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INVESTIGATING THE EFFECTS OF ENVIRONMENTAL AND ENERGY POLICIES IN TURKEY USING AN ENERGY DISAGGREGATED CGE MODEL

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Abstract

This article investigates environmental and energy policies that Turkey needs to adopt on its way to a sustainable development path. A multi-sectoral CGE model is developed to analyze the effects of several environmental and energy policy scenarios available for the Turkish economy to attain a low-carbon society with a reduced reliance on fossil fuel imports. Domestic energy demand has significantly increased in Turkey over the past decades, and this has put a lot of pressure on policymakers as the economy greatly depends on imports of natural gas and oil as far as current energy consumption is concerned.

The CGE model used in this study is based on an energy-disaggregated Social Accounting Matrix (SAM), constructed in previous work by the authors. The energy-disaggregated SAM serves as the benchmark database and the high disaggregation of the energy commodities and the electricity sector to include 8 different types of power generating sectors (5 of which are renewable energy sources) enables electric power substitution in the model. The energy-disaggregated SAM is further linked with satellite accounts which include data on derived energy demand and greenhouse gas (GHG) emissions.

The macroeconomic and environmental impacts of three distinct sets of scenarios are analyzed with respect to the baseline scenario. The first scenario simulates a 30% increase in energy efficiency in the production sectors and the residential sector and evidence is found for reaching the 21% GHG mitigation target set in Turkey's pledge for Paris Agreement compliance by 2030. The second set of scenarios is the inclusion of a medium and high-level carbon tax rates for coal, oil and natural gas. The carbon tax scenarios produce significant effects on both emission reduction targets and substituting fossil fuel technologies with cleaner energy technologies. The third scenario estimates the effects of changes in world prices of energy on the Turkish economy. A 20% increase in world energy prices, i.e. oil, natural gas, and coal, induces substantial changes in the breakdown of TPES and the power-generating sector and puts a lot of pressure on the current account deficit of the country. A carbon tax policy proves to be the most viable scenario which leads to reduced energy intensities in all sectors, a 21% GHG emissions abatement, and a transformation of the energy sector towards having a low-carbon content along with a reduced reliance on fossil fuel imports.

Keywords: Computable general equilibrium (CGE) models; Social Accounting Matrices (SAM); Turkey; Energy and environmental policies; Carbon tax.
JEL Classifications: D58, E16, Q40, Q50, F41.

ملخص

تبحث هذه الورقة في سياسات البيئة والطاقة التي تحتاج تركيا إلى تبنيها في طريقها إلى مسار التنمية المستدامة. وقد تم تطوير نموذج للتوازن العام المحوسب (CGE) متعدد القطاعات لتحليل آثار العديد من سيناريوهات السياسات البيئية وسياسات الطاقة المتاحة للاقتصاد التركي لتحقيق مجتمع منخفض الكربون مع تقليل الاعتماد على واردات الوقود الأحفوري. وقد ازداد الطلب المحلي على الطاقة بشكل كبير في تركيا على مدى العقود الماضية، ووضع هذا الكثير من الضغط على صانعي السياسات حيث يعتمد الاقتصاد بشكل كبير على واردات الغاز الطبيعي والنفط فيما يتعلق باستهلاك الطاقة الحالي.

يعتمد نموذج التوازن العام المحوسب (CGE) المستخدم في هذه الدراسة على مصفوفة المحاسبة الاجتماعية المصنفة بالطاقة (SAM)، والتي قام المؤلفون بإنشائها في عمل سابق. وتشكل هذه المصفوفة المصنفة بحسب الطاقة قاعدة بيانات مرجعية، كما أن التصنيف العالي لسلع الطاقة وقطاع الكهرباء يشمل 8 أنواع مختلفة من قطاعات توليد الطاقة (5 منها مصادر للطاقة المتجددة) يتيح استبدال الطاقة الكهربائية في النموذج. وترتبط هذه القائمة المصنفة بحسب نوع الطاقة أيضا بالحسابات الفرعية التي تشمل بيانات عن الطلب المشتق على الطاقة وانبعاثات غازات الدفيئة.

يتم تحليل الآثار الاقتصادية الكلية والبيئية لمجموعات ثلاث متميزة من السيناريوهات فيما يتعلق بسيناريو خط الأساس. يحاكي السيناريو الأول زيادة بنسبة 30٪ في كفاءة الطاقة في قطاعات الإنتاج والقطاع السكني، وتم العثور على أدلة تفيد الوصول إلى هدف التخفيف من غازات الدفيئة بنسبة 21٪ المحدد في تعهد تركيا بالامتثال لاتفاقية باريس بحلول عام 2030. المجموعة الثانية من السيناريوهات هي إدراج معدلات ضريبة الكربون متوسطة وعالية المستوى للفحم والنفط والغاز الطبيعي. وتؤثر سيناريوهات ضريبة الكربون تأثيرات كبيرة على كل من أهداف خفض الانبعاثات واستبدال تكنولوجيات الوقود الأحفوري بتكنولوجيات الطاقة الأنظف. السيناريو الثالث يقدر آثار التغيرات في الأسعار العالمية للطاقة على الاقتصاد التركي. وتؤدي الزيادة بنسبة 20٪ في أسعار الطاقة العالمية، أي النفط والغاز الطبيعي والفحم، إلى تغييرات كبيرة في انهيار قطاع والكهرباء وقطاع توليد الطاقة في تركيا وتضع الكثير من الضغط على عجز الحساب الجاري للبلاد. تثبت سياسة ضريبة الكربون أنها السيناريو الأكثر قابلية للتطبيق والذي يؤدي إلى انخفاض كثافة الطاقة في جميع القطاعات، وخفض انبعاثات غازات الدفيئة بنسبة 21٪، وتحويل قطاع الطاقة نحو الحصول على محتوى منخفض الكربون إلى جانب تقليل الاعتماد على واردات الوقود الأحفوري.

1. Introduction

Turkey greatly depends on imports of natural gas and oil. Over the past two decades, the Turkish economy has grown at a rate of 5% on average and has thus driven energy demand and investments in the energy market. Consumption of energy in Turkey has been growing rapidly and is expected to roughly double by 2025 with respect to 2010. The different types of energy use by main economic sectors are summarized in Table 1.1. Energy-intensive industries and transportation sectors, followed by residential use, are the main sectors using up a big portion of fossil fuels. Turkey is an important emerging economy with a big potential and has a major influence in its region due its geopolitical position being in the crossroads of Middle East, North Africa and Europe. A sustainable economic and social development in Turkey would not only lead to an enhancement in the living standards of Turkish people but would also contribute to the region. Exploring and applying the right policy choices of economy-energy-environment would lead Turkey towards a sustainable, low-carbon path.

Table 1.1: Energy use by main economic sectors (2016, ktoe)

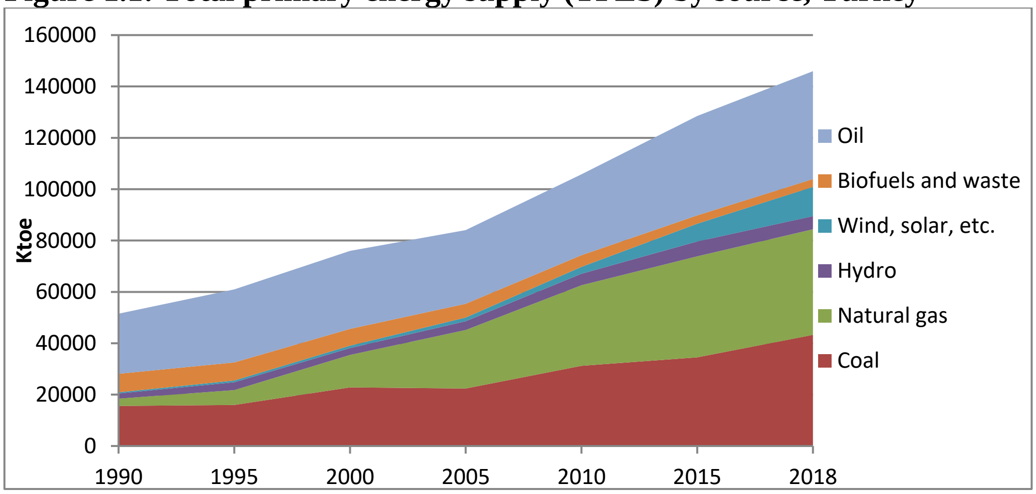
Main economic activities	All products	Solid fuels	Crude oil &petroleum	Gas	Renewable energies	Electricity
Energy-intensive industry*	20,335	7,711	343	7,192	-	5,089
Nonenergy-intensive industry**	7,794	756	497	2,270	288	3,983
Transportation	30,533	-	29,971	326	136	99
Commercial and public services	12,417	3,705	680	2,551	-	5,481
Residential	20,711	2,053	250	9,567	4,438	4,403
Agriculture/Forestry	3,686	-	2,477	56	580	574
Primary production	35,629	15,498	2,645	302	17,135	19,639***

Source: Energy Balance Sheets, 2018 Edition, Statistical Books, Eurostat.
Note: *Energy-intensive industry includes iron and steel, chemical and petrochecmical, non-metallic minerals, food, beverages and tobacco, paper, pulp and printing and wood products.
**Nonenergy-intensive industry includes transport equipment, machinery, mining and quarrying, construction, textile and leather, and not elsewhere specified in industry.
***Electricity available for final consumption is taken as transformation output from conventional thermal power stations added to exchanges, transfers and returns.

Affordable energy is a key in increasing the living standards of people residing in Turkey. To experience sustainable economic growth in the near future, large investments need to take place in energy infrastructure, especially in electricity and natural gas (IEA, 2016). Even though Turkey has shown a threefold increase in installed capacity in the past 15 years, the power generating

capacity needs to be further diversified, especially by enhancing the capacity of renewable energies such as hydro, wind, solar and geothermal energies.
Figure 1.1 shows the total primary energy supply (TPES) in Turkey is dominated by fossil fuels. Considering that Turkey imports all the oil and gas and a part of the coal it uses, importing energy has proven to be very costly for Turkey. Coupled with unpredictable energy prices, Turkey needs to take decisive action in implementing a sustainable energy policy. This requires diversifying the imports of energy from suppliers and intensifying different types of energy production technologies in the country.

Figure 1.1: Total primary energy supply (TPES) by source, Turkey



Source: IEA World Energy Balances 2019 https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics.

The motivation behind this work is to construct an economic model to portray the economy-energy-environment link in Turkey and to assess the potential policy scenarios pertaining to energy and environmental issues. For this purpose, we develop a detailed energy-focused multi-sector computable general equilibrium, hereafter called TurkMod.

The model entails a high degree of disaggregation in the production sectors and specific features with respect to the energy structure and policy-oriented instruments are included. The CGE model in this study is developed using sector-specific production technologies endogenously, retrieving intermediate consumption and demand for capital and labor from the price mechanism. In the electricity sector, the choice of production factors is based on the explicit modeling of technologies where 8 different sources of power generation are utilized.

An enhanced treatment of demand and supply for energy, differentiated by source, is another important characteristic of a CGE model. Given that the response of the economy to energy policies cannot be analysed by examining its parts separately, partial equilibrium models are not sufficient in investigating the behaviour of different actors and sectors of the economy simultaneously. Analysing the different types of multiplier effects of changes in energy policies necessitates a general equilibrium approach. Thus, CGE models that can incorporate energy substitution mechanisms appear as one of the few approaches which meet all the required methodological criteria for analysing energy policies. CGE models present themselves as comparatively advantageous with respect to other models as there is an ability to explicitly acquire relationships between the various sectors of production, to link different levels of analysis (i.e., micro, meso and macro), and to evaluate the overall and disaggregated impacts of changes in policies imposed as exogenous shocks.

The remainder of the paper is organized as follows. Section 2 discusses several background studies providing a theoretical and an empirical framework for the analysis, Section 3 explains the methodology and data in a bit more detail and Section 4 refers to the various policy scenario analyses conducted and presents results. Some concluding remarks and policy recommendations are offered in Section 5.

2. Review of studies for Turkey

CGE models have proven to be very useful for policy-making purposes as they provide consistent frameworks to assess the linkages and trade-offs between different policy-scenarios. The influence of CGE modeling has been powerful in a wide range of issues for a very long time, including structural adjustment policies, international trade, public finance, agriculture, and more recently energy and environmental policies. Wickens (2012) argues that dynamic general equilibrium (DGE) macroeconomics presents itself as a recent stage in the evolution of macroeconomics since the work of Keynes in the 1930s. DGE macroeconomics is regarded as an important attempt to integrate macroeconomics with microeconomics by presenting micro-foundations for macroeconomic work. Especially in developing and emerging economies, robust models which guide sound policies have become a crucial development tool. In this respect, Turkey, being an emerging economy that undoubtedly faces significant economic and financial sustainability challenges, needs to have powerful modeling tools to make the best decisions. A multi-sectoral, energy-disaggregated computable general equilibrium (CGE) model aimed at environmental and energy policies will be a tool that policymakers both at the public and the private sectors can benefit from.

The literature on CGE model applications on energy and environmental policy is vast. Notable examples are the EPPA model (Paltsev, et al, 2005), GEM-E3 model (Capros et al, 2013), GTAP-E model (Peters, 2016), an inter-regional CGE application to China (Tang and Wu, 2016) and a recent study on the Spanish electricity system (Langarita, et al, 2019). A considerable number of studies have also investigated the energy-economy-environment link in Turkey using a CGE framework. There are also some CGE studies which have investigated carbon taxes for Turkey in the recent years (Aydin, 2018, Kolsuz&Yeldan, 2017). One of the first CGE studies looking into the environment-economy interrelationship in Turkey is the study by Boratav, Turel and Yeldan (1996). They use a discrete-dynamic CGE model and statistics from the OECD and investigate the GHG emissions and pollution caused by energy consumption of the industrial sector. The standard specifications of a CGE model is applied where the model reaches equilibrium with market-clearing conditions applied in the product markets, labor market and the current account balance. Three simulation experiments are conducted to study the effects of energy-environment policies. A which are a parametric increase of the production tax rate in energy by 100%, a carbon emission ceiling in industry together with a direct tax on CO2 emissions, and a shift in the market specification. Boratav, et al (1996) concluded that environmental targets will not be achieved if Turkey moves away from the competitive market structure dynamics. This led them to suggest that the government of Turkey needs to play an important role in guiding the economy-environment link in the coming periods.

Another study investigating the energy-environment-economy link in Turkey was carried out by Kumbaroglu (2003) where a dynamic CGE model was constructed on a 1991 baseline data including seven production sectors. This study explores economic effects of environmental taxation using an energy–economy–environment CGE model of the Turkish economy. The main results from the scenarios suggest emphasizing emission taxation as a viable policy instrument to achieve environmental targets, using more oil and gas in the power generation mix instead of hard coal and lignite, and reducing energy imports to foster economic development. The study concludes by arguing that not complying with the policy recommendations mentioned in the study would pose an economic burden of approximately 6% of GDP.

Ercan, Telli, and Voyvoda (2005) constructed a multi-sector, static CGE model for Turkey to explore the energy-related developments in Turkey over the 2003-2008 period. The CGE model is based on the 1996 input-output table of the Turkish economy published by TurkStat, which uses seven sectors in the input-output core of the Turkish economy. The model is calibrated to 2003 base-year data by utilizing a multi-sectoral SAM of the Turkish economy. Even though the model is static, the period 2003-2008 is scanned under a pseudo-dynamic structure with exogenously provided growth rates of the labor supply and factor productivity, under the assumption of constant coefficients for sectoral allocation of investments. Their simulation results suggest that an increase in the world price of energy leads to a deterioration in the growth performance of the Turkish economy (with an average value of 1.96 percentage points lower with respect to benchmark for 2006-2008). Increase in world energy prices doesn't change the trade balance much, even though both the import bill and the export revenues increase, because of weighty dependence on energy imports, and relatively lower domestic prices, respectively.

Telli, Voyvoda, and Yeldan (2008) collaborated in 2008 and studied the effects of sectoral emission reduction policies for climate change in Turkey. The model used in this study is a dynamic, multi-sectoral CGE model used to analyse environmental and macroeconomic policy issues over the period 2006-2020. The model is calibrated using 2006 as the baseline year and the socio-economic impacts of various policy scenarios are investigated thereof. Many different policy scenarios are tried out such as direct quota on carbon emissions, taxing energy input use, and environmental policy instruments with abatement investment. The results suggest that necessary abatement investments reaching 1.5% of GDP per year would require a 23% tax rate on the usage of energy products. Output levels and unemployment rates are also adversely impacted by this scenario of indirect taxes on production.

Aydin and Acar (2010) study the economic and environmental implications of Turkish accession to the European Union. As an EU candidate country, Turkey is now in a position to adopt a similar climate change policy as the EU. The authors use the readily available GTAP model and modify it to make it consistent with factor mobility. The first scenario looks at the labor mobility between Turkey and the EU. The results of the first scenario indicate that roughly 200,000 unskilled and 20,000 skilled workers are likely to migrate from Turkey to the EU. This result is based on the assumption that only the real wage rate is changing. In the second scenario, capital is regarded as mobile across regions, and due to the fact that the EU is relatively capital abundant, and Turkey is relatively labor abundant, a transfer of production factors would be realized. The second scenario indicates that the EU's position would deteriorate from these factor movements with real GDP decreasing by about 3.18% and the total net factor income decreasing by 2.32%. This study concludes that provided that the EU and Turkey apply the EU's emissions strategy, Turkey would be in a more advantageous position with respect to factor mobility and cost of carbon emissions.

Akkemik and Oguz (2011) examine the potential impacts of full liberalization in the electricity market using a static CGE model for Turkey for the first time. The data used in the study is a balanced SAM prepared by using the 2002 Input-Output table of Turkey and a disaggregated data set of the electricity sector. The study carries out a counter-factual simulation where the regulation in the energy sector is removed. Full liberalization is found to create efficiency gains in the electricity market, decrease in energy prices for households, and an improvement in utility level of the consumers. As electricity prices decrease, this affects the electricity generation and transmission sectors negatively and those industries that are dependent on electricity positively. Consequently, results show that there are potential efficiency and welfare gains from full liberalization of the electricity sector.

Olcum and Yeldan (2013) investigated the post-Kyoto period for Turkey using an applied general equilibrium model of commodity and permit trading. The model has a multi-region, multi-sector arrangement based on the GTAP 7 data set. The establishment of national emissions trading system along with the EU ETS (Emissions Trading System) was a policy emphasized by the Turkish officials in the beginnings of 2010. The scenarios in the study were built under the EU 20-20-20 emission target and the impacts of these policies on Turkish economy were investigated. The results of this study suggest that under domestic abatement policies, Turkey would induce welfare losses. The results also show that when Turkey decides whether to participate or not in the EU ETS, the EU's total emission target needs to be considered as well. Under international cooperation through an EU ETS, Turkey would benefit from increased overall economic gains.

The most recent CGE application on the Turkish energy sector[3] is a study by Kat, Paltsev and Yuan (2018) where Turkey's pledge at the 2015 Paris Agreement to cut down GHG emissions by 21% in 2030 poses as the baseline scenario. They develop a CGE model for the Turkish economy with a macroeconomic representation of non-electric sectors and a detailed power sector disaggregation. As for the emission trading schemes, several scenarios are investigated, including a nuclear scenario and a renewable subsidy scheme. Their model is a recursive-dynamic model built on the GTAP Power Data Base with a benchmark year of 2011. GTAP Power data base is an electricity-detailed extension of the GTAP 9 data base which includes 140 regions globally. The model is simulated from 2015 to 2030 using five year intervals. Two backstop technologies are defined in this study and these are nuclear power and solar power. Even though these two power technologies are almost non-existent in Turkey, they pose an important potential and there are on-going investment plans in these power technologies. The scenarios in this study assume economy-wide policies where all fuels and sectors are covered which would lower the overall costs of the policy.

In the business-as-usual (BAU) scenario, natural gas share would decrease from 46% to 23% in 2030. A reduced natural gas share reflects an increase in total electricity generation. Primary energy continues to rely on fossil fuels in 2030 under the BAU scenario. In contrast, in the non-nuclear scenario, natural gas would replace the share of nuclear and gain a larger share of primary energy supply. In the emission reduction scenarios, an emission cap would reduce both power generation and primary energy supply. The carbon constraint of this policy would remove all coal-fired generation by 2030 and lead to an increase in wind and solar power generation.

There are certain weaknesses in these applications due to data issues and the representation of the energy and the power-generation sectors in the models. Most of the previous applications have either utilized aggregated representations for power generation or relied on readily prepared databases which leads to a deficiency in capturing technological details. An aggregated representation of power generation also means that the abatement potential of the energy sectors cannot be fully captured. Therefore, considering these shortcomings in the literature, building a CGE model with a rich disaggregation in the energy sectors and specifically in the power generation technologies using fossil fuels and renewables and using a self-constructed energy-disaggregated SAM with recent data as the baseline dataset became the novelty of this paper. A CGE model calibrated on a well-built SAM, coupled with environmental and energy satellite accounts brings significant value-added to the literature and is highly purposeful for a comparative impact analysis of competing policies on the path to a low-carbon, sustainable economic development in Turkey.

3. Methodology and data

[3] For other recent CGE applications to Turkey on low-carbon development paths and climate change, see Yeldan and Voyvoda (2015) and Kolsuz and Yeldan (2017).

The model used in this paper is based on the theoretical foundations of general equilibrium theory. CGE models represent simulations which bring together the general equilibrium structure and the economic data to simultaneously solve for the levels of supply, demand, and prices across the markets in the economy. It represents the economy in equilibrium with economic agents' maximizing behavior under their respective budget or technology constraints. The core of the database of a CGE model is the SAM with an input-output core which enables it to trace the channels through which policy and changes in the global environment are transmitted. The system of simultaneous equations works such that the shifts in endogenous prices affect the demand for sectoral output and thus lead to an alteration in the resource allocation of factors of production. The data in the SAM is backed by satellite accounts regarding detailed energy and environmental data.

The motivation behind the methodology choice is threefold. CGE models have been extensively used in investigating the economic impacts of energy and climate policies throughout the world (Cai and Arora, 2015) as they are constructed in such a way as to measure the direct and indirect effects of economic policy changes in different periods of time and can depict the nature and magnitude of the economic impacts of these policies. As energy goods are such vital inputs in almost all sectors of the economy, the consequences of energy policies have a ripple effect through multiple markets of the economy simultaneously. Hence, this type of a phenomenon necessitates a general equilibrium approach where the impacts of various policies can be analyzed in different sectors of the domestic economy as well as the international environment.

The second reason for choosing a CGE model is that it reproduces the structure of the economy quite well and when this structure is linked with a detailed SAM, a powerful policy-analysis tool is created. The main premise of a CGE model is that "structure" matters and therefore CGE models can provide detailed and pragmatic representations of the economy with linkages between all agents, sectors and other economies. They capture the interaction of various actors in an economy modeling them as multi-functional agents. For instance, households are modeled as private consumers, suppliers of labor and savers in the economy whereas firms act as producers of intermediate and final goods, consumers of intermediate goods, and as investors in the domestic economy. CGE models are constructed with special emphasis on structural characteristics, and they are used to evaluate impacts including changes in prices, demand and supply relationships, and sectoral output and employment levels. The advantage of using this kind of analysis is that they can evaluate direct and indirect costs, spillovers and economic trade-off effects in a multi-region and inter-temporal perspective (Antimiani, Costantini and Paglialunga, 2015).

The third reason is being able to link the model to such a detailed database in the form of either an Input-Output (I-O) matrix or a SAM and quantifying the inter-industry flows of goods and services in a system of national income and product accounts (Pyatt and Round, 1985). The existence of explicit information on inter-industrial flows allows designing the model using interactions between industries with respect to a change in relative prices or the level of demand for commodities or factors. This system gives way to linking the variables and the set of equations through behavioral parameters or elasticities. Especially when analyzing policy shifts, the elasticity values that are fed into the model equations become crucial.

3.1 Main technical features of TurkMod

TurkMod incorporates the behavior of five economic agents: firms, households, the government, the investors and the rest of the world. The model is currently calibrated on an energy-disaggregated SAM for Turkey for the year 2012, year for which a consistent dataset can currently be constructed. The model is coded and solved using the general algebraic modeling system GAMS. The behavior of the agents are summarized in the following sections.

3.1.1 Household behavior

TurkMod has one representative household in its specification. Households receive capital and labor income from their ownership of production factors, from other institutions and also income as transfers from the rest of the world. The household also makes transfers as factor income payments to the rest of the world. The household expenditure is allocated between consumption, tax payments and savings. The representative household opts to maximize its utility with the consumption of commodities and primarily it decides on the allocation of its income between present and future consumption of goods. The household pays a certain percentage of its income as income taxes and saves a share of the remaining net income. The disposable budget for consumption is allocated between different goods and services according to a Stone-Geary utility function. This leads to the Linear Expenditure System (LES) which means that a subsistence level of each commodity will first be allocated before the remaining income is allocated between the consumption goods. This type of a utility function is more realistic than a Cobb-Douglas type with regards to the elasticity values. When using a Cobb-Douglas utility function, the income elasticities are assumed to be one, the own price elasticities minus one, and the cross-price elasticities are equal to zero. However, in a LES where a Stone-Geary utility function is utilized, there is more flexibility concerning elasticity values. Therefore, the utility function of the household is maximized as follows:

$$U(C_c) = \prod_c (C_c - \mu Hc)^{\alpha Hc} \quad (1)$$

subject to the budget constraint:

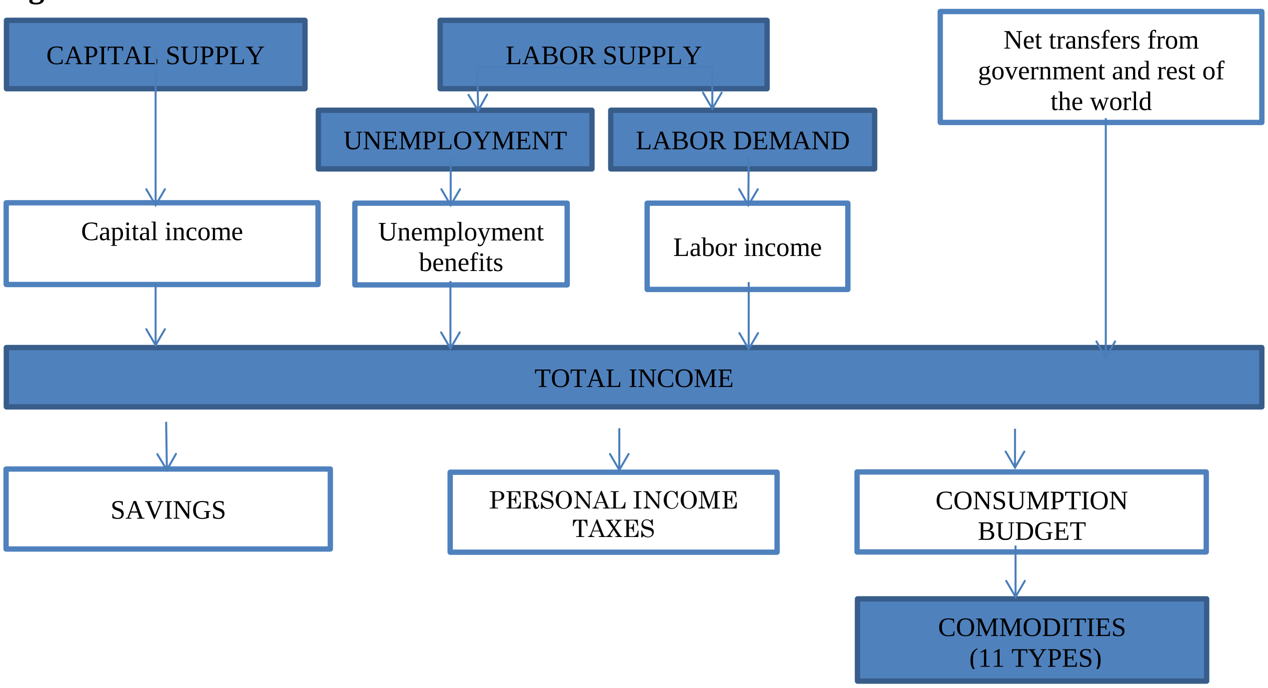
$$CBUD = \sum_c \left\{ \left[\sum_{ctm} (tchtm_{ctm,c}.P_{ctm}) \right].(1 + tc_c).C_c \right\} \quad (2)$$

Equating the sum of the power of each commodity in the LES utility function to one yields the demand equations for the commodities:

$$\sum_c \alpha H_c = 1 \quad (3)$$

Consumption of commodity c (C_c) is valued at purchaser's prices, which include trade and transport margins($\sum_{ctm} tchtm_{ctm,c}.P_{ctm}$), and taxes on commodities (tc_c) where P_c is the price of commodity *c* net of taxes but including subsidies. The consumer first decides on the subsistence level of consumption of commodity which corresponds to the minimum subsistence level (μH_c). The minimum subsistence level is the minimum required quantity which the consumer purchases first. Then, the remaining income ($Y - PD_c . \mu H_c$), which is sometimes referred to as the "supernumerary income", is allocated between different types of commodities according to fixed fractions which are essentially the marginal budget shares(αH_c) (EcoMod Modeling School, 2018).

Figure 3.1: Decision structure of the household



A schematic representation of the household's decisions is outlined in figure 3.1. The representative household receives capital income, labor income, unemployment benefits and net transfers from the government and the rest of the world. Then, the household pays for the personal income taxes, saves a fraction of its income given the saving rate and spends the remaining income on the commodities.

3.1.2 Firms' behavior

A CGE model works with groups of similar firms aggregated into branches and thus each producer is represented by an activity in the production sectors in the SAM. The model distinguishes 18 perfectly competitive branches of activity (see table 3.1). 17 of these sectors represent private enterprises whereas the 18th branch represents public administration and defense. 11 of these 18 sectors are energy-producing activities and 8 of them combine to produce solely one commodity, i.e., electricity. The usual assumption in a CGE model is that producers are profit maximizing firms which act in perfectly competitive markets, and they determine the optimal level of input and output by either maximizing profits or minimizing costs. When it comes to determining the level of imports and exports, the output prices are assumed from the global markets. With domestic and international competition, domestic firms need to be as efficient as possible to minimize their production costs and reach profit maximization for a constant returns to scale technology.

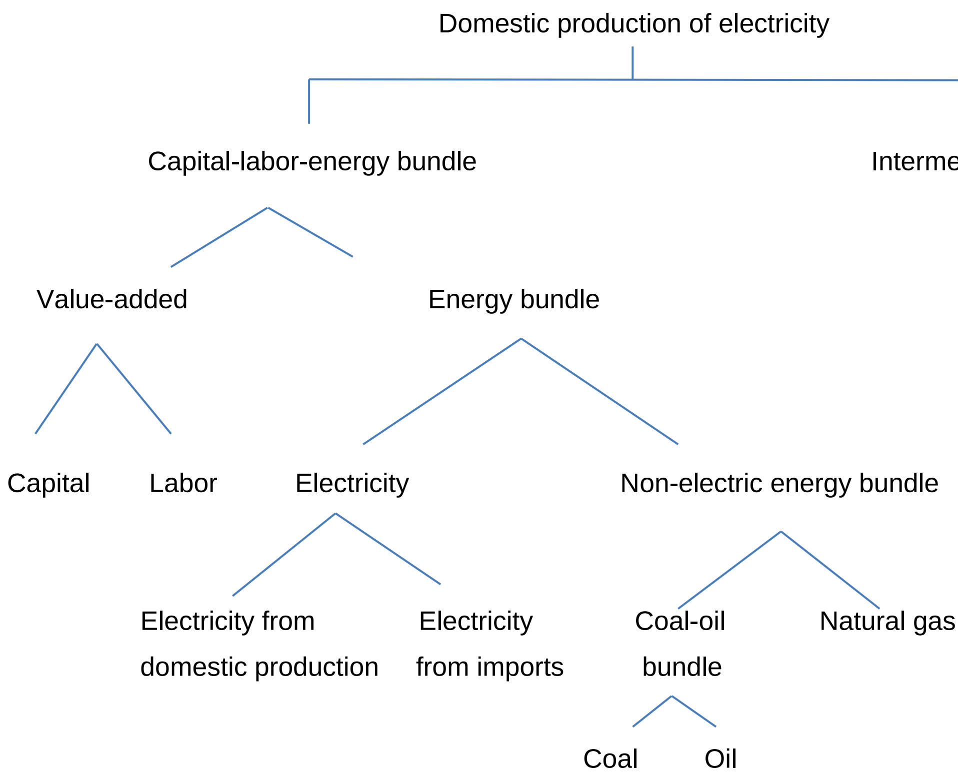
A nested production structure is utilized to determine production for each branch of activity. Production functions determine the ways in which capital, labor, energy, and intermediate inputs can be used to produce an output for each sector. The representation in our model enables each individual sector to be structured according to its underlying production technology implying the extent to which labor, capital, and energy may be substituted for each other. In the production of electricity, there are three fossil fuel resources which are coal-fired power, gas-fired power and oil-fired power. The other five sectors which produce electricity are renewable sources, i.e. hydroelectric, solar, wind power, geothermal, and biomass and waste. For those sectors that produce electricity, the producers are assumed to choose in the first stage between intermediate inputs and a capital-labor-energy (KLE) bundle according to a Leontief production function.

Table 3.1: Disaggregation of production activities in TurkMod

1	Agriculture, Forestry & Fishing
2	Solid fuels
3	Liquid fuels
4	Natural gas
5	Coal-fired power
6	Gas-fired power
7	Oil-fired power
8	Hydroelectric power
9	Solar power
10	Geothermal
11	Wind power
12	Biomass and waste
13	Energy-intensive industries (manufacturing)
14	Non-energy intensive manufacturing
15	Construction
16	Transportation and storage
17	Services
18	Public Administration and Defence

In the second stage, the optimal mix between value-added and energy is given by another optimization process, where substitution possibilities between value added and energy are represented by a constant elasticity of substitution (CES) function. In the third stage, value added is given by a CES function of capital and labor while the energy bundle is represented by a CES function of electricity and a non-electric energy bundle. In the fourth stage, the optimal mix between natural gas and the coal-oil bundle is given by another optimization process, where substitution possibilities between natural gas and the coal-oil bundle are represented by another CES function. Finally, in the fifth stage the optimal allocation of the coal-oil bundle between different energy inputs is provided by another CES function (see figure 3.2).

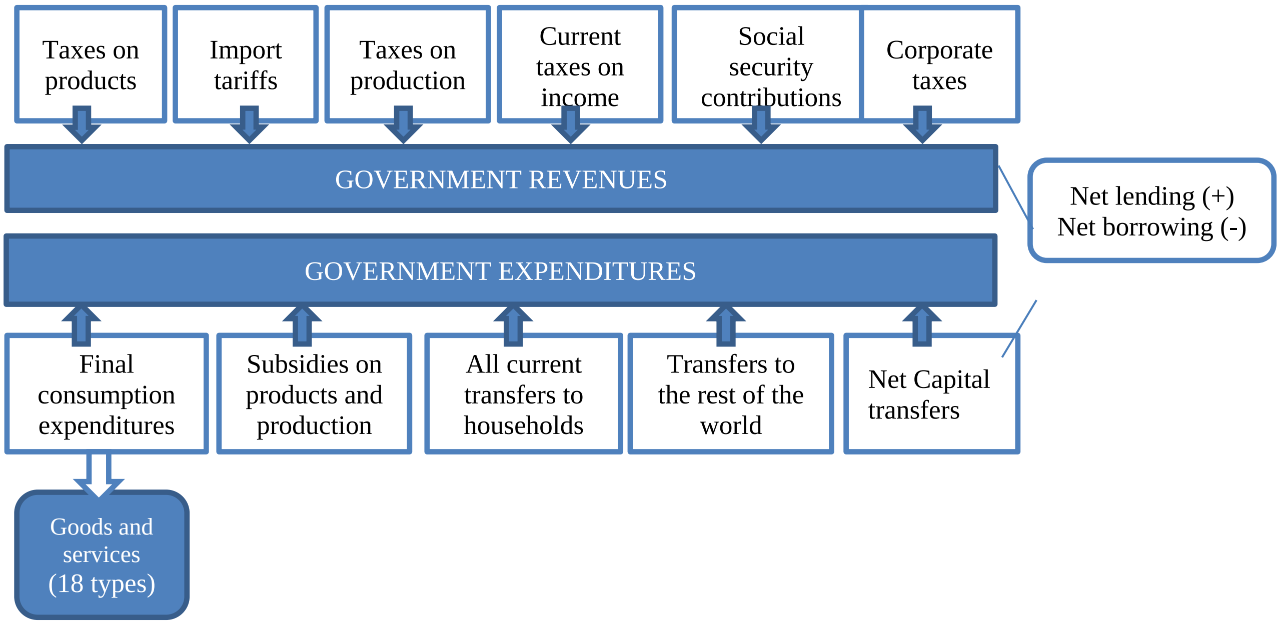
Figure 3.2: The nested Leontief and CES production technology for the domestic production of electricity



3.1.3 Government's behavior

The government in our model acts as an independent body which collects taxes and in turn spends these on consumption expenditures, transfers, and subsidies. Government collects all the taxes, including current taxes on income and wealth, value added tax (VAT), excise duties, other taxes on products, tariffs, social security contributions and corporate taxes (see figure 3.3).

Figure 3.3: Structure of the government budget



The difference between government revenues and government expenditures gives the government net lending (+) / net borrowing (-) which is expressed in real terms as *SGBAL* and in nominal terms as *SGBALN* which is converted using the GDP deflator as the price index.

$$SGBAL.GDPDEF = GREV - GEXP \qquad (4)$$

$$SGBALN = SGBAL\,.GDPDEF \qquad (5)$$

3.1.4 Investment Demand

In TurkMod, it is assumed that there is an investment bank which receives all the savings which are then used to purchase investment goods. Total savings (*S*) in the economy is given by:

$$S = SH + SF.ER + SGBALN, \qquad (6)$$

where *SH* represents household savings, *SGBALN* is the government net lending (+)/ net borrowing (-) in nominal terms, and *SF* is the current account balance expressed in the domestic currency using the exchange rate (*ER*). Savings are allocated over the investment demand from the firms according to a Cobb-Douglas utility function. The investment demand for commodities is executed by the agent 'Bank' and is derived by a Cobb-Douglas utility function.

3.1.5 Foreign Sector

This CGE model encompasses an open economy with a foreign sector which interacts with the Turkish economy through a composite world price index. Taking on the standard specification of a small-country assumption, the Turkish economy is a price taker in both its export and import markets. When introducing imports and exports into the model, commodities are differentiated with respect to their origin and destination, and therefore imports for domestic use and exports by domestic producers. On the side of imports, we assume imperfect substitution between domestically produced and imported goods and to this end we use the Armington assumption. Domestic consumers use composite goods (X_c) of imported and domestically produced goods according to a CES function which can also be named as the Armington equation. As we discussed earlier in the technical section, the elasticity of substitutions in the production or utility functions are of upmost importance in CGE analysis. In this case, the elasticity of substitution between imports and domestically produced goods (σA_c) is given by $1/(1 + \rho A_c)$.

A fairly similar representation is used when it comes to the distinction between the exported goods by the domestic producers (E_c) and the domestic goods supplied on the domestic market (XDD_c). A constant elasticity of transformation function (CET) is used to capture the differentiation between exports and domestically supplied goods and services. The domestically produced commodity (XD_c) is now sold either in the domestic market (XDD_c), or abroad (E_c). The representative firm tries to maximize its revenues using the CET function. The current account balance in TurkMod is given by the difference between foreign expenditures and foreign receipts.

Price equations and market-clearing conditions play an important role in attaining general equilibrium and in the closure of the system of simultaneous equations. The CGE model is calibrated on the benchmark dataset provided by the energy-disaggregated SAM.

3.2. Data

The calibration of the CGE model is implemented through the use of a benchmark dataset that is assumed to represent equilibrium for the economy so that the CGE model is solved using the concept of equilibrium (Shoven and Whalley, 1992). The benchmark dataset used in this study is systematically represented in the form of an energy-disaggregated SAM linked with satellite accounts. One of the main features of a SAM is that the SAM accounts are represented as a "square matrix" whose corresponding columns and rows present the expenditure and receipt accounts of economic actors. The equilibrium required by the calibration process is assured by the SAM being square. Row and column sums in a SAM need to be equal to one another as all income accrued must be accompanied by an outlay (Pyatt and Round, 1979). Gathering all the necessary data and compiling all this data into a SAM is not an easy process. It requires rigorous effort and time. The benchmark data needs to mirror the real structure of the economy as approximately as possible. A SAM can serve as a unique economic database for structural analysis given that it is able to capture inter-industry linkages and household income and expenditure composition while being consistent with macroeconomic accounts at the same time. It is a framework that brings together data from all three levels of analysis: micro, meso, and macro. This enables the analysis to be a multi-level one. For a SAM to be fruitful for policy-making purposes, it needs to be carefully disaggregated with a special emphasis on the policy area for which the database and the proceeding model will be used for. In the case of Turkey, the NACE Rev. 2 classification is used with slight differences arising due to a detailed disaggregation of energy sectors in our model. The two main data sources for constructing the disaggregated SAM are the Turkish Statistical Institute and Eurostat and they both use the NACE Rev.2 classification.

The18-sector energy-disaggregated SAM is valued in million Turkish liras (TL) and balanced using the cross-entropy method. The basic balance requirements in a SAM are the commodity balances, flow of funds balances and macroeconomic balances. SAM entries are in value terms and the row sums and associated column sums have equal values since they represent balances. Examples for these balances are as follows:

- Commodity balances in value terms
- Budgets
- Firm profits
- Government budget
- Balance of payments

Each agent in a SAM has an account and all agents satisfy their budget constraints. Rows record the incomes of the agents and columns record their expenditures. The institutions in the Turkish energy-disaggregated SAM include households, the government, and the rest of the world accounts. There are mainly 7 accounts in the 2012 SAM for Turkey. These are the commodities account, activities account, factor accounts, household account, government account, capital account, and the rest of the world account.

The energy-disaggregated SAM is linked with satellite accounts, i.e. energy balances and carbon emission statistics so as to provide a complete picture in tackling policy questions in environmental and energy issues. As the values in the SAM are expressed in monetary terms (million TL) as a magnitude of value but the energy balances and carbon dioxide emissions are calculated in physical magnitudes such as energy units (kJ/kg or tonnes of oil equivalent (toe)), a new adjusted energy balance and additional information on greenhouse gas emissions were necessary to tackle the environmental and energy scenarios for Turkey. Using various data sources, implicit price levels are derived for the energy commodities and energy vectors are retrieved by branch of activity expressed in million TL per TJ , implicit price level of energy vector consumed by the residential sector in million TL per TJ, and GHG emissions on fuel combustion by sectors, by households, by the transport sector expressed in Kt.

4. Policy scenarios and results

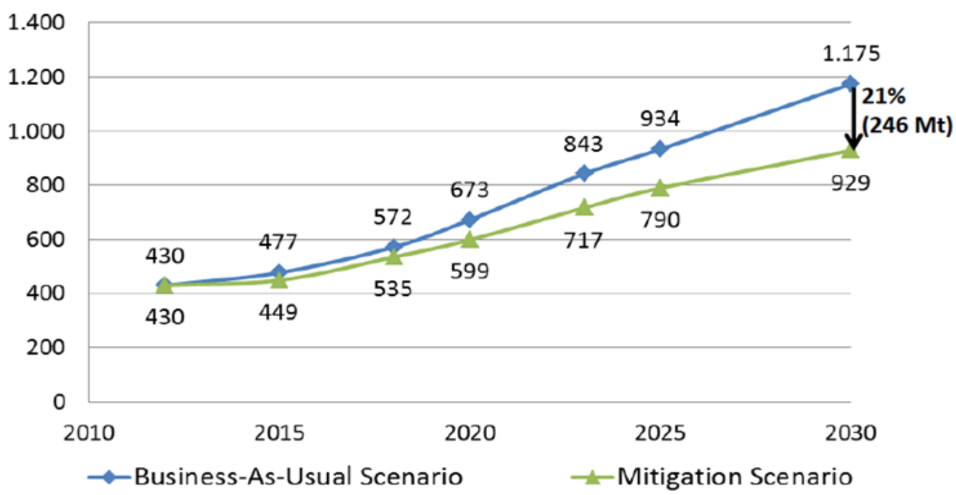
The baseline scenario in TurkMod rests upon the foundations provided by an energy-disaggregated SAM for 2012, satellite accounts which include energy vectors used in the production process by branch of activity and by the residential sector expressed in energy units (TJ), and a satellite account on GHG emissions represented as CO2, N2O and CH4 emission factors by fuel and branch of activity expressed in Kt per TJ. Several scenarios regarding energy and environmental policy options for Turkey are developed to analyze the potential impacts of Turkey's compliance with the Paris Agreement, the use of a carbon tax scheme and subsidizing renewable energy sources. The results of these scenarios are provided in the following sections.

4.1 The Paris Agreement scenario

With the INDC submitted by Turkey to UNFCCC in 2015, Turkey has pledged a National Climate Change Action Plan with emission controls and adaptation policies and measures to be implemented in all sectors of the economy. As of February 2020, all UNFCCC members signed the Paris Agreement and 189 others have become parties to it, however, Turkey has still not signed or become a party to the Paris Agreement. Turkey needs to accelerate its efforts in contributing to climate change action.

The greenhouse gas inventory of the baseline year 2012 revealed that the total emissions in 2012 expressed in CO2 equivalent were 440 million tons in Turkey. The energy sector had the largest share with 70.2%, industrial processes followed with 14.3%, and the waste sector and agriculture with 8.2% and 7.3%, respectively. Turkey's per capita greenhouse gas (GHG) emissions for the same year was 5.9 ton CO2 equivalent, which is much lower than the EU and OECD averages, but rising. Turkey has pledged with its INDC a 21% decrease in total GHG emissions between 2021 and 2030. Figure 6.1 shows the emissions reduction target set by the INDC submitted by Turkey to the UNFCCC. The BAU (business-as-usual) scenario and the mitigation scenario divert significantly from each other after 2020. Turkey's INDC does not provide emission reduction targets for different points in time within the 2012–2030 time period.

Figure 4.1: Total greenhouse gas emissions (Mt CO_2e)



Source: Intended Nationally Determined Contribution (INDC) of Turkey, 2015, Extracted from https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Turkey/1/The_INDC_of_TURKEY_v.15.19.30.pdf.

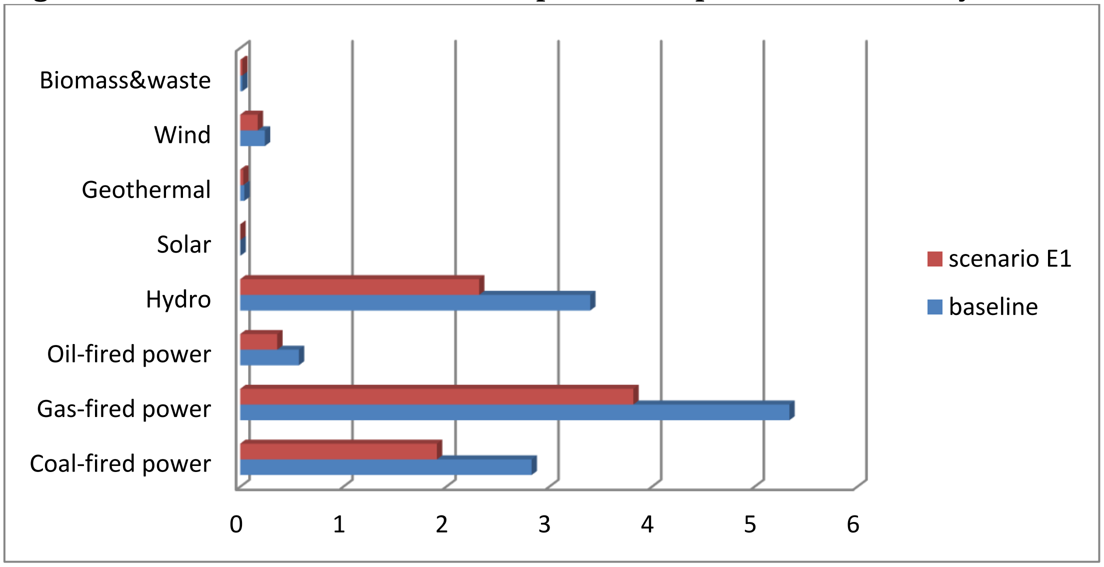
Rather, the INDC only indicates the reduction path for the target year of 2030. Relative to the BAU scenario, a 21% reduction in overall GHG emissions is required to reach the target level of 929 million tonnes CO_2e. However, these official projections assume a high GDP growth path. Generation of electricity, demand for energy and GHG emissions are all driven by the assumption of achieving a high level of GDP growth. Per contra, Turkey's political and social conjuncture coupled with economic problems recently deepened by the Covid19 crisis demonstrates that Turkey will not be able to achieve the desired levels of growth. Since August 2020, almost after two years of an earlier currency crisis, Turkey has been experiencing a substantial depreciation of its currency TL with respect to the foreign currencies, especially US dollar, euro, and the UK pound. The Turkish lira is indeed one of the most volatile currencies in the world which makes the financial sector even more fragile. This volatility puts the economy of Turkey in a much more difficult position with regards to its current account deficit and high government debt denominated in foreign currency. Battling with the Covid19 health crisis and economic and financial problems that were already existent in the Turkish economy puts Turkey in a very difficult position in the coming years.

The first scenario here entails increasing energy efficiency in all production sectors by 30%. Sectoral improvements in energy efficiency are approximated to reach the goal of 21% reduction in GHG emissions in compliance with the Paris Agreement. $MUeneffb_s$ is introduced as a parameter in the model equations and represents the sectoral change in the efficiency parameter due to the change in the energy intensity indicators in TurkMod. This parameter is utilized to hypothetically increase the overall energy efficiency by 30% in order to reach the targeted levels of GHG emissions. The major contributor to the mitigation of GHG emissions is through a reduction in energy intensity by improving energy efficiency in the power generating sectors, industrial sectors and the transportation sector. With an increase of 30% in energy efficiency, the energy intensity of almost all the sectors decrease, thus decreasing the demand for energy products. This in turn reduces the GHG emissions of the sectors of the economy to reach the 21% target. An increase in GDP growth is realized due to the energy efficiency shock which brings in a shock wave of higher incomes without any costs. Thus, a total factor productivity (TFP) shock parameter is introduced in the model to account for this GDP growth rate. A 0.06% negative TFP shock is introduced into the scenario along with the 30% increase in energy efficiency to neutralize this effect. Even with the introduction of the negative TFP shock, overall positive effects are accounted for this scenario. The unemployment rate declines by 7.40% in the economy which is associated with increases in labor demand as labor supply is fixed. In fact, labor demand decreases for all of the firms operating in the power-generating sectors who also decrease their domestic output. However, labor demand increases at a substantial rate of 62.08% in the natural gas sector, and slightly in the public administration sector with a 5.57% upsurge. Construction, transport and services sectors also experience very small increases. The natural gas sector increases its domestic production by 27.22%.

Considering the substitution possibilities of the firms in their nested production structures, the natural gas sector naturally demands both more labor and more energy products in order to increase its production by 27.22%. The sectoral capital stock is fixed in the model so firms cannot demand more capital goods. As mentioned earlier, labor demand by the natural gas sector increases by 62.08% and demand for the energy bundle increases by 41.39%. When the index of energy inputs used in the production by branch of activity is investigated, it's striking to see that all the sectors decrease their use of energy inputs significantly except the natural gas sector. Natural gas uses 8% lower levels of solid fuels, liquid fuels and natural gas in its production compared to the baseline; however, its use of electricity increases by 10.28%.

Figure 4.2 portrays the change in the coal-oil bundle used in the power generation sector due to an increase in energy efficiency. The decline in the use of coal-oil bundle is an important indicator in the transformation towards a low-carbon economy. The leading contributors to the cutback on the use of coal-oil bundle are the gas-fired power, coal-fired power and hydro sectors. The percentage declines in coal-oil bundle usage range between 28% and 37% for the different power generation sectors.

Figure 4.2: Coal-oil bundle used in the production process of electricity



Sectoral contributions to GHG mitigation are analyzed in the results as well. The transport activities contribute the highest with a share of 33% followed by the energy sectors at 31%. The emissions from all the transport activities are separated in our model and duly included in the transport sector which explains the high share of contribution to GHG mitigation. This means that the transport sector in Turkey has a big potential of becoming more energy efficient. Power-generation is the leading GHG emitter in many countries as increases for the demand of energy push economies to increase their primary energy supply and thus their CO2 emissions. Turkey's electricity generation is mainly based on gas-fired power, hydro and coal-fired power, but trends indicate a positive change towards the use of more renewable energies in the production mix of electricity. The 31%

contribution to the abatement of GHG emissions is comprehensible in this case as reducing energy intensities in the power generating sector of Turkey will have a huge impact on carbon emissions.

4.2 Carbon tax scenarios

Energy inputs differ in terms of their carbon content. In the baseline scenario, electricity production is a mix of fossil fuels and other power generation technologies including renewables. When a carbon tax policy is applied in order to reduce emissions, the cost of all types of fuel used in power generation rises as there are no carbon free inputs except electricity[4]. However, the rise in input prices makes low carbon energy sources relatively cheaper than high carbon intensity fuels like coal. This shift in the energy mix of inputs in favour of low carbon fuels stimulates the economy-wide decline in carbon emissions (Peters, 2016).

Two alternative carbon tax scenarios are introduced in this work according to the carbon tax levels. A medium carbon tax level and a high carbon tax level are set up and compared with the baseline results to analyze the impacts on the overall economy including GDP, income, savings and government accounts, and on sectoral energy intensities, primary power supply and GHG emissions. These results indicate whether an effective carbon tax policy can be used as an environmental economic policy tool in Turkey. The carbon tax scenarios in this work are formulated by exploring the carbon content of the energy input. There are 4 types of energy inputs in TurkMod. These are solid fuels (hard coal and lignite), liquid fuels (crude petroleum products and other liquid fuels), natural gas, and electricity. Electricity as an energy input has zero carbon content and therefore no carbon tax is levied on electricity as a product. However, power generation is taxed on the fossil fuels they consume for electricity production. Although there are notable differences in emission factors between different types of a given fuel (e.g. different coal types), general trends are defined by the Intergovernmental Panel on Climate Change (IPCC) in the relative level of emissions between coal, oil and gas. According to the IPCC (2014), coal typically produces the most CO2 per unit energy (360-400 kgCO2/MWh), followed by oil (260 kgCO2/MWh) and natural gas (201 kgCO2/MWh). Coal is the most polluting fossil fuel and has the highest carbon content and therefore a higher carbon tax rate is levied on the use of coal in the production process of firms. Therefore, in the carbon tax scenarios, solid fuels are taxed at a relatively higher level than liquid fuels and liquid fuels at a higher rate than natural gas.

The price mechanism of the market pushes the electricity producers to move to clean energy and products with low carbon content to achieve the emission reduction targets. The magnitude of the price increase in commodities undoubtedly depends on the carbon content. Sectors which utilize higher-carbon content energy products are faced with a higher cost whereas firms which use lower-carbon content products face lower costs. The carbon tax forces a substitution towards low-carbon

[4] Electricity as an energy input is regarded as a zero-carbon energy commodity as consuming electricity for residential or production purposes does not emit any GHG emissions into the atmosphere. Therefore, no carbon tax is levied on electricity as a commodity. Estimations from different studies show that liquid fuels have the highest carbon content, followed by solid fuels and natural gas.

energy goods even though there is inelastic CES substitution between the different energy commodities. Elasticity values between value added and the energy bundle and between electricity and non-electric energy bundle are lower than one, pointing to inelastic substitution but still giving way to moving away from high-carbon content commodities. The CES elasticity values are carefully chosen to fit the nesting structure of the model and are consistent with the values in the literature. For instance, lower elasticity of substitution values is utilized for agriculture, transport sector and energy sectors and higher estimates for the services.

Other things remaining constant, when consumers pay higher prices for electricity and other energy goods, they are left with less money to spend on other commodities. This means that overall demand in the economy would shrink. When only the supply side is considered in the short run, it's realized that an increase in electricity prices would mean that firms need to spend more for the same level of production as electricity has a rather low elasticity of substitution. This in turn means there will be fewer resources available for producing other goods. Thus, it's anticipated that aggregate supply would shrink due to an increase in the price of electricity. Reduced output and demand mean lower employment of factors of production like capital, labor, and other intermediate inputs. The decline in total output will not be the same across sectors as the degree to which sectors use electricity differs enormously. Those that use less electricity will see modest change while those that rely on electricity will see noticeable decline in output.

As a result of the carbon tax scheme, low-carbon content in the economy drives the reduction in GHG emissions throughout the whole economy. The decline in carbon use is mostly attained by the power-generating sectors and the energy-intensive manufacturing sectors. Scenario C1 which is the medium-level carbon tax scenario imposes a 15% carbon tax rate on solid fuels, 10% on liquid fuels and 8% on natural gas whereas scenario C2 (the high-level carbon tax scenario) levies 25% on solid fuels, 20% on liquid fuels and 15% on natural gas. Examining the economy-wide effects of this specific carbon tax policy, it is realized that moving to a low-carbon economy does not have such big costs to the Turkish economy. In scenario C1, the GHG abatement of 12% is achieved whereas in scenario C2, the INDC GHG mitigation target of 21% is reached. The detailed outcomes of these two carbon tax scenarios will be discussed below, using percentage changes with respect to the baseline results.

Starting with analyzing the overall impact on the economy, the net decline in GDP growth rate is 0.16% in C1 and 0.28% in C2 compared to the baseline scenario. The reductions in GDP are not very high considering that no reallocation scheme[5] is applied. A reallocation scheme would mean that revenues generated as a result of the carbon tax scheme would be transferred to the households or the private sector. This in turn would mean higher consumption or investment levels and this would lower the decline in GDP growth. Even though households now receive 0.57% and 1.02%

[5] Reallocation schemes do exist for carbon tax policies. These include income transfer mechanisms where revenues from the carbon tax are allocated to households as transfers or using these revenues for subsidizing renewable energies. There are mixed results on the efficiency of these types of schemes.

higher transfers from the government in C1 and C2, the income of households decrease by 0.83% in C1 and by 1.35% in C2. The decline in households' income is considerably high in the high-level carbon tax scenario so a reallocation scheme would be useful in transferring the carbon tax revenue to the households to alleviate this. The increase in household transfers can be attributed to an increase in the unemployment benefits as the unemployment rate increases in C1 and C2 scenarios by 2.63% and 4.48%, respectively. Households now have lower incomes, so they save less and consume less. Households' demand for commodities declines due to lower household income and higher prices in the market for goods and services induced by increasing energy prices. The highest decline in the consumers' demand for commodities is recorded for electricity (2.56%), construction (1.82%), services (1.01%) and energy-intensive manufacturing goods (0.69%) in scenario C1. In scenario C2, highest decline is accounted for in electricity (4.74%), construction (3.10%), public services (1.75%) and transportation and storage (1.57%). Investment demand for commodities rises slightly (2.5-3%) except for the energy-intensive industrial products where only a 0.68% increase in investments is realized.

The government is the ultimate winner in the carbon tax scenarios as the revenues from the carbon tax are allocated to the government budget. Government revenues in scenarios C1 and C2 increase by 2.35% and 3.71%, respectively, and government savings increase at even a greater extent at 13.41% and 21.20% due to the fact that the government's consumption budget is fixed, so the extra revenues received by the government are saved instead of consumed. As mentioned earlier, this increase in government revenues induced by the carbon tax scheme could be put into very good use with sound policymaking aiming at alleviating the decline in incomes and GDP and aiming at using this extra revenue for Turkey's sustainable development path.

Examining the domestic sales (X_c), indexed by the composite commodity of domestically produced and imported goods, all of the commodities except non-energy intensive manufacturing and construction sectors in C1 and only the construction sector in C2 fall down. The hardly-hit commodities in terms of domestic sales are the carbon taxed commodities with a decline in domestic sales of 6.94%, 4.08%, and 2.81% for solid fuels, liquid fuels and natural gas, respectively. Along similar lines, the demand for imports is affected negatively for fossil fuels. In scenario C1, demand for solid fuels decrease by 4.63%, liquid fuels by 3.52% and natural gas by 1.67% whereas in scenario C2 the decline in imports is much higher. A 10.21% drop in imports of solid fuels is followed by a 3.37% decline in liquid fuel imports and 2.79% in natural gas. This is a significant result as one of the major reasons for Turkey to adopt a carbon tax scheme would be reducing the dependence on fossil fuel imports.

Moreover, demand for electricity imports increase significantly by 14.42% and 29.59% in scenarios C1 and C2, respectively, trying to substitute for the high-priced domestic electricity. Demand for imports of the construction commodity rises with a notable 8.11% upsurge in the high-level carbon tax scenario due to the result that the composite domestic commodity price of transport increases by 1.57%, pushing the consumers to substitute the domestic good with the imported one.

Table 4.1: Sectoral impacts of the carbon tax scenarios C1 & C2

	Sectors / Percentage change w.r.t. baseline	Domestic production		Energy intensity		GHG emissions	
		C1	C2	C1	C2	C1	C2
sec1	Agriculture	-0.04	-0.07	-10.26	-16.03	-9.14	-16.75
sec2	Solid fuels	-0.52	-0.90	-12.87	-20.39	-10.58	-18.92
sec3	Liquid fuels	-2.71	-4.98	-13.54	-22.16	-12.05	-21.44
sec4	Natural gas	-3.39	-6.36	-16.03	-25.07	-15.16	-26.71
sec5	Coal-fired power	-0.42	-0.77	-7.14	-12.61	-10.90	-19.46
sec6	Gas-fired power	-1.20	-2.26	-7.82	-13.90	-11.55	-20.61
sec7	Oil-fired power	-1.40	-2.11	-5.83	-10.32	-11.17	-20.21
sec8	Hydro	-0.43	-0.87	-7.26	-12.96	-10.78	-19.33
sec9	Solar	0.67	1.26	-3.95	-6.99	-	-
sec10	Geothermal	0.22	0.40	-8.86	-15.58	-	-
sec11	Wind	0.16	0.28	-3.24	-5.78	-	-
sec12	Biomass&waste	-0.13	-0.23	-3.22	-5.73	-11.60	-20.98
sec13	Energy-intensive industries	-0.54	-0.96	-11.37	-19.16	-11.53	-20.44
sec14	Non-energy intensive industries	-0.20	-0.36	-8.98	-15.42	-11.28	-20.00
sec15	Construction	0.28	0.46	-10.55	-18.57	-9.62	-17.46
sec16	Transportation	-0.81	-1.35	-15.39	-23.60	-14.45	-22.94
sec17	Services	-0.31	-0.54	-8.56	-14.23	-11.43	-20.21
sec18	Public administration	-0.07	-0.12	-11.14	-17.52	-	-

The major reason for enacting a carbon tax policy is to reach desired levels of GHG mitigation and become a low-carbon economy by abbreviating energy use in the production sectors and the residential sector of the economy. Recalling on the nested production structure of firms in TurkMod, energy demand takes place at different levels of the production process. Demand for the energy bundles in the different nests of the production process mostly decrease with a carbon tax policy. The energy bundle ($ENER_s$), which is joined with the value added to form the KLE (capital-labor-energy) bundle, declines for all sectors except the three renewable energy sectors. These renewable energy sources are namely solar, geothermal and wind power and are the ‘clean’ sources of energy with very low levels of carbon content.

The energy intensity indicator by branch of activity defined in terms of energy consumption (TJ) per value added for manufacturing and services sectors and energy consumption per GDP for the transport sector is the best measure to use in testing the effectiveness of carbon tax policy. The second column in table 4.1 shows the energy intensities for the different sectors of the Turkish economy. With higher rates of carbon tax, energy intensities decrease further. All sectors experience lower energy intensities in both scenario C1 and scenario C2. The highest decline is recorded by natural gas at 24.18%, followed by the transportation sector, liquid fuels and energy-intensive industries at 23.60%, 22.16% and 20.39%, respectively. These sectors are followed by solid fuels where a 18.62% reduction is realized. Renewable energy sectors record the lowest percentage changes in energy intensities with respect to the baseline scenario.

4.3 Renewable energy subsidy scenarios

Renewable energy production has increased substantially in Turkey in the past couple of decades. Installed power-generation capacity from renewables has reached 45.2% in 2019. The latest report of Turkish Energy Market Regulatory Authority stated that the country's share in renewable sources in electricity production has also shown a substantial increase, from 30.7% in 2018 to 42.1% in 2019. Erdin and Ozkaya (2019) state that the Ministry of Energy and National Resources (MENR) is striving to improve the whole capacity of renewables to 61,000 MW by 2023. 34,000 MW of this total installed generation will be composed of hydropower: 20,000 MW of wind power, 1000 MW of geothermal, 5000 MW of solar, and 1000 MW of biomass energy. Hydropower is the leading source of renewable electricity production in Turkey today, accounting for 20% of power generation, followed by wind with a 14.6% of total power generating capacity. Wind power is succeeded by geothermal, solar power and biomass. This significant increase in power generation from renewables is due to the revised feed-in tariffs scheme adopted by Turkey in 2010. Feed-in tariffs are often used by countries to promote renewable energies as they are a relatively easy policy tool and they are flexible as they use a differentiation by technology to reflect the differences in generation costs between the various renewable energy technologies. Feed-in tariffs are fixed electricity prices that are paid to renewable energy producers for each unit of energy produced and thus injected into the electricity grid. In Turkey, the feed-in tariff was available for 10 years after commissioning of the plant (UNDP, 2014). Under the law on Renewables, producers of renewable energy who have started their operation between May 18, 2005 and December 31, 2015 were guaranteed power purchase prices for a period of ten years, with the feed-in tariffs.

Using the current feed-in tariffs officially published by the Turkish Government, subsidy rates are computed using the regular feed-in tariff rates and the ones with domestic equipment being utilized. The effects of this renewable energy subsidy scenario on the overall economy seem to be quite small. This renewable energy subsidy scenario does not have significant effects on GDP, household income or savings. This can be attributed to two reasons. The volumes of production of the renewable energy sectors, except hydro, are still at very low levels with respect to gross domestic production. The second reason is that the implied subsidy rates are too low to see any profound changes. Government expenditures increase by 0.05% as the government pays for these subsidies, and as expected government savings decline by 0.16%.

The feed-in tariffs currently in place do not foster the necessary development of renewable energy production to a level that will replace imports of fossil fuels and contribute to becoming a low-carbon society. A more conformed subsidy scenario is then introduced with higher levels of subsidy rates to enhance the desired levels of production from renewable energy sources and move away from fossil fuels. If the Turkish government is decisive in applying a renewable subsidy scheme that will have significant impacts on the sustainable development path of the country, then the current feed-in tariff rates need to be increased. The direct subsidy rates are higher for wind, solar and geothermal, and lower for biomass and hydro. Biomass and waste are presented in the same sector in TurkMod and there are GHG emissions arising from these sectors, specifically methane (CH_4) and nitrous oxide (N_2O) emissions.

In this scenario, GDP growth rate increases by 0.02% with respect to the baseline and the income levels increase by 0.3%. Total savings in the economy decline by 0.61% whereas transfers from the government to the households increase by 1.05%. The index of government savings deteriorates by 5.91% due to an increase in government expenditures of 1.57% because of the renewable subsidy scheme. Unemployment rate declines by 0.47% as demand for labor in the renewable energy sectors increase notably, but as mentioned in the previous section, this significant increase in domestic production and labor demand by renewable technologies does not transform into a significant change in the overall unemployment rate as renewable technologies use little labor. The sectoral increase in labor demand is highest in the geothermal sector with a 107.70% increase, followed by the wind power sector at 80.35%, solar power sector at 62.96%, biomass and waste at 32.85% and lastly hydroelectric power at 16.18%. These notable increases in demand for labor are also due to the restriction in the model that fixes sectoral capital demand as a necessary condition for the closure of the model. Therefore, the firm cannot increase capital as a factor of production and thus increases its demand for labor and also the demand for energy goods in order to be able to produce more commodities.

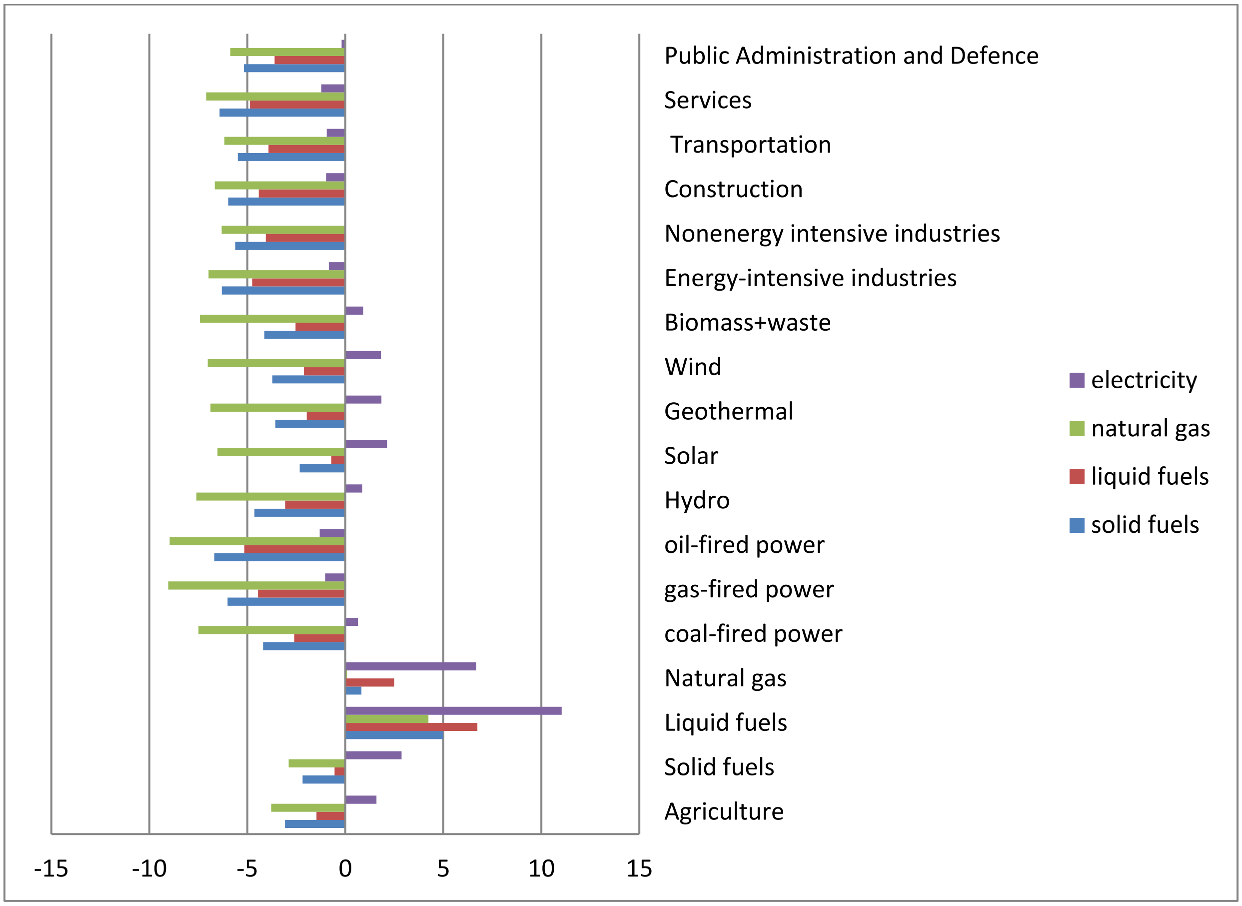
4.4 World prices of energy scenario

The fourth scenario simulates a change in world market prices of energy goods, essentially the three types of fossil fuels. Turkey currently imports a high amount of natural gas and petroleum products and a considerable amount of coal to be able to meet the growing energy demand in the economy. The dependency of the Turkish economy on fossil fuels is a major problem which needs to be dealt with using sound macroeconomic and energy policies. This scenario hypothetically increases the world market prices of natural gas, liquid fuels and solid fuels by 20%.

The results of this scenario are quite significant. Total GHG emissions in Turkey reduce by 20.86% when world energy prices increase by 20%. Therefore, the GHG mitigation target of Turkey for

2030 is reached under this scenario. The increase in the import price of fossil fuels drives the boost in domestic commodity prices as well. Moreover, the national currency TL experiences a depreciation of 0.78% as a result of the increase in the world prices of energy. Investigating the overall impact on the economy, GDP growth rate is negative 0.45% under the WPE scenario. The income of households is adversely impacted as well but only a 0.34% decline is recorded. Total savings in the economy fall by 1.18%. Government budget is hardly hit in this scenario as an 8.85% drop in government savings is recorded. This is due to 3.41% higher transfers being made to the households, and an increase of 1.38% in the nominal consumption budget of the government. The government's consumption budget is fixed in real terms and therefore this 1.38% increase represents the increase in the price index corresponding to government final consumption expenditure. It is unfortunate to also recognize that unemployment rate in the Turkish economy increases by 7.52%. This increase in the unemployment level is due to some sectors reducing their demand for labor. These sectors utilize a high amount of imported energy in their production process, i.e. gas-fired power, oil-fired power, energy-intensive industries, transport, construction and services sectors.

Figure 4.3: Index of energy inputs used in the production process under world energy prices scenario (WPE)



This scenario shows us that an exogenous price shock could bring about highly significant changes in the Turkish economy. Under this scenario, the GHG mitigation of 21% is reached without applying any other carbon tax policy or increasing energy efficiency. These results point to the dependency on imported fossil fuels and sends out a powerful message to policy makers in Turkey that transforming to a low-carbon economy would not bring about such big costs to the economy. Even in this scenario where the shock is exogenous and a planned scheme is not applied within the economy, the GHG mitigation of 21% is achieved with only a 0.45% contraction in GDP. The reliance on fossil fuels is reduced greatly. An adverse impact is realized on the governments' side but that could be alleviated with additional schemes that would provide revenues to the government. For instance, similar results are achieved by imposing equivalent tariff levels on the imported energy goods. This would increase the price of natural gas, liquid fuels and solid fuels and lead to a low-carbon economy with lower energy intensities and an abatement in GHG emissions. At the same time, this would provide extra income to the government and therefore alleviate the aforementioned issue of government balances.

5. Concluding remarks and policy implications

The simulation results suggest that significant policy options do exist for Turkey in transforming to a low-carbon sustainable growth path. The scenario on subsidizing renewable energies does not induce sufficient changes in the Turkish economy regarding the GHG mitigation targets and reducing the reliance on fossil fuels. To prove effective, this policy needs to be coupled with other policies such as a carbon tax scheme or induced gains in energy efficiency. Turkey has already been increasing the share of renewable energies in its power-generating sector, dominated by hydro and followed by increases in the installed power capacities in wind, geothermal, biomass and solar power.

The carbon tax policy would bring about strong impacts on the Turkish economy. The high-level carbon tax scenario generates a reduction of 21% in overall GHG emissions of Turkey. Energy intensities of the production sectors and the residential sector decline substantially as well (on average 20%). However, this scenario indicates a slight welfare loss with a 1.54% decline in household incomes, a 0.28% GDP contraction, and a 4.45% increase in the unemployment rate. Though, as mentioned in previous sections, the 21.20% increase in government savings could be used to alleviate the welfare loss of the households. A reallocation scheme could accompany the carbon tax policy to use the generated revenues in stimulating the economy, however, the distributional effects of the carbon tax are not analyzed in this study. Government-induced green growth investments, innovations and job creation mechanisms could also be applied but these will be investigated in further work with a recursive-dynamic CGE model. The "ideal" scenario portrays an optimal possibility of using a part of the carbon tax revenues for subsidizing renewable energies. This would mean that the subsidies on renewables could be greatly enhanced as the carbon tax revenues would be used to finance them. The results of the ideal scenario need to be interpreted in a way that it points to a prospect of coupling the GHG mitigation strategy with an enhancement in self-sufficiency in meeting energy demand with domestic sources.

The energy efficiency scenarios are effective in transforming Turkey into becoming a low-carbon economy and reaching the GHG mitigation targets. Additionally, there is a welfare gain as a result of the increase in energy efficiencies. Households are better off with 0.22% higher incomes and a 9.43% decline in the unemployment rate. The government's budget balance deteriorates by 4.60% as the price index for government demand for commodities increase by 1.05%. When sectoral impacts are analyzed, one sector stands out. The domestic production of natural gas increases quite significantly (29.24%) accompanied by a decrease in natural gas imports by 22.70%. This shows that the Turkish economy would attempt to cover the decline in gas imports by domestic production. These results need to be analyzed considering that nuclear power is not available in the scenarios. Many papers argue that natural gas could be replaced by nuclear power when domestically available. In the scenarios applied in this work, reliance on natural gas would be reduced only with a carbon tax policy or an increase in world prices of natural gas as nuclear power is not integrated in our simulations. As nuclear power is not operational in Turkey yet, it will be integrated in our model simulations when the dynamic CGE model is utilized in further work.

Consequently, analysing the different scenarios using TurkMod provides promising pathways for the Turkish economy. With abundant factors of production, a dynamic labor force and a high renewable energy potential, Turkey has the potential capacity of achieving a low-carbon, sustainable economic growth in the long-run. Within the scope of the model and policy scenarios utilized in this work, a carbon tax scheme stands out as a powerful policy tool for Turkey. Introducing a carbon tax policy along with supportive environmental and energy policies would sustain stability in the economic and financial sectors of the economy and this would bring substantial positive impacts to the Turkish economy.

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