sectors)	Option 4 (11 sectors)	Option 5 (12 sectors)
A01_A02	Agriculture	15.5	17.2	9.4	9.2
B05_B06	Mining, energy producing products	-0.6	-0.5	-3.4	-3.4
B09	Mining support service activities	0.2	0.2	0.1	0.1
C10-C12	Manufacture of food, beverages and tobacco products			1.6	1.6
C19	Manufacture of coke and refined petroleum products			1.3	1.0
C20	Manufacture of chemicals	1.1		0.9	0.7
C23	Manufacture of other non-metallic minerals	17.5	19.7	16.6	7.4
C24	Manufacture of basic metals	3.6		3.4	2.1
C28	Manufacture of machinery and equipment	1.6		1.5	1.3
D35	Electricity, gas, steam and air conditioning supply	14.7	18.1	13.8	13.3
E36-E39	Water supply; sewerage, waste management and remediation	2.0	4.7	1.9	1.9
F41-F43	Construction				1.3
TOTAL (% of Relevant Years Total Reduction)		53.5	56.7	45.0	33.5

Table 10: Total Emission Reductions in Policy Option 1 in 2022-2030 Periods

NACE Rev.2 Code	NACE Rev.2 Labels	Emission Reductions (% of Total Reductions in (Table 4)
A01_A02	Crop and animal production, hunting and related service activities; Forestry and logging	16.3
A03	Fishing and aquaculture	0.0
B05_B06	Mining and quarrying, energy producing products	0.9
B07_B08	Mining and quarrying, non-energy producing products	0.1
B09	Mining support service activities	0.2
C10-C12	Manufacture of food products; beverages and tobacco products	1.6
C13-C15	Manufacture of textiles, wearing apparel, leather and related products	0.7
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.1
C17_C18	Manufacture of paper and paper products; Printing and reproduction of recorded media	0.3
C19	Manufacture of coke and refined petroleum products	1.5
C20	Manufacture of chemicals and chemical products	2.3
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.1
C22	Manufacture of rubber and plastic products	0.2
C23	Manufacture of other non-metallic mineral products	16.1
C24	Manufacture of basic metals	3.9
C25	Manufacture of fabricated metal products, except machinery and equipment	0.3
C26	Manufacture of computer, electronic and optical products	0.0
C27	Manufacture of electrical equipment	0.2
C28	Manufacture of machinery and equipment n.e.c.	1.4
C29	Manufacture of motor vehicles, trailers and semi-trailers	0.1
C30	Manufacture of other transport equipment	0.0
C31-C33	Manufacture of furniture; other manufacturing; Repair and installation of machinery and equipment	0.2
D35	Electricity, gas, steam and air conditioning supply	32.9
E36-E39	Water supply; sewerage, waste management and remediation activities	3.8
F41-F43	Construction	1.3
G45-G47	Wholesale and retail trade; repair of motor vehicles and motorcycles	3.4
H49	Land transport and transport via pipelines	5.4
H50	Water transport	0.2
H51	Air transport	0.8
H52	Warehousing and support activities for transportation	0.2

H53	Postal and courier activities	0.1
I55_I56	Accommodation and food service activities	0.8
J58-J60	Publishing activities; Motion picture, video, television programme production; programming and broadcasting activities	0.1
J61	Telecommunications	0.0
J62_J63	Computer programming, consultancy, and information service activities	0.1
K64-K66	Financial and insurance activities	0.3
L68	Real estate activities	0.6
M69-M75	Professional, scientific and technical activities	0.6
N77-N82	Administrative and support service activities	0.4
O84	Public administration and defence; compulsory social security	1.4
P85	Education	0.3
Q86-Q88	Human health and social work activities	0.3
R90-R93	Arts, entertainment and recreation	0.1
S94-S96	Other service activities	0.3
T97_T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	0.0
TOTAL		100.0

Table 11: Total Emission Reductions in Policy Options 2, 3, 4, and 5 in 2022-2030 Periods

NACE Rev.2 Code	NACE Rev.2 Labels	Emissions (% of 2018 Total Emissions)	Emission Reductions (% of Total Reductions in Table 4)			
			Option 2 (9 sectors)	Option 3 (6 sectors)	Option 4 (11 sectors)	Option 5 (12 sectors)
A01_A02	Agriculture	16.3	20.9	23.2	20.2	19.8
B05_B06	Mining, energy producing products	0.9	1.2	1.3	1.2	1.1
B09	Mining support service activities	0.2	0.3	0.3	0.3	0.3
C10-C12	Manufacture of food, beverages and tobacco products	1.6			1.9	1.9
C19	Manufacture of coke and refined petroleum products	1.5			1.8	1.8
C20	Manufacture of chemicals	2.3	2.9		2.8	2.8

C23	Manufacture of other non-metallic minerals	16.1	20.7	22.9	19.9	19.6
C24	Manufacture of basic metals	3.9	5.0		4.8	4.7
C28	Manufacture of machinery and equipment	1.4	1.8		1.7	1.7
D35	Electricity, gas, steam and air conditioning supply	32.9	42.3	46.9	40.7	40.1
E36-E39	Water supply; sewerage, waste management and remediation	3.8	4.9	5.4	4.7	4.6
F41-F43	Construction	1.3				1.6
TOTAL		82.2	100.0	100.0	100.0	100.0
Total Shares in 2018 Emissions		82.2	77.8	70.3	80.9	82.2

5. Conclusion

The economic impact of the Paris Agreement and emission reductions on sectoral output in Türkiye is analyzed in this paper based on input-output modelling. The 45 sector 2018 input-output data provided by the OECD is used to analyze the impact on industrial output. Based on the available data and assumptions in the NDC. GHG emissions in the 2022-2030 period are estimated for different scenarios. Then, sectoral emission reductions are estimated according to the five policy options proposed. Based on sectoral emission reductions, changes in sectoral output are estimated.

The impact of emission reductions on output is significant, from 3.4% to 53.5% depending on scenarios and policy option choice. The absolute emission reduction (AER) scenario which requires Türkiye to reduce higher emissions like a developed country results in a higher cost to the economy then the business-as-usual (BAU) scenario. Regarding the 5 policy options, options with more targeted sectors are much costly than less targeted ones. Output losses are justifiable taking into account annual emission reductions.

Regarding policy instrument choice to reduce initial emissions, there are mainly two approaches government may follow: either using market based instruments or command-and-control type instruments. Market based instruments include carbon taxes, emission trading systems, incentive measures, etc. Command-and-control instruments basically enforce emission reductions or fix emission limits (emission quotas). Details and analysis of these instruments and their effectiveness are beyond the scope of this study. A report on "Assessment of Market Based Climate Change Policy Options for Türkiye" (Turkish Ministry of Environment, Urbanization and Climate Change, 2018) provides such an analysis in detail. We assessed briefly some of these instruments and their effectiveness in achieving emission reduction targets as follows:

a. Imposing emission reductions: The government may choose to reduce the emissions of targeted sectors through regulations on clean technology usage and/or output reductions, etc. This approach is very effective regarding implementation and achieving targets. As this instrument is very straight forward and what is done is transparent to the public, it may not be preferable for politicians.

b. Carbon tax: a tax on carbon is imposed by the government for targeted sectors. Carbon tax may be imposed on production and/or inputs of production. In the case of inputs of production being carbon taxed, other sectors using the same input may be affected. Thus, imposing the tax on production is more efficient in achieving targets. The efficiency of carbon tax depends on whether the tax rate is appropriate and/or tax is discouraging enough for all targeted industries or companies. Depending on supply and demand conditions, etc., some targeted industries or companies may continue to produce the same amount of output. This may reduce efficiency in achieving emission targets. Thus, the efficiency of carbon tax in achieving emission targets is limited.

c. Emission trading system (ETS): Government fixes emission upper limits (threshold) for companies in all or selected industries. Companies with low emissions will be provided "emission certificates" at an amount up to the threshold. Those companies with high emissions should purchase a sufficient amount of "emission certificates" from the market to compensate for their emissions in excess of the threshold. Emission certificates traded in the market basically represent an extra cost for carbon emissions, and, thus, discourage high emitters if the price is appropriate. Similar to carbon tax, its efficiency in achieving emission reduction targets depends on a well-functioning trading market, linkage to international markets, appropriate certificate price, etc. An ETS market is not established and functioning in Türkiye yet. An ETS does not seem to be an instrument choice for Türkiye for the time being.

d. Incentive measures: Reducing emissions may be supported by soft credits or tax incentives or by other means by the government. The government may support investment in energy efficiency, and the replacement of existing technologies with clean/green technologies, etc. The major problem is that the outcome of such incentives is not easy to predict and may take some time. Plus, providing incentives only to targeted sectors may not be politically correct. Thus, the efficiency in achieving targets is limited. On the contrary, providing incentives may be plausible for politicians.

In our view, instead of reducing industrial output, investments in green/clean technologies in targeted sectors can be supported by the government. In this way, the same amount of industrial output will be produced and GHG emissions will be reduced. The problem here is that this process and its outcome (i.e. emission reduction) will take some time. In addition, green/clean technologies produced domestically should be supported specifically because the transformation of some industries into green/clean technologies will be a large-scale business and sizeable deal across the economy and thus, adverse effects on the current situation should be avoided. Policies which have considerable implications on the current situation cannot be long-lasting and affordable in Türkiye.

Alternatively, a hybrid model for emission reduction may be followed; some sectors may be supported for green/clean technologies to produce the same output level at lower emissions and other sectors may be asked to reduce emissions however much they can afford. Sectoral choice may depend on the availability of budgetary sources, sectoral priorities, the importance of sectors with regard to industrial output losses, relevance of sectors with regard to emission reduction, etc.

It is also our view that the proceeds of carbon taxes may be channeled into green investments. However, such revenues earmarked for special expenses received some question marks regarding their efficiency in Türkiye in the past. Among others, difficulty in estimating tax proceeds and expenses for budgetary purposes, a timing mismatch between proceeds and expenses in the budgetary period can be recalled. Thus, if decided, resources for supporting green investments may be allocated separately.

Regarding emission reduction responsibility, taking into account that Türkiye is a developing country and has a very low historical responsibility on the global GHG emissions (i.e. 0.7%), annual emission reductions should be justifiable and comparable to her historical responsibility. Türkiye declared an emission reduction of up to 21% from no-reduction scenario level by 2030. As economic effects are much higher in the upper-ends (i.e. 21%), rather moderate reductions (like 15%) may be considered. This would still be in line with the NDC.

In case absolute emission reduction is required, Türkiye would probably prefer to exit the Agreement. Such a decision would be in parallel with the reservations Türkiye declared in ratification of the Agreement.

In the case of an EXIT scenario, there will be no emission reductions and, thus, these effects on industrial output and GDP are not expected. However, there may be costs like limitations on trade and finance imposed on those countries who are not party to the Agreement. Non-party countries may be subject to tariffs and or quotas for their export goods in near future. International finance facilities are already demanding the observance of environment and climate change rules. Access of non-party countries to international public finance is especially subject to international rules and obligations stemming from the Paris Agreement. Thus, exiting the Agreement may have economic effects on the Turkish economy as well. This requires further analysis and is beyond the scope of this study.

Ethics Committee Approval: The article uses exclusively publicly available data and conducts analysis based on these data. It is not a study that could cause harm to nature, living beings, or any other way. Therefore, there is no need for Ethical Committee Approval.
Peer-review: Externally peer-reviewed.
Author Contributions: Conception/Design of Study- M.B., B.K.; Data Acquisition- M.B.; Data Analysis/Interpretation- M.B., B.K.; Drafting Manuscript- M.B.; Critical Revision of Manuscript- B.K.; Final Approval and Accountability- M.B., B.K.
Conflict of Interest: The authors have no conflict of interest to declare.
Grant Support: The authors declared that this study has received no financial support.

References

Altieri, K. E., Trollip, H., Caeano, T., Hughes, A., Merven, B., & Winkler, H. (2016). Achieving Development and Mitigation Objectives through a Decarbonisation Development Pathway in South Africa. *Climate Policy*, 16/1, S78-S91. https://doi.org/10.1080/14693062.2016.1150250

Babatunde, K.A., Begum, R.A., & Saida, F.F. (2017). Application of Computable General Equilibrium (CGE) to Climate Change Mitigation Policy: A systematic review. *Renewable and Sustainable Energy Reviews*, 2017/78, 61-71. https://doi.org/10.1016/j.rser.2017.04.064

Blitzer, C.R., Eckaus, R.S., Lahiri, S., & Meeraus, A. (1990). The General Equilibrium Analysis of the Effects of Carbon Emission Restrictions on Economic Growth in a Developing Country. *MIT Working Papers*, 558. Retrieved from http://hdl.handle.net/1721.1/63674

Bouzaher, A., Sahin, S., & Yeldan, E. (2014). How to go Green: A General Equilibrium Investigation of Environmental Policies for Sustained Growth with an Application to Turkey's Economy. *Lett SputResourSci*, 2015/8, 49-76. http://dx.doi.org/10.1007/s12076-014-0124-0

Dejuan, O., Lenzen, M., & Cadarso, M.A. (Eds.) (2018). *Environmental and Economic Impacts of Decarbonisation: Input – Output Studies on the Consequences of the 2015 Paris Agreement*. New York, NY: Routledge Explorations in Environmental Economics, 50.

EUROSTAT. (2021, December 17). *Air Emissions Accounts by NACE Rev. 2 Activity*. Retrieved from https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_ainah_r2&lang=en

Jorgenson, D. & Wilcoxen, P. (1989). Environmental Regulation and the US Economic Growth. *The RAND Journal of Economics*, 21/2, 314-340. https://doi.org/10.2307/2555426

Kayacan, B. (2020). *Türkiye Ekonomisinin Sektörler Arası Girdi-Çıktı Analizi* (2nd ed.) [Interindustry input-output analysis in Turkish economy]. İstanbul, Türkiye: Yalın Yayıncılık.

Kolsuz, G. & Yeldan, A.E. (2017). Economics of Climate Change and Green Employment: A General Equilibrium Investigation for Turkey. *Renewable and Sustainable Energy Review*, 2017/70, 1240-1250. http://dx.doi.org/10.1016/j.rser.2016.12.025

Kratena, K. & Schleicher, S. (1999). The Impact of CO_2 Reduction on the Austrian Economy. *Journal of Economic Systems Research*, 1999/11(3), 245-261. https://doi.org/10.1080/0953531 9900000017

la Rovere, E.L., Wills, W., Grottera, C., Dubeuxc, B.S., & Gesteira, C. (2018). Economic and Social Implications of Low-Emission Development Pathways in Brazil. *Journal of Carbon Management*, 9/5, 563-574. https://doi.org/10.1080/17583004.2018.1507413

Lixon, B., Thomassin, P.J., & Hamaide, B. (2008). Industrial Output Restriction and the Kyoto Protocol: An Input–Output Approach with Application to Canada. *Elsevier Ecological Economics*, 68, 249-258. https://doi.org/10.1016/j.ecolecon.2008.03.001

Marcucci, A. & Zhang, L. (2019). Growth Impacts of Swiss Steering-Based Climate Policies. *Swiss Journal of Economics and Statistics*, 155/9. https://doi.org/10.1186/s41937-019-0043-5

Miller, R.E. & Blair P.D. (2009). *Input – Output Analysis: Foundations and Extensions.* Cambridge: Cambridge University Press.

OECD. (2021a, November 19). *Input-Output Database, IOTs 2021: Input-Output Tables.* Retrieved from https://stats.oecd.org/Index.aspx?DataSetCode=IOTS

OECD. (2021b, December 24). *Gross Domestic Product (GDP).* Retrieved from https://stats.oecd.org/

Telli, C., Voyvoda, E., & Yeldan, E. (2007). Economics of Environmental Policy in Türkiye: A General Equilibrium Investigation of the Economic Evaluation of Sectoral Emission Reduction Policies for Climate Change. *ScienceDirect Journal of Policy Modeling*, 2008/30, 321-340. https://doi.org/10.1016/j.jpolmod.2007.03.001

Turkish Ministry of Environment, Urbanization and Climate Change. (2018). Modelling Fiscal, Economic and Sectoral Impacts of Carbon Pricing in Turkey Final Report. *Vivideconomics***.**

Turkish Ministry of Environment, Urbanization and Climate Change. (2021, December 19). *Türkiye. 2021 Common Reporting Format (CRF) Table.* Retrieved from https://unfccc.int/documents/271541

UNFCCC. (2022a, November 19). Paris Agreement-Status of Ratification. Retrieved from https://unfccc.int/process/the-paris-agreement/status-of-ratification

UNFCCC. (2022b, November 19). *Republic of Türkiye: Intended Nationally Determined Contribution.* Retrieved from https://unfccc.int/sites/default/files/NDC/2022-06/The_INDC_of_TURKEY_v.15.19.30.pdf