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Opinion paper

Environmental impacts of coal subsidies in Turkey: A general equilibrium analysis

Sevil Acar[a], A. Erinc Yeldan[b,*]

[a] Istanbul Kemerburgaz University, Department of Economics, Istanbul 34217, Turkey
[b] Bilkent University, Department of Economics, Ankara 06800, Turkey

HIGHLIGHTS

- Turkey supports the coal sector providing both production and investment subsidies.
- Eliminating production subsidies leads to a 2.5% decline in total CO2(eq) by 2030.
- Additionally, removal of regional investment subsidies reduces CO2(eq) by 5.4%.
- The macro-effects of both scenarios are found to be quite small.
- Coal subsidies could be transferred to the financing of green policy alternatives.

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ABSTRACT

In this study we aim at providing an analytical framework for Turkey to study the macroeconomics and environmental impacts of the existing coal subsidization scheme. To this end we develop a regionally differentiated applied general equilibrium model spanning over 2015–2030. Our analytical apparatus focuses exclusively on the fiscal implications as well as the environmental repercussions of the removal of the subsidies on greenhouse gas emissions. With the aid of a set of alternative policy scenarios against a “business as usual” path, we study the regional and sectorial performances of growth, employment, investment and capital accumulation, consumption/welfare and trade balance. Our results indicate that by simple elimination of the coal subsidization scheme, Turkey can reduce its aggregate gaseous emissions by as much as 5% without a significant loss in its GDP.

1. Introduction

As a developing middle-income country, Turkey is facing increased demand for electricity and utilization of primary energy sources. The Ministry of Energy and Natural Resources (MENR) estimates indicate that per capita energy use rose from 1276 kgoe (kilograms of oil equivalent) in 2005 to 1663 kgoe in 2013. Total energy demand currently stands at 135.3 millions toe (tons of oil equivalent). These signal a significant projected expansion of energy demand in the next decade. Official figures project substantial pressures for continued increase in energy demand, with installed capacity expected to grow from 64 GW in 2014 to approximately 120 GW in 2023 (Acar et al., 2015). The implication of these expectations is that Turkey has not attained stability with respect to its energy demand per capita. Supporting the expected level of growth in demand is in itself a challenge, requiring significant investments in generation capacity and energy infrastructure, as well as continuation of the energy market reforms initiated in the 2000s. However, Turkey is also grappling with the challenges of ensuring a cost-competitive energy supply for its population and the industrial sectors, attaining energy security, and realizing emissions reduction.

* Corresponding author.
E-mail addresses: sevil.acar@kemerburgaz.edu.tr (S. Acar), yeldane@bilkent.edu.tr (A.E. Yeldan).

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Our proposed analysis looks at how current policy meets these challenges, focusing on plans for expansion of coal-fired power and renewable energy generation, and asking what role the existing coal subsidies play in the broad policy mix. Available rudimentary data reveal that subsidies to coal mining and coal-fired electricity generation amount to 730 million USD in 2013, or 11 USD per MWh of generation (Acar et al., 2015). This corresponds roughly to 0.1% of the aggregate GDP. By contrast, subsidies to renewable energy sources are dwarfed against the coal subsidization programme.

In this study we investigate the macroeconomic and environmental effects of Turkey's existing coal subsidies using an applied general equilibrium model of the computable general equilibrium (CGE) variety. Prospecting on the 2015–2030 macroeconomic path of the Turkish economy, our analytical apparatus focuses on the direct and indirect incentivization of coal mining, exploration, and power generation. With the aid of a set of alternative policy scenarios against a business as usual path, we evaluate the environmental gains of abatement through the removal of these subsidies, and study the regional and sectorial performances of growth, employment, investment and capital accumulation, consumption/welfare, trade balance, and emissions.

The paper is organized as follows: as a continuation of this section, we document the extent and characteristics of Turkey's energy policy, the subsidization of coal in particular. In Section 2, we introduce the salient features of the algebraic equations of the CGE model along with the data sources in Section 3. Next, we report and discuss the results of our policy analysis, using the CGE apparatus as a social laboratory in Section 4, while Section 5 concludes.

1.1. Aspects of Turkey's energy policy and CO2 emissions

Turkey has been experiencing a dramatic structural change with respect to its escalated utilization of electricity and primary energy sources. In line with its growing population and GDP, it has been facing increased energy demand in the recent decades. In 2013, installed electricity capacity reached a level of 64,000 MW, more than 12-times the 1980 capacity level (TEIAS, 2013). The bulk of electricity generation stems from the utilization of fossil fuels, comprised of mainly natural gas and coal. In 2013, gross electricity generation was composed of 44% natural gas, 27% hard coal and lignite, 25% hydro, 3% wind, and a negligible share of geothermal power. Since the country does not own any significant oil or gas reserves, it is highly dependent on energy imports. IEA (2014) reports that, in 2012, energy imports accounted for more than 80% of total primary energy supply. Within this composition, 99% of total gas demand, 93% of oil and 55% of coal were imported from various countries.

In order to decrease the reliance on foreign energy sources, ensure energy security, and meet the growing energy demand, Turkey has pursued strong commitment to utilization of all the domestic coal resources, together with its plans to install three nuclear power plants in the near future. On the other hand, the potential of renewable resources such as solar, geothermal, and wind remains hugely untapped in producing energy. The focus on coal has gone so far as to announce the year 2012 as “the year of coal”. In all the ten-year development plans as well as strategy documents of the Ministry of Energy and Natural Resources (MENR), boosting coal mining and coal-fired electricity generation appears to be among the priorities of the country, with a strong emphasis on the need to increase investments, extend exploration and rehabilitation budgets, and introduce new incentives to the coal sector. For instance, in the 2015–2019 Strategic Plan of the MENR, coal resources are targeted to be utilized to the most efficient extent possible and generation of electricity from domestic coal is aimed to reach an annual level of 60 billion kWh by the end of the plan period. In order to attain these targets, investments in the sector will be accelerated and new reserves will have to be explored. Similarly, in the *Tenth Development Plan*, the desire to intensify the efforts to explore new lignite reserves (as well as oil and gas) is repeated. As part of the program, available coal fields that are ready to be operated will be transferred to the private sector via the “royalty tender system”, public coal-fired power plants will be rehabilitated and investments to build new coal-fired power plants will be facilitated (p. 196).

Coal is still a widely used energy source in the international arena. Data from IEA (2014) reveal that the share of coal in world electricity production rose from 37.4% in 1990 to 40.3% in 2012. Some of this production owes to the availability of generous subsidies provided by governments to the coal sector in many countries. These subsidies are usually designed in order to lower the cost of coal-fired electricity production, increase the price received by energy producers, or decrease the price paid by energy consumers. They take several forms ranging from direct financial transfers and tax exemptions to market price support and provision of services below market rates (provision of land, water, infrastructure, permissions, etc.) based on the WTO definition (WTO, 1994). The cost of fossil fuel subsidies, covering oil, gas and coal subsidies, globally totalled US$ 548 billion, which was four times more than renewable energy subsidies in 2013 according to IEA (2014).

Fossil fuel subsidies in Turkey are mainly comprised of coal subsidies. The most substantial of producer subsidies to coal is direct transfers from the Undersecretariat of Treasury to the hard coal sector in the form of capital and duty loss payments. These transfers are provided with the aims of subsidizing local employment in the hard coal mining regions and amounted up to around US$ 300 million in 2013. Besides, the government supports the coal sector with R&D expenditures, funding for the rehabilitation of hard coal mines and coal power stations, exploration budgets, funding of new coal power plants and investment guarantees to some coal power plants as well as distribution of free coal to poor families as part of its social policy program. Yet, some of the support measures remain unquantifiable since they are not purely financial transfer mechanisms. For instance, exemptions from environmental regulation including temporary exemptions for existing coal plants and permissive environmental impact assessment procedures enable most of the coal projects to be implemented although they are harmful to the environment (Acar et al., 2015, pp. 8–11). Furthermore, Turkey introduced a new investment incentive scheme in 2012, which is comprised of various instruments, ranging from VAT and customs duty exemption, income or corporate tax reduction to social security premium support to the employer, interest support and land allocation. Defined as “priority areas”, new coal mining and power generation projects are subsidized within the regional investment incentive scheme with the most generous measures of Regions V and VI.

Using the data for quantifiable incentives in 2013, Acar et al. (2015) estimate a producer subsidy for coal of around US$0.01 per kWh, which increases to US$0.02 per kWh when coal aid to consumers is included. In 2013, total amount of subsidies to the coal sector reached 0.1% of GDP. Needless to say, these figures serve as an underestimate of the total subsidy amount since they do not cover incentives such as investment guarantees, ease of access to credit, exemption from value-added tax and import duties (within the regional investment incentive scheme), or any of the other subsidies identified, which are expected to be significant. Moreover, based purely on production costs, coal is currently only marginally cheaper than onshore wind and significantly cheaper than solar PV. Yet, adding the identified subsidies and the external costs (such as health and environmental damages), coal becomes more expensive than the alternative renewables such as wind and solar power (Acar et al., 2015). It has to be noted that this assessment is still based on highly incomplete data on coal subsidies and the failure to estimate full social costs of coal. Extending the analysis to include the dynamic effects towards 2030, a recent report by the WWF-Turkey together with Bloomberg New Energy Finance (BNEF, 2014) argues that accounting for decreases in financial costs of renewable technologies and associated declines in subsidies; both solar PV and wind will likely become much cheaper than coal-fired power generation in Turkey. Estimates from various scientific reports (see e.g. Fraunhofer ISE, 2013) confirm that coal power will remain behind renewable energy technologies as an expensive technology, whereas renewable technologies are expected to get cheaper in the next few decades. However, taking advantage of this fall in costs is likely to prove difficult if the energy sector has already configured its technical and institutional structure to support coal-fired generation, and where financial support to the coal industry has become part of the established status quo. This may lead to the danger of, what is termed by Aghion and others, as *path dependence*; that is, firms might be "locked" in dirty technologies. Given the distorted price signals, firms with a history of dirty innovations may be further led to innovate towards maintaining dirty technologies and creating path-dependence in the long run (Aghion, 2014).

As a natural consequence of its energy and subsidy policy, Turkey is simultaneously grappling with the challenge of combating climate change. Although the country does not contribute much to the global level of emissions (around 1% of the world's greenhouse gas (GHG) emissions according to UNFCCC, 2013), it experiences the fastest increase in GHG emissions with respect to its counterparts in the OECD. Aggregate CO2 emissions have increased by 2.8 times since 1990, reaching a level of 403.55 million tons of CO2(eq) in 2010. Fig. 1 demonstrates that over half of these emissions arise from energy combustion, followed by industrial processes, household waste and agriculture respectively. The fact that energy combustion in electricity production releases the highest amount of emissions is because electricity is mainly generated from fossil fuels. Among various industries, cement and iron and steel sectors are the most emission-intensive ones.

These figures reveal that the structure of the current energy and industrial sectors and the existing coal subsidies in Turkey exacerbate the climate change problem triggering higher levels of GHG emissions. As a result of the rapid increase in energy supply embodying a coal-biased composition, the already high rate of increase in emissions will likely to get even worse.

To test this hypothesis, we make use of an applied CGE model. We study the economic and environmental impacts of the current coal subsidy scheme and test various scenarios for the impact of the removal of these subsidies.

2. Methodology: the analytical model

The model is composed of 12 production sectors spanned over two regionalization bodies for the Turkish economy as *High* versus *Low Income*; a representative private household to carry out savings-consumption decisions; a government to implement public policies towards environmental abatement; and a "rest of the world" account to resolve balance of payments transactions. Antecedents of the model rest on the seminal contributions of the CGE analyses on gaseous pollutants, energy utilization, and economics of climate change for Turkey as narrated in Lise (2006), Kumbaroglu (2003), Sahin (2004), Vural (2009), and Telli et al. (2008), Akin-Olcum and Yeldan (2013) Voyvoda and Yeldan (2011) and Bouzaher et al. (2015). All these, however, were based on *national* aggregates. Yet, given the official focus on regional investment and subsidization programme of Turkey, we find it pertinent to work with a regional diversification. Such an exercise was implemented in Yeldan et al. (2013, 2014) in the context of duality of *middle income* versus *poverty traps* of the Turkish socioeconomic structure. Here, we follow their procedure for compilation of data at the regional level. More details of this procedure are narrated in Section 3.

2.1. Commodity structure and regional commodity markets

In this modeling attempt, in the absence of an official *regional* I/O data, we follow the procedure of Yeldan et al. (2013, 2014) in setting a regional differentiation of the components of final demand. Aggregate national accounts are decomposed into two regions: *High* and *Low Income*. Based on this decomposition, we generate a "final good aggregate" in macroeconomic demand based on product differentiation and imperfect substitution a la Armington (1969). The *Armingtonian composite good* structure is

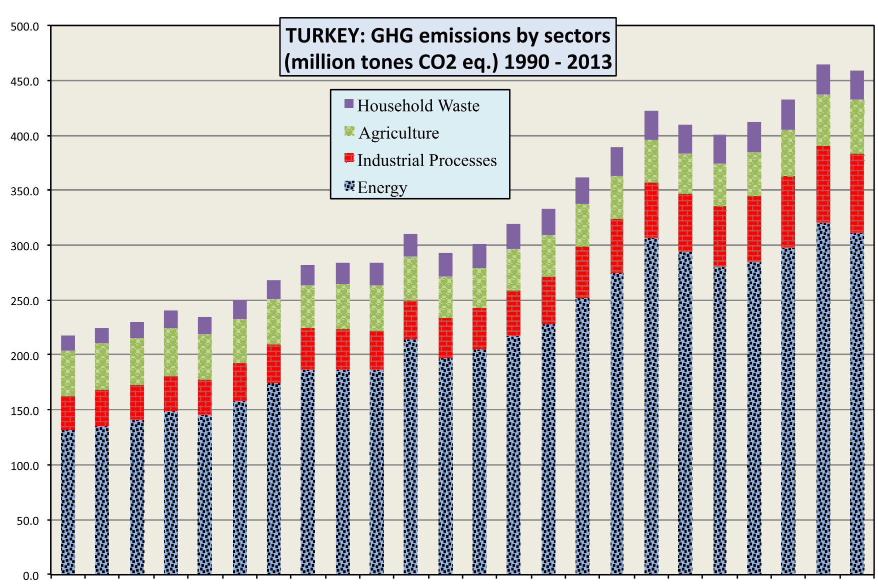

Fig. 1. GHG emissions by sectors (million tons of CO2 eq.) 1990–2013. Source: TurkStat.

Table 1
Distribution of CO2 emissions from sectoral production activities by source of origin. *Source*: Adopted from energy balances tables, min of energy and natural resources.

	Sector	Industrial processes	Primary energy utilization	Secondary energy utilization
AG	Agriculture	0.00	0.00	1.00
CO	Coal	0.00	0.30	0.70
PG	Crude Oil and Natural Gas	0.00	0.80	0.20
PE	Refined Petroleum	0.00	0.88	0.12
CE	Cement	0.66	0.16	0.18
IS	Iron and Steel	0.67	0.15	0.18
MW	Machinery and White Goods	0.00	0.00	1.00
ET	Electronics	0.00	0.75	0.25
AU	Auto Industry	0.00	0.30	0.70
EL	Electricity Production	0.00	1.00	0.00
CN	Construction	0.00	0.00	1.00
OE	Other Economy	0.00	0.40	0.60

utilized in setting the demand for the domestically produced good versus imports of total absorption $(Q^S + M - X)$. We extend this notion across regions, and decompose the sectorial domestically-produced good aggregate, DC_i, into the regional sources as,

$$DC_i = BC_i\left[\gamma_i DC_{i,RH}^{-\rho_i} + (1-\gamma_i)DC_{i,RL}^{-\rho_i}\right]^{-1/\rho_i} \tag{1}$$

Thus, $DC_{i,R}(R = RH, RL)$ forms the aggregate domestic good along an imperfect substitution specification of the Armington aggregate. Aggregate composite good (absorption) is then given as a CES aggregation of imports M_i and domestic good aggregate DC_i,

$$CC_i = AC_i\left[\delta_i DC_i^{-\phi_i} + (1-\delta_i)M_i^{-\phi_i}\right]^{-1/\phi_i} \tag{2}$$

On the production side, production activities are differentiated given regional data on production, employment, and exports.

2.2. Production technology and gaseous pollutants

In each sector i, production of gross output is modelled as a two-stage activity. At the top stage gross output of region R, sector i is given by an expanded Cobb–Douglas functional of the form:

$$Q_{i,R}^S = A_{i,R}\left[K_{i,R}^{\lambda K,i,R} LF_{i,R}^{\lambda LF,i,R} LI_{i,R}^{\lambda LI,i,R} E_{i,R}^{\lambda E,i,R}\left(\prod_{j\notin CO,PG,EL} IN_{j,i,R}^{\lambda IN,j,i,R}\right)\right] \tag{3}$$

In (3), A denotes exogenously determined total factor productivity (TFP) parameter; and K, LF, and LI are the physical capital, formal labor and informal (vulnerable) labor, respectively. Each sector uses intermediate inputs $IN_{j,i}$ as derived from the I/O data. The variable E denotes the energy composite aggregate comprised of three environmentally-sensitive activities of energy generation, viz. coal, petroleum and gas, and electricity. At the lower end of the two-stage characterization of sectorial output, this energy composite is determined by a CES function of its components:

$$E_{i,R} = A_{i,R}^E\left[\varphi_{CO,i,R} IN_{CO,i,R}^{-\varrho i,R} + \varphi_{PG,i,R} IN_{PG,i,R}^{-\varrho i,R} + \varphi_{EL,i,R} IN_{EL,i,R}^{-\varrho i,R}\right]^{-1/\varrho i,R} \tag{4}$$

Under the given energy production technology, optimum mix of inputs of CO, PG, and EL is determined by equating their marginal rate of technical substitution to their respective (input) prices, as to be affected by possible fiscal policy:

Table 2
Input–output Table, 2010 (at basic prices) (Millions TL).

Input-Output Table, 2010 (at basic prices) (Millions TL)

	AG	CO	PG	PE	CE	IS	MW	ET	AU	EL	CN	OE	*Total Intermediate Exp*
AG: Agriculture	25,614.800	67.481	0.897	1,405.056	15.659	9.832	105.001	11.710	9.907	25.964	32.107	77,442.838	**104,741.251**
CO: Coal	49.489	81.947	0.003	51.805	513.335	153.587	14.271	44.415	2.497	1,778.488	32.032	2,801.273	**5,523.143**
PG: Oil and Gas	0.387	0.000	44.432	15,593.164	347.095	153.455	23.208	229.109	36.199	9,590.807	0.767	3,410.723	**29,429.345**
PE: Petroleum Prod Chemicals	9,879.887	323.164	37.078	31,591.743	2,614.506	1,007.931	3,058.065	2,571.708	3,202.099	296.015	5,059.616	71,856.071	**131,497.883**
CE: Cement	199.739	15.532	3.899	886.104	5,012.698	1,591.391	817.311	280.956	539.854	11.199	11,333.485	11,001.081	**31,693.249**
IS: Iran and Steel	7.422	146.704	55.897	1,579.797	229.833	20,994.608	15,992.953	3,145.276	4,776.962	320.216	9,025.592	12,898.080	**69,173.340**
MW: Machinery, White Goods	1,973.396	348.448	16.550	1,578.608	925.739	1,190.378	7,216.930	1,211.597	2,792.033	804.082	9,659.331	15,460.026	**43,177.117**
ET: Electronics	88.738	102.878	6.593	99.412	35.144	18.452	1,639.666	10,203.164	257.943	1,435.500	2,559.128	8,149.167	**24,595.785**
AU: Automative	333.440	0.558	19.221	96.052	63.983	28.459	290.058	64.989	8,040.339	48.060	153.254	8,451.327	**17,589.741**
EL: Electricity	823.915	245.720	96.009	1,570.230	1,092.475	2,527.124	998.247	852.472	277.948	26,862.293	300.334	16,959.532	**52,606.300**
CN: Construction	474.112	23.563	0.426	25.172	6.480	7.567	31.049	11.392	7.420	16.311	1,893.239	6,670.128	**9,166.858**
OE: Other economy	20,568.361	783.729	383.044	29,157.980	11,567.470	10,761.159	12,388.789	7,530.604	6,912.122	3,498.792	21,551.685	508,553.757	**633,657.491**
TOTALS													
Compensation of Employees	4,251.031	1,946.206	153.186	3,723.160	5,419.872	4,016.534	6,604.407	4,445.773	5,695.888	2,368.524	19,508.345	264,853.639	**322,986.564**
Gross Payments to Capital	110,295.535	2,070.317	1,879.114	23,901.056	7,285.312	7,770.953	15,836.297	4,486.609	2,726.235	17,825.235	29,436.706	514,390.659	**737,904.030**
Net Taxes	6,960.333	214.285	13.395	3,169.442	579.151	570.320	672.224	245.702	186.064	191.325	2,810.758	27,246.207	**42,859.207**
Total VA	121,506.899	4,230.808	2,045.695	30,793.658	13,284.335	12,357.807	23,112.929	9,178.085	8,608.187	20,385.084	51,755.810	806,490.505	**1,103,749.801**
Total Production Supply	181,520.585	6,370.531	2,709.743	114,428.781	35,708.751	50,801.751	65,688.477	35,335.476	35,463.511	65,072.811	113,356.380	1,550,144.508	2,256,601.305
Total Supply	185,783.349	10,340.011	29,443.928	187,955.607	40,271.114	84,240.406	113,988.455	62,086.340	53,940.919	65,765.859	113,356.380	1,601,909.049	2,550,633.692

Input-Output Table, 2010 (at basic prices) (Millions TL)

	PCE: Private Consumption Exp	GGCE: Government Consumpiton Exp.	GFCF: Gross Fixed Capital Formation	EXP: Exports	IMP: Imports (-)	*Total Exp on Value Added*	Total Expenditures
AG: Agriculture	72,183.835	332.187	87.141	8,438.935	4,262.764	76,779.334	181,520.585
CO: Coal	4,569.355	241.183	0.000	6.329	3,969.479	847.388	6,370.531
PG: Oil and Gas	0.000	0.000	0.000	14.583	26,734.185	-26,719.601	2,709.743
PE: Petroleum Prod Chemicals	40,367.858	2,541.310	0.000	13,548.556	73,526.826	-17,069.103	114,428.781
CE: Cement	2,001.362	0.000	4.112	6,572.392	4,562.364	4,015.502	35,708.751
IS: Iran and Steel	29.054	0.000	0.000	15,038.012	33,438.655	-18,371.589	50,801.751
MW: Machinery, White Goods	8,838.840	25.228	48,549.527	13,397.743	48,299.978	22,511.360	65,688.477
ET: Electronics	10,718.725	0.000	15,140.130	11,631.699	26,750.864	10,739.691	35,335.476
AU: Automative	9,105.060	0.000	11,250.165	15,995.953	18,477.408	17,873.770	35,463.511
EL: Electricity	13,074.364	0.000	0.000	85.194	693.048	12,466.511	65,072.811
CN: Construction	188.191	0.000	99,455.197	4,546.134	0.000	104,189.522	113,356.380
OE: Other economy	633,273.970	154,311.370	36,865.130	143,801.088	51,764.540	916,487.017	1,550,144.508
TOTALS	**787,269.557**	**157,451.278**	**219,984.734**	**233,076.618**	**294,032.387**	**1,103,749.801**	2,256,601.305

Table 3
Economic indicators across regions (Bill TL, 2010).
Source: TurkStat

Region	Population (Millions)	Gross regional value added	Regional exports	Regional imports	Tax revenues	Public investment
High-income (1)	40.43	745.40	83.27	111.71	130.62	12,399.20
Low-income (2)	33.31	355.30	18.87	29.22	40.70	10,318.78
(1) High income region: TR10, TR21, TR31, TR41, TR42, TR51, TR61						
(2) Low-income region: TR62, TR63, TR71, TR72, TR81, TR82, TR83, TR90,TR52, TR32, TR33, TR22, TRA1, TRA2, TRB1, TRB2, TRC1, TRC2, TRC3						

Note: HIGH income versus POOR Turkey is partitioned using Turkey average per capita income as the cut off.

Table 4
Aggregate CO2 (Eq) emissions, 2010, millions tons.

Total CO2 emissions from energy combustion:		**226.98**
AG	Agriculture	13.69
CO	Coal	2.57
PG	Crude Oil and Natural Gas	13.86
PE	Refined Petroleum	5.58
CE	Cement	16.36
IS	Iron and Steel	8.27
MW	Machinery and White Goods	1.16
ET	Electronics	2.08
AU	Auto Industry	0.07
EL	Electricity Production	112.41
CN	Construction	0.02
OE	Other Economy	50.91
Total CO2 emissions by households		**50.47**
Total CO2 emissions from industrial processes		**49.06**
	Cement	31.74
	Iron and Steel	17.32
Total CO2 emissions from agri processes		27.13
Total GHG emissions (CO2 eq)		85.64
	CH4	60.44
	N2O from transportation	19.48
	F Gasses	5.72
Total CO2 (eq).		**411.74**

$$\frac{IN_{CO,i,R}}{IN_{EL,i,R}} = \left[\left(\frac{\varphi_{CO,i,R}}{(1-\varphi_{CO,i,R}-\varphi_{PG,i,R})}\right)\left(\frac{P_{EL,i,R}}{(1+t^{ENV}_{CO,i,R})P_{CO,i,R}}\right)\right]^{\sigma_{i,R}} \tag{5}$$

$$\frac{IN_{PG,i,R}}{IN_{EL,i,R}} = \left[\left(\frac{\varphi_{PG,i,R}}{(1-\varphi_{CO,i,R}-\varphi_{PG,i,R})}\right)\left(\frac{P_{EL,i,R}}{(1+t^{ENV}_{PG,i,R})P_{PG,i,R}}\right)\right]^{\sigma_{i,R}} \tag{6}$$

where t^{ENV} is the relevant tax instrument on the pollutant activity, and σ is the elasticity of substitution with $\sigma = 1/(1+\varrho)$.

Sectorial demands for capital, labor, and the remaining intermediate inputs follow the conventional optimization rules with equating marginal products with their respective input prices. The production technology for gross output in (3) is of constant returns; thus,

$$\lambda_{K,i,R} + \lambda_{LF,i,R} + \lambda_{LI,i,R} + \lambda_{E,i,R} + \sum_j \lambda_{ID,j,i,R} = 1 \tag{7}$$

We capture the aggregate $CO2$ emissions in each sector (and region) from three sources of origin: primary energy combustion (EE), secondary energy combustion (SE), and industrial processes (IND). In our specification, secondary energy combustion is due to utilization of refined petroleum (RP), and emissions from industrial processes are derived exclusively from iron and steel (IS) and cement (CE). Making use of the aggregate energy material balances data we map each sector's $CO2$ emissions to these major sources with the aid of the following summary table:

Depending on the source of origin of the gaseous $CO2(eq)$ emissions we specify distinct mechanisms. For capturing emissions from the primary energy combustion activities we set

$$CO2^{EE}_{j,i,R} = \epsilon_{j,i,R} \cdot a_{j,i,R} \cdot Q^S_{j,i,R} \tag{8}$$

and for the combustion of secondary energy source (refined petroleum) we implement,

$$CO2^{SE}_{RP,i,R} = z_{RP,i,R} \cdot a_{RP,i,R} \cdot Q^S_{RP,i,R} \tag{9}$$

The parameter $\epsilon_{j,i,R}$ in (8) summarizes the energy use coefficients as calibrated from the Material Energy Balances Tables to set the composition of emissions from primary energy via combustion of coal and petroleum and gas in each sector. The $z_{RP,i,R}$ parameter in (9) similarly narrates the emission coefficient due to combustion of RP. The traditional input–output coefficient, $a_{j,i} = IN_{j,i}/Q^S_i$ is responsive to price signals via optimization on costs, given technology (3). This is in contrast to the traditional CGE analyses where $a_{j,i}$ is typically regarded fixed as in a Leontieff technology.

Emissions from industrial processes are recognized within iron and steel (IS) and cement (CE). These emissions are simply regarded as proportional to respective real output:

$$CO2^{IND}_{i,R} = \eta_{i,R} Q^S_{i,R}, \quad i \in \{IS, CE\} \tag{10}$$

Emissions from agricultural processes are similarly set proportional to agricultural gross output. Emissions of non-CO2 gasses (CH4, F and NO2) are set proportional to the primary energy combustion activities. Thus, $CO2(eq)$ emissions of CH4 become:

$$CO2^{CH4}_{j,i,R} = \varepsilon_{j,i,R} \cdot a_{j,i,R} \cdot Q^S_{i,R} \quad \text{for } j = \{CO, PG\} \tag{11}$$

as for CH4 from waste,

$$CO2^{WST}_{j,i,R} = \varpi_{j,i,R} \cdot Q^S_{i,R} \tag{12}$$

Households' demand for energy results in a further source of $CO2(eq)$ emissions. This is regarded as proportional to the household consumption of basic fuels, viz. coal and refined petroleum. Thus,

$$CO2^{HH} = \sum_{i \in CO,RP} \kappa_i C^D_i \tag{13}$$

Aggregate $CO2(eq)$ emissions is the sum of each of these sources:

$$CO2^{TOT} = \sum_{j,i,R} (CO2^{EE}_{j,i,R} + CO2^{SE}_{j,i,R} + CO2^{CH4}_{j,i,R} + CO2^{WST}_{j,i,R}) + \sum_{i \in IS,CE} CO2^{IND}_{i,R} + \sum_R CO2^{AGR}_R + CO2^{HH} \tag{14}$$

2.3. Labor markets, income generation and general equilibrium

We distinguish two types of labor: *formal* and *informal/vulnerable*. Based on ILO's specification,[1], vulnerable employment is

[1] ILO, *World of Work*, various issues, Geneva.

Table 5
Parameters of the labor market (2010).
Source: TurkStat, Household Labor force surveys and our calculations.

	Sector	Total labor emp	Labor employment (thousand workers)				Total Wages (Millions 2010 TL)				Wage Rates (Thousands 2010 TL)			
			High income region		Low income region		High income region		Low income region		High income region		Low income region	
			Formal labor emp	Informal labor emp	Formal Labor emp	Informal Labor emp	Formal Labor	Informal labor	Formal Labor	Informal labor	Formal Labor	Informal labor	Formal Labor	Informal labor
AG	Agriculture	5682.853	34.153	1502.994	72.210	4073.496	454.322	534.326	1,119.376	2757.047	13.303	0.356	15.502	0.677
CO	Coal	65.518	16.496	0.652	46.723	1.648	529.123	13.237	1063.762	20.801	32.077	20.315	22.767	12.624
PG	Crude Oil and Natural Gas	5.313	0.453	0.000	4.556	0.304	20.407	0.000	153.631	1.274	45.068	0.000	33.720	4.191
PE	Refined Petroleum	138.960	30.308	2.405	98.077	8.171	839.195	32.825	3268.372	120.560	27.689	13.648	33.325	14.756
CE	Cement	299.684	56.802	12.734	188.408	41.740	1281.284	173.130	3,018.463	305.369	22.557	13.596	16.021	7.316
IS	Iron and Steel	183.921	55.112	4.706	109.157	14.946	1543.939	66.926	2792.838	192.999	28.015	14.220	25.586	12.913
MW	Machinery and White Goods	393.738	67.917	22.131	220.388	83.301	1556.816	218.166	5,086.336	697.063	22.922	9.858	23.079	8.368
ET	Electronics	177.762	40.885	5.445	118.237	13.195	1432.170	38.870	1736.353	72.098	35.030	7.138	14.685	5.464
AU	Auto Industry	228.894	66.461	3.425	149.705	9.303	2,157.231	59.785	1,682.640	38.005	32.458	17.458	11.240	4.085
EL	Electricity Production	72.614	21.134	0.589	50.082	0.809	801.617	8.386	1883.194	17.449	37.929	14.241	37.602	21.565
CN	Construction	1431.475	182.495	186.373	441.946	620.660	4,563.734	1875.159	4,974.495	2,969.171	25.007	10.061	11.256	4.784
OE	Other Economy	13,913.520	2,409.235	1,154.141	6646.650	3703.494	76,400.728	6,569.125	193,509.924	26,630.625	31.712	5.692	29.114	7.191
Total		22594.252	**2981.450**	**2895.595**	**8146.139**	**8571.068**	**91580.566**	**9589.933**	**220289.384**	**33822.462**				

characterized by informal/unregistered employees without any social security coverage; self-employed, and unpaid family workers. The two labor categories obey different labor market characteristics. We set the formal wage rates exogenously given, calibrated above the otherwise market clearing wage rate to generate the level of regional unemployment rates as of 2010. Thus, the formal labor market clears by quantity adjustments on employment,

$$U_{LF,R} = L^S_{LF,R} - \sum_i LF^D_{i,R} \tag{15}$$

The informal/vulnerable labor market, on the other hand, operates with fully flexible wages. The low level of informal wages is a symptomatic proxy for poverty of vulnerable labor.

Over periods, the regional labor markets are linked by migration. This is based on (expected) wage differences across the high income versus low income Turkey, and is driven along the classic *Harris–Todaro* (1970) specification. Thus, given the migrants from each labor type, $l = LF, LI$

$$MIG_l(t) = \mu_l \left[\frac{(E[W_{l,RH}] - W_{l,RL})}{W_{l,RL}} \right] L^S_{l,RL} \tag{16}$$

where $E[W_{l,RH}]$ is the expected wage rate of labor type-l ($= LF, LI$) in the high income region, and μ_l is a calibration parameter.

Given $MIG_l(t)$, based on wage expectations from region-*High*, labor supplies evolve according to,

$$L^S_{l,RL}(t+1) = (1 + n_{l,RL}) L^S_{l,RL}(t) - MIG_l(t)$$
$$L^S_{l,RH}(t+1) = (1 + n_{l,RH}) L^S_{l,RH}(t) + MIG_l(t) \tag{17}$$

Capital stocks evolve given fixed investments net of depreciation. Allocation of aggregate net investment funds to sectors (investment by sector of destination) is accomplished through the calculus of regional profitability. Given sectorial profit rates, $r_{i,R}$, across region and the economy-wide average profit rate, r^{AVG}, sectorial investment allocations, $\Delta K_{i,R}(t+1)$ are given by the following simple rule:

$$\Delta K_{i,R}(t+1) = \Pi_{i,R} + \Pi_{i,R} \left[\frac{r_{i,R-r^{AVG}}}{r_{i,R}} \right] \tag{18}$$

where $\Pi_{i,R}$ is the share of aggregate profits in sector *i*, region *R*. This share sets the allocation of physical investments to be reused via differences in profits in the second part of the equation.

Private household income is composed of labor wage incomes and remittances of profits from the enterprise sector. In turn, the public sector revenues comprise tax revenues from wage and capital incomes, and non-tax sources of income from various exogenous flows. The income flow of the public sector is further augmented by indirect taxes and environmental taxes. The model follows the fiscal budget constraints closely. Given public earnings, government's "transfer expenditures to households" is adjusted endogenously to sustain other components of public demand (public investment and consumption expenditures) as fixed ratios to national income.

The general equilibrium of the system is obtained via endogenous solutions on prices, wage rates and the exchange rate. Informal wage rates across regions clear regional labor markets. The balance of payments is cleared through flexible adjustments on the real exchange rate (ratio of domestic good price to imports in the CGE folklore) while the *nominal* conversion factor across domestic and world prices serving as the *numérairé* of the system.

The model is solved iteratively by updating of the annual "solutions" of the model up to 2030. Aggregate output supplies grow through three channels: (i) exogenous growth of labor supplies; (ii) investments on physical capital net of depreciation; and (iii)

Table 6
Macroeconomic results (Bill TL, 2010 fixed prices).

	Base path				Scenario 1: Eliminate production subsidies on coal				Scenario 2: Eliminate both production and investment subsidies on coal			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
High income region total supply	1765.3	2,141.9	2572.5	3145.3	1763.2	2,139.2	2569.1	3141.0	1759.7	2,133.8	2561.8	3131.2
Low income region total supply	1055.8	1,306.7	1,600.0	1863.9	1054.1	1,304.5	1597.1	1860.6	1051.3	1,300.5	1591.7	1853.7
Total GDP	1,367.3	1,660.4	1991.9	2,371.0	1,365.7	1,658.3	1989.2	2,367.7	1,362.4	1,653.4	1982.7	2,359.2
Real rate of growth GDP	4.6	3.7	3.3	3.5	4.6	3.7	3.3	3.5	4.6	3.7	3.3	3.4
High income region value added	680.7	818.0	981.4	1,190.9	679.4	816.3	979.4	1,188.5	677.2	813.3	975.4	1,183.4
Low income region value added	425.8	515.8	625.9	739.9	424.8	514.7	624.4	738.2	423.4	512.7	621.8	734.9
Formal labor employment in high income region (Mill Per)	3.6	3.6	4.0	4.5	3.6	3.6	3.9	4.5	3.6	3.6	3.9	4.5
Formal labor employment in low income region (Mill Per)	8.7	10.0	11.5	12.7	8.7	10.0	11.5	12.7	8.7	10.0	11.4	12.6
Formal labor employment, Total (Mill Per)	12.3	13.7	15.5	17.2	12.3	13.6	15.4	17.2	12.2	13.6	15.4	17.1
InFormal labor employment in high income region (Mill Per)	2.8	2.8	3.0	3.3	2.8	2.8	3.0	3.3	2.8	2.8	3.0	3.3
InFormal labor employment in low income region (Mill Per)	9.7	10.9	12.1	13.2	9.7	10.9	12.1	13.2	9.7	10.9	12.1	13.2
Informal labor employment, Total (Mill Per)	12.5	13.7	15.1	16.5	12.5	13.7	15.1	16.5	12.5	13.7	15.1	16.5
Total labor employment (Mill Per)	24.8	27.4	30.5	33.7	24.8	27.3	30.5	33.7	24.7	27.3	30.4	33.6
Informal labor migration (1000s)	−21.0	9.5	19.9	44.7	−21.1	9.5	19.9	44.7	−21.0	9.5	19.9	44.8
Unemployment rate high income	8.0	8.0	8.0	7.0	8.1	8.0	8.0	7.0	8.2	8.1	8.1	7.0
Unemployment rate low income	12.0	11.0	9.0	8.0	12.1	11.2	9.2	8.2	12.3	11.4	9.5	8.5
Average unemployment rate	11.0	10.3	8.8	7.8	11.1	10.4	8.9	7.9	11.3	10.6	9.1	8.2
Private disposable income	1053.9	1254.4	1507.4	1806.4	1051.9	1251.9	1504.3	1802.7	1048.7	1247.4	1498.3	1794.9
Government revenues/GDP	25.2	25.1	25.0	24.9	25.2	25.1	25.1	25.0	25.3	25.2	25.1	25.0
PSBR/GDP	−1.1	0.3	0.3	0.2	−1.1	0.3	0.3	0.2	−1.1	0.3	0.3	0.2
Aggregate investment	275.2	325.2	376.8	440.1	275.0	325.0	376.5	439.8	274.6	324.3	375.6	438.6
Aggregate consumption	942.7	1,129.8	1,349.1	1598.4	940.8	1,127.5	1,346.2	1594.8	937.8	1,123.3	1,340.7	1587.7
Private foreign Debt/GDP	55.6	68.3	74.9	77.5	55.6	68.4	75.0	77.6	55.7	68.5	75.2	77.8
Government foreign Debt/GDP	24.6	20.4	16.9	14.0	24.6	20.4	16.9	14.0	24.7	20.5	17.0	14.1
Government domestic Debt/GDP	19.6	10.8	10.4	9.9	19.6	10.8	10.4	9.9	19.7	10.9	10.5	10.0
Current account deficit/GDP	5.4	4.4	3.7	3.1	5.4	4.4	3.7	3.1	5.4	4.5	3.7	3.1

total factor productivity (TFP) growth, which in turn is regarded exogenous. In each period, capital stocks across regions and sectors are augmented with net investments. Regional labor supplies are increased exogenously by population growth and the migration process (see Eq. (16)). Technical factor productivity rates are updated in a Hicks-neutral manner. Formal real wage rates are updated by the cost of living level index (endogenously solved).

3. Data sources and calibration methodology

3.1. Construction of the regional social accounting data base

Input–Output (I/O) data at the regional level are not present in Turkey. The most recent I/O data is tabulated in 2002 by TurkStat. Given the lack of official regional data, we strive to differentiate regional economic activities based on the standard tools of CGE applications. We first update the 2002 I–O table as officially published by TurkStat to 2010 using the national income data on macro-aggregates. Then using the RAS's on sectorial shares, we obtained sectorial components of final demand. Labor remunerations are obtained from ILO and TurkStat Household Labor Force Surveys (HLFS) data.

The aggregated I/O table for 2010 is displayed below.

In reaching the regional SAM (which is available upon request), we decomposed the national macro-aggregates via the shares of gross regional value added (RGVA). Based on our differentiation of the *level-2* NACE-1 data, we distinguish 7 regions as "High-Income" and 19 regions are classified under "Low Income". Data reveal that the *Low Income* region hosts about 60% of the total population of 73.7 million persons, and produces about 32% aggregate value added while the remaining 68% is originated in the *High Income* region. For further specifics of the regional macro-data, see Table below.

The SAM tabulates the micro-level I/O data along with the aggregate macro data on public sector balances and resolution of the saving-investment equilibrium. The latter discloses a current account deficit (foreign savings) of TL72.5 billion (roughly 6.5% to the GDP). The two regions identified, *High* versus *Low Income* Turkey yield the production activities; while components of aggregate national demand are revealed by way of imperfect substitution in demand, and are calibrated through standard methods of the Armingtonian composite system.

This procedure is definitely a poor alternative to a more direct approach based on regionally differentiated production structures. This, however, would necessitate *regional* input–output data along with regional material balances. In the absence of official and/or independent data at the regional level, we had to resort to the Armingtonian imperfect substitutability framework based on cost optimization.

Note that the specification here is designed only to capture the regionally differentiated component of (investment) subsidization, and should not be regarded as a detailed structural characterization of the dualistic (fragmented) patterns of production attributable to the Turkish economy, an issue which is clearly beyond the scope of this paper.

Table 7
Environmental results.

	Base path				Scenario 1: Eliminate production subsidies on coal				Scenario 2: Eliminate both production and investment subsidies on coal			
	2015	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**
CO2 total, Mill tons	406.2	493.3	584.3	682.3	392.9	477.6	566.3	662.2	377.7	459.4	545.4	638.5
Total CO2 (Eq), Mill tons, Mill tons	506.0	604.0	708.7	821.9	492.0	587.8	690.4	801.6	476.0	569.0	669.0	777.4
High income, CO2 emissions from coal burning for energy	47.8	55.2	61.4	67.4	38.2	44.1	49.1	54.0	27.2	31.5	35.1	38.6
Low income, CO2 emissions from coal burning for energy	12.6	15.5	18.4	20.9	10.0	12.4	14.8	16.7	7.2	8.9	10.5	12.0
High income, CO2 energy related	218.6	258.5	293.8	328.7	209.9	248.4	282.5	316.3	200.2	237.1	269.8	302.3
Low income, CO2 energy related	61.3	78.0	94.9	109.4	59.0	75.2	91.5	105.6	56.5	72.0	87.8	101.2
High income, CO2 industrial processes	54.0	68.7	87.8	114.4	53.8	68.4	87.5	114.0	53.5	68.0	87.0	113.3
Low income, CO2 industrial processes	12.5	15.9	20.3	24.8	12.5	15.9	20.3	24.7	12.4	15.8	20.1	24.5
High income, CO2 eq: Agriculture	24.8	28.8	32.6	38.9	24.8	28.8	32.6	38.9	24.8	28.7	32.5	38.8
Low income, CO2 eq: Agriculture	24.6	31.8	38.7	43.9	24.6	31.8	38.7	43.9	24.6	31.8	38.6	43.8
CO2 households	59.8	72.2	87.4	105.1	57.8	69.7	84.5	101.7	55.1	66.5	80.7	97.1
Total CO2 energy related	339.7	408.7	476.1	543.2	326.7	393.3	458.6	523.6	311.8	375.6	438.3	500.7
Total CO2/GDP (kg/$GDP)	0.535	0.535	0.528	0.518	0.518	0.518	0.512	0.503	0.499	0.500	0.495	0.487
CO2 from Energy/GDP(kg/$GDP)	0.447	0.443	0.430	0.412	0.431	0.427	0.415	0.398	0.412	0.409	0.398	0.382
Intermediate demand coal in low income	2.302	2.707	3.194	3.705	1.839	2.164	2.556	2.968	1.311	1.543	1.826	2.125
Intermediate demand coal in high income	4.239	4.941	5.761	6.835	3.389	3.951	4.612	5.478	2.416	2.818	3.296	3.922
Intermediate demand Petr&Gas in low income	12.961	16.086	19.871	23.790	13.043	16.181	19.979	23.914	13.148	16.293	20.101	24.046
Intermediate demand Petr&Gas in high income	23.266	28.245	34.314	41.958	23.416	28.416	34.508	42.183	23.613	28.625	34.734	42.434
Intermediate demand Ref Petr in low income	62.632	78.443	97.802	117.526	62.527	78.309	97.628	117.315	62.361	78.065	97.291	116.880
Intermediate demand Ref Petr in high income	103.463	128.010	157.713	195.276	103.317	127.823	157.476	194.982	103.087	127.475	156.996	194.343

Table 8
Real Output (Bill TL, 2010 fixed prices)

	Sector	Base path				Scenario 1: eliminate production subsidies on coal				Scenario 2: eliminate both production and investment subsidies on coal			
		2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Real output by sectors, low income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	182.861	236.169	286.969	325.894	182.951	236.249	236.249	325.892	182.898	236.045	286.598	325.322
CO	Coal	2.517	2.983	3.548	4.057	1.796	2.129	2.129	2.894	1.162	1.376	1.635	1.867
PG	Crude Oil and Natural Gas	1.482	2.125	2.811	3.310	1.495	2.142	2.142	3.334	1.511	2.162	2.855	3.359
PE	Refined Petroleum	54.129	71.191	91.789	111.123	54.081	71.122	71.122	110.999	53.985	70.955	91.437	110.661
CE	Cement	15.758	19.452	23.772	27.799	15.686	19.362	19.362	27.673	15.580	19.223	23.485	27.464
IS	Iron and Steel	24.705	33.105	45.011	57.756	24.616	32.981	32.981	57.536	24.495	32.803	44.581	57.195
MW	Machinery and White Goods	29.864	37.092	45.712	53.859	29.818	37.033	37.033	53.766	29.744	36.924	45.485	53.577
ET	Electronics	17.280	23.245	30.995	38.017	17.260	23.217	23.217	37.967	17.226	23.159	30.866	37.847
AU	Auto Industry	18.021	25.688	37.714	49.599	18.031	25.705	25.705	49.659	18.032	25.701	37.746	49.664
EL	Electricity Production	31.285	41.457	53.823	65.958	31.345	41.526	41.526	66.040	31.420	41.594	53.949	66.073
CN	Construction	55.667	70.042	84.552	97.496	55.670	70.037	70.037	97.468	55.609	69.927	84.362	97.244
OE	Other Economy	622.220	744.168	893.265	1029.015	621.321	743.034	743.034	1027.328	619.628	740.669	888.688	1023.454
Real output by sectors, high income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	55.100	63.839	72.344	86.319	55.077	63.809	72.306	86.268	55.036	63.733	72.199	86.112
CO	Coal	4.994	5.798	6.682	7.879	3.568	4.142	4.773	5.626	1.852	2.149	2.474	2.914
PG	Crude Oil and Natural Gas	2.199	2.693	3.096	3.627	2.217	2.714	3.119	3.652	2.241	2.741	3.147	3.683
PE	Refined Petroleum	95.268	120.626	151.567	190.783	95.183	120.510	151.417	190.589	95.043	120.273	151.069	190.100
CE	Cement	30.796	37.901	45.943	56.575	30.678	37.754	45.765	56.354	30.506	37.525	45.477	55.984
IS	Iron and Steel	48.444	65.054	89.841	125.697	48.294	64.848	89.553	125.283	48.103	64.560	89.128	124.652
MW	Machinery and White Goods	58.242	72.754	89.156	111.180	58.204	72.703	89.088	111.092	58.142	72.592	88.921	110.853
ET	Electronics	32.357	41.541	54.504	72.607	32.329	41.504	54.455	72.542	32.288	41.432	54.347	72.382
AU	Auto Industry	34.203	44.370	63.590	95.340	34.225	44.401	63.656	95.484	34.245	44.414	63.690	95.587
EL	Electricity Production	53.754	67.655	84.709	106.287	53.849	67.762	84.826	106.419	53.987	67.889	84.938	106.511
CN	Construction	96.065	112.904	129.886	153.346	96.055	112.884	129.851	153.295	95.964	112.724	129.618	152.969
OE	Other Economy	1253.900	1506.745	1781.172	2,135.624	1253.532	1506.144	1780.299	2,134.413	1252.283	1503.795	1776.800	2,129.466

Table 9

	Sector	Base path				Scenario 1: eliminate production subsidies on coal				Scenario 2: eliminate both production and investment subsidies on coal			
		2015	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**
Capital stocks by sectors, low income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	97.577	136.008	172.299	196.418	97.697	136.144	172.408	196.516	97.727	136.077	172.197	196.185
CO	Coal	0.183	0.246	0.308	0.350	0.131	0.176	0.220	0.250	0.064	0.086	0.108	0.122
PG	Crude oil and Natural Gas	0.910	1.366	1.819	2.106	0.919	1.379	1.834	2.123	0.930	1.393	1.851	2.140
PE	Refined Petroleum	9.085	13.061	17.142	20.001	9.094	13.070	17.149	20.008	9.096	13.062	17.126	19.974
CE	Cement	0.898	1.245	1.579	1.803	0.897	1.244	1.577	1.801	0.895	1.240	1.572	1.794
IS	Iron and Steel	1.072	1.597	2.220	2.737	1.071	1.595	2.217	2.733	1.069	1.591	2.210	2.723
MW	Machinery and White Goods	1.841	2.558	3.250	3.711	1.843	2.559	3.250	3.712	1.842	2.557	3.245	3.705
ET	Electronics	1.687	2.507	3.411	4.022	1.689	2.510	3.413	4.024	1.690	2.509	3.409	4.018
AU	Auto Industry	1.609	2.532	3.778	4.756	1.613	2.538	3.788	4.769	1.617	2.543	3.794	4.777
EL	Electricity Production	7.637	10.855	14.165	16.651	7.701	10.940	14.268	16.768	7.782	11.043	14.386	16.896
CN	Construction	13.739	18.948	23.431	26.300	13.765	18.979	23.460	26.330	13.776	18.979	23.444	26.301
OE	Other Economy	24.060	32.701	41.276	47.042	24.077	32.717	41.283	47.046	24.067	32.677	41.205	46.940
Capital stocks by sectors, high income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	25.902	29.004	30.824	34.733	25.898	28.996	30.815	34.719	25.888	28.970	30.776	34.661
CO	Coal	2.279	2.597	2.787	3.086	1.632	1.859	1.995	2.208	0.743	0.846	0.907	1.003
PG	Crude Oil and Natural Gas	1.565	1.852	2.002	2.220	1.578	1.868	2.017	2.236	1.597	1.887	2.037	2.257
PE	Refined Petroleum	20.583	24.672	27.750	31.868	20.585	24.673	27.749	31.865	20.585	24.658	27.723	31.825
CE	Cement	8.298	9.810	10.792	12.248	8.290	9.798	10.779	12.232	8.275	9.776	10.750	12.194
IS	Iron and Steel	7.975	10.174	12.494	15.831	7.965	10.160	12.476	15.806	7.953	10.139	12.446	15.762
MW	Machinery and White Goods	16.256	19.377	21.384	24.398	16.263	19.383	21.389	24.403	16.271	19.382	21.380	24.384
ET	Electronics	5.402	6.615	7.741	9.364	5.404	6.617	7.744	9.367	5.407	6.618	7.742	9.362
AU	Auto Industry	3.950	4.906	6.244	8.458	3.957	4.915	6.257	8.480	3.966	4.924	6.270	8.502
EL	Electricity Production	14.526	17.187	19.196	21.929	14.635	17.309	19.326	22.071	14.785	17.471	19.491	22.246
CN	Construction	30.662	34.800	36.527	39.885	30.690	34.828	36.553	39.910	30.705	34.826	36.536	39.875
OE	Other Economy	486.945	566.930	618.037	692.147	487.213	567.170	618.237	692.300	487.317	566.939	617.716	691.437

3.2. Parametrization of gaseous pollutants

A total of 411.74 million tons of $CO2(eq)$ was reportedly released in Turkey in 2010. TurkStat data distinguish this sum into four sources: energy combustion (284.8 mtons), industrial processes (60.0 mtons), agricultural processes (39.8 mtons), and waste (27.2 mtons). At a different level of aggregation, 326.1 mtons of this sum is due to emissions of $CO2$, 60.44 mtons is due to emissions of CH4; 19.48 mtons to N_2O, and 5.72 mtons to F-gasses.

In order to direct these data into sectorial sources of origin, we make use of the TurkStat data as reported to the UNFCCC inventory system. The original data on greenhouse gas source and sink categories are used whenever it was possible to make a direct connection between the sectors recognized in the official data and the sectors distinguished in the model: agriculture, refined petroleum, cement, iron and steel, and electricity. We have allocated the remaining unaccounted CO2 emissions by the share of sectorial intermediate input demand to the aggregate. This exercise yields the following summarization of $CO2(eq)$ emissions across production sectors and other activities.

Using data in the above table we first calculate total sectorial emissions, $CO2_i^{TOT}$. This sum is then decomposed into three main sources of origin, emissions from combustion of primary energy (EE) and of secondary energy (SE), and from industrial processes (IND). This is done with the aid of Table 1 above. Let $\pi_{S,i}$ ($s \in EE, SE, IND$) be a typical element of Table 1, then:

$$CO2_{S,i} = \pi_{S,i} \cdot CO2_i^{TOT}$$

The coefficient $z_{RP,i}$ is then calibrated by (Tables 2 and 3)

$$z_{RP,i} = \frac{CO2_{RP,i}^{SE}}{IN_{RP,i}}$$

For distinguishing this aggregate into the regional activities, regional shares of sectorial output had been used. Ideally the source of $CO2(eq)$ emissions ought to be used for regions. However, in the absence of precise data across regional measurements, we had to abstain from making ad hoc specifications. For the EE sources of $CO2(eq)$ emissions across sectors (for $j \in CO$ and PG) we follow a similar procedure and find $CO2_{j,i}^{EE}$ from data displayed in Table 4 by applying the $\varepsilon_{j,i}$ for $j \in CO$ and PG.

3.3. Calibration of the labor markets

Two types of labor are distinguished in the model: formal (LF) and informal/vulnerable (LI). The characterization is based on the ILO's definition of vulnerable employment as: informal (unregistered employment that is under any social security coverage) + self-employed + unpaid family labor. Based on these criteria, total employment of 22,594 thousand workers is distributed across regions and sectors using the HLFS data of TurkStat. See Table 5 for parametrization of the labor markets.

In setting the formal labor share in national income, the I/O Wage and Salary data is used. Using this point data, we then used the formal/vulnerable employment shares from the HLFS data to reach aggregate wage income data of the informal/vulnerable labor. Finally, by using the sectorial income shares of the I/O table sectorial/regional wage remunerations across labor types are obtained. Full data is summarized in Table 5 above.

Table 10

	Sector	Base path				Scenario 1: eliminate production subsidies on coal				Scenario 2: eliminate both production and investment subsidies on coal			
		2015	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**
Exports by sectors, low income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	10.465	14.968	18.302	19.294	10.503	15.017	18.354	19.347	10.541	15.060	18.393	19.381
CO	Coal	0.002	0.003	0.003	0.004	0.001	0.001	0.002	0.002	0.000	0.001	0.001	0.001
PG	Crude Oil and Natural Gas	0.010	0.017	0.024	0.028	0.010	0.017	0.024	0.028	0.010	0.017	0.025	0.028
PE	Refined Petroleum	7.011	9.955	13.549	16.518	7.011	9.954	13.545	16.513	7.007	9.942	13.521	16.478
CE	Cement	2.906	3.669	4.549	5.220	2.883	3.640	4.514	5.181	2.851	3.599	4.462	5.122
IS	Iron and Steel	7.526	10.526	14.962	19.465	7.491	10.476	14.890	19.372	7.445	10.407	14.788	19.235
MW	Machinery and White Goods	6.157	7.885	10.001	11.733	6.149	7.874	9.986	11.715	6.136	7.854	9.957	11.678
ET	Electronics	5.989	8.517	11.935	14.814	5.983	8.508	11.921	14.796	5.973	8.488	11.889	14.752
AU	Auto Industry	8.578	12.942	20.116	27.015	8.588	12.958	20.145	27.061	8.595	12.965	20.158	27.084
EL	Electricity Production	0.047	0.070	0.098	0.123	0.047	0.070	0.098	0.122	0.046	0.069	0.097	0.121
CN	Construction	2.447	3.305	4.159	4.734	2.449	3.308	4.161	4.737	2.450	3.307	4.158	4.732
OE	Other Economy	55.732	66.569	79.041	87.020	55.666	66.485	78.936	86.902	55.541	66.309	78.702	86.625
Exports by sectors, high income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	2.656	3.101	3.320	3.832	2.661	3.107	3.326	3.838	2.669	3.114	3.333	3.845
CO	Coal	0.005	0.006	0.006	0.007	0.002	0.003	0.003	0.004	0.001	0.001	0.001	0.001
PG	Crude Oil and Natural Gas	0.012	0.015	0.016	0.018	0.012	0.015	0.016	0.019	0.013	0.015	0.017	0.019
PE	Refined Petroleum	12.049	16.022	20.877	27.237	12.049	16.021	20.875	27.233	12.049	16.011	20.855	27.199
CE	Cement	5.970	7.494	9.164	11.462	5.931	7.446	9.106	11.390	5.877	7.377	9.020	11.280
IS	Iron and Steel	15.356	21.507	31.212	45.933	15.298	21.424	31.092	45.752	15.227	21.315	30.924	45.492
MW	Machinery and White Goods	12.577	16.240	20.391	26.206	12.578	16.241	20.391	26.204	12.581	16.236	20.378	26.178
ET	Electronics	11.379	15.113	20.710	28.868	11.372	15.104	20.697	28.851	11.364	15.086	20.668	28.803
AU	Auto Industry	16.527	22.011	33.240	52.662	16.547	22.039	33.293	52.773	16.572	22.065	33.343	52.880
EL	Electricity Production	0.077	0.103	0.134	0.176	0.076	0.102	0.134	0.174	0.076	0.101	0.132	0.173
CN	Construction	4.008	4.755	5.460	6.501	4.011	4.758	5.463	6.504	4.013	4.758	5.461	6.499
OE	Other Economy	121.844	146.795	169.551	201.030	121.955	146.911	169.671	201.150	122.064	146.953	169.648	201.040

4. Results and discussion of the policy analysis

4.1. The "business-as-usual" base path

Following the general CGE tradition, we start by integrating a "business-as-usual" base path into our analysis. This will be used as a reference path to assess the macroeconomic and environmental performance of our policy scenarios.

Over this path we first introduce the projections of the exogenously specified flows and parameters. "Population" growth rates for the two labor types across regions are adapted from the UN projections and TurkStat data, and are set at 2% per annum for low income region; and 0.8% for the high income region. The migration elasticity parameter in Eq. (16) is taken as 0.05 for both labor types. Capital stocks are updated by new (fixed) investments net of depreciation. Both the depreciation rate and sectorial/regional total factor productivity (TFP) growth rates (growth rate of A in Eq. (3) above) are adjusted to obtain the projected growth of the domestic economy over 2015–2030, at the rate of 4% per annum. Detailed official growth projections are given for Turkey, albeit on a very rough analytical backing, and for a short duration. The Medium Term Programme, for instance, follows a 5% target in its macroeconomic projections over 2014–2017. In contrast, OECD (2014) and IMF's World Economic Outlook (2015, April) projections suggest that the Turkish growth rates will likely be on the order of 3.5–4.0% over the next decade. Stockholm Environment Institute's Climate Equity Reference Calculator (C-EQR) also uses a 3.6% rate of growth per annum in its projections for the Turkish economy towards 2030. Given these international evidence and data, we adopted the average annual growth target of 4% as our base path rate over the 2015–2030 horizon. This assumption brings the aggregate real GDP to 2371 billion TRY in 2030 (in fixed 2010 prices), with an aggregate gross production of 3145 billion TRY in the high income region, and of 1864 billion TRY in the low income region (see Table 6).

Exogenous foreign flows are set at their historical ratios to GDP, and were gradually reduced to yield a current account deficit of 3.1% by 2030. Currently this deficit stands at around 5% and is regarded as an important source of fragility for the Turkish economy, raising concerns over its sustainability. In the labor markets, formal wage rates were maintained at their real levels by continuously updating with the "price level" as solved endogenously by the model. Finally, government's fiscal parameters are left intact at their current (historically realized) levels.

The model is solved sequentially up to 2030 with each "solution" referring to a calendar year. We document a summary of macro and environment indicators of this base path in the first part of Table 6. With an average annual rate of growth of 4% over 2015–2030, Turkish aggregate CO2 emissions reach to 682 million tons (to 821.9 million tons of CO2(eq) gaseous emissions in total). This is reported to stand at 459 million tons of CO2(eq) in 2013 by the TurkStat (Table 7).

In terms of efficiency, we observe that total CO2 emissions per unit of GDP initially stand at 0.535 kg per US$ GDP until 2020, and recede to 0.518 kg/$GDP by the end of 2030. This fall is due to the gains in efficiency implicitly attained by applications of the (exogenous) gains in sectorial/regional TFPs.

It has to be noted from the outset that this procedure by no means gives a projection of the domestic economy to be read from a crystal ball; but rather, should be regarded as a historically trended future path against which alternative policy environments can be contrasted. In fact, at the time of writing Turkey had

Table 11

		Base path				Scenario 1: eliminate production subsidies on coal				Scenario 2: eliminate both production and investment subsidies on coal			
		2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Aggregate energy demand by sectors, low income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	0.834	1.063	1.322	1.580	0.825	1.052	1.308	1.564	0.812	1.036	1.288	1.540
CO	Coal	0.138	0.169	0.206	0.245	0.096	0.117	0.143	0.170	0.061	0.074	0.091	0.108
PG	Crude Oil and Natural Gas	0.071	0.097	0.126	0.152	0.071	0.097	0.126	0.152	0.072	0.098	0.126	0.153
PE	Refined Petroleum	7.859	10.017	12.602	15.203	7.844	9.996	12.576	15.171	7.819	9.959	12.525	15.105
CE	Cement	0.888	1.109	1.364	1.621	0.858	1.072	1.321	1.570	0.819	1.024	1.262	1.502
IS	Iron and Steel	1.424	1.937	2.641	3.411	1.406	1.913	2.609	3.370	1.383	1.881	2.565	3.314
MW	Machinery and White Goods	0.493	0.627	0.782	0.937	0.489	0.622	0.777	0.931	0.484	0.616	0.769	0.921
ET	Electronics	0.559	0.755	1.003	1.237	0.554	0.749	0.995	1.227	0.548	0.740	0.983	1.212
AU	Auto Industry	0.164	0.236	0.345	0.455	0.163	0.235	0.344	0.454	0.162	0.233	0.342	0.451
EL	Electricity Production	17.799	22.945	29.204	35.869	17.765	22.899	29.141	35.790	17.721	22.829	29.038	35.651
CN	Construction	0.164	0.206	0.250	0.294	0.162	0.203	0.247	0.290	0.158	0.199	0.242	0.285
OE	Other Economy	9.847	12.145	14.953	17.806	9.674	11.937	14.704	17.515	9.441	11.653	14.359	17.107
Aggregate energy demand by sectors, high income region (Bill TL, 2010 fixed prices)													
AG	Agriculture	0.274	0.328	0.393	0.483	0.271	0.325	0.389	0.478	0.266	0.319	0.383	0.471
CO	Coal	0.263	0.318	0.382	0.459	0.182	0.221	0.265	0.319	0.103	0.125	0.151	0.181
PG	Crude Oil and Natural Gas	0.116	0.146	0.177	0.214	0.117	0.147	0.178	0.214	0.118	0.148	0.178	0.215
PE	Refined Petroleum	13.998	17.415	21.542	26.634	13.970	17.379	21.498	26.578	13.928	17.319	21.416	26.471
CE	Cement	1.693	2.110	2.582	3.176	1.636	2.042	2.501	3.078	1.563	1.951	2.393	2.946
IS	Iron and Steel	2.738	3.733	5.156	7.129	2.705	3.689	5.096	7.047	2.661	3.630	5.014	6.934
MW	Machinery and White Goods	0.939	1.200	1.492	1.860	0.933	1.192	1.483	1.849	0.925	1.181	1.469	1.832
ET	Electronics	1.039	1.354	1.776	2.339	1.031	1.343	1.762	2.321	1.019	1.328	1.742	2.295
AU	Auto Industry	0.309	0.410	0.587	0.868	0.308	0.409	0.585	0.866	0.306	0.406	0.582	0.862
EL	Electricity Production	31.434	39.488	49.353	61.339	31.373	39.408	49.248	61.204	31.298	39.292	49.083	60.978
CN	Construction	0.290	0.352	0.416	0.495	0.286	0.347	0.410	0.489	0.280	0.340	0.402	0.479
OE	Other Economy	19.051	23.562	28.748	35.026	18.730	23.175	28.287	34.475	18.298	22.645	27.649	33.702

announced its *Intended Nationally Determined Contribution* (INDC) programme to the UNFCCC as part of its efforts to report in the COPE 21 meetings in Paris, December 2015. The official INDC traces a business-as-usual, base-path covering 2013 to 2030, and reveals a projected path for gaseous emissions reaching to 1175 million tones of CO2(eq).[2] This projection is significantly higher than our base path specification which puts aggregate CO2(eq) emissions to 821.9 mtons by 2030.[3] This difference could be due to several reasons. One is that the assumed growth rate of GDP could have been significantly higher than our projected average rate of growth of 4%; or at comparable growth rate projections, the officially assumed path might have involved an increase in the carbon intensity per $GDP. Thirdly, the difference in the projected base paths may also be based on differences in modeling techniques. The official projection, being based mostly on a *bottom-up* approach, aims at cost minimization given a path of economic activity. The CGE model utilized in this study, in contrast, is based on an *up-bottom* approach with the level of economic activity being solved endogenously and releasing its environmental impacts as dependent outcomes.[4] In any event, the official INDC is observed to reveal an acceleration in total emissions by 155% from 459 mtons in 2013, to the projected 1175 mtons of CO2(eq) in 2030. Considering that over a period of twenty three years from 1990 to 2013 aggregate CO2(eq) emissions had increased by only a total of 110%, suggest that the official INDC projections are not in line with the recent Turkish historical pathway.

4.2. *Investigating alternative policy scenarios*

Given our policy questions we first intervene to the coal market and study implications of eliminating the existing subsidization scheme. To this end we first investigate the macro and environmental implications of eliminating the subsidies on coal production. As discussed in Section 1, the existing scheme of coal subsidization amounts to 730 m US$, on the average of 0.1% as a ratio to the GDP. In the first scenario we reduce this subsidy to zero.

4.2.1. *Eliminate subsidies on coal production*

Elimination of the coal subsidies generates contractionary pressures in coal production. As of 2030 coal production falls by 29% in both regions. These imply a reduction of 0.17% in the aggregate real gross domestic product by 2030, or a total 4 billion TRY in fixed 2010 prices. Gains in total CO2(eq) are on the order of 2.5% (20.3 million tons) over the base path by 2030. The bulk of these gains originates from reductions of emissions from coal combustion, 4.2 million tons in low income; 13.4 million tons in the high income region. There is a further reduction of 3.2% (3.4 million tons) of energy related emissions from the household sector. These numbers imply that CO2 emissions from energy per $ of GDP fall to 0.398 kg under the scenario, from 0.412 kg of the base path (see Table 6).

Clearly, all these findings are the end-result of the reallocation of resources due to the general equilibrium dynamics across sectors and regions. We find that there is a slight increase in the average unemployment rate by 0.1%, with no change in the high

[2] Ministry of the Environment and Urban Affairs, retrieved from http://www4.unfccc.int/submissions/INDC/Published%20Documents/Turkey/1/The_INDC_of_TURKEY_v.15.19.30.pdf.

[3] We are grateful to an anonymous referee of the *Energy Policy* for bringing this issue to our attention.

[4] On the difference and discussions of *up-bottom versus bottom-up* approaches, see Bohringer and Loeschel (2006).

Table 12
Support measures of the regional investment incentive scheme.
Source: Ministry of economy (Table and notes retrieved from http://www.ekonomi.gov.tr/portal/faces/home/yatirim/yatirimTesvik/yatirimTesvik-Genel_Bilgi)

Support measures		Regions					
		1	2	3	4	5	6
VAT exemption[a]		Yes	Yes	Yes	Yes	Yes	Yes
Customs duty exemption[b]		Yes	Yes	Yes	Yes	Yes	Yes
Tax deduction[c]	Tax reduction rate (%)	**30**	**40**	**50**	**60**	**70**	**90**
	Reduced tax rate (%)	**14**	**12**	**10**	**8**	**6**	**2**
	Rate of contribution (%)	**10**	**15**	**20**	**25**	**30**	**35**
Social Security Premium (SSP) Support (Employer's Share)[d]	Term of support (years)	–	–	**3**	**5**	**6**	**7**
	Cap for support (Certain Portion of Investment Amount - %)	–	–	**20**	**25**	**35**	**No limit**
Land allocation[e]		Yes	Yes	Yes	Yes	Yes	Yes
Interest rate support[f]	TL denominated loans (points)	–	–	**3**	**4**	**5**	**7**
	FX Loans (points)			**1**	**1**	**2**	**2**
	Cap for support (Thousand TL)	–	–	500	600	700	900
SSP support (Employee's share) (years)[g]		–	–	–	–	–	**10**
Income tax withholding support (years)[h]		–	–	–	–	–	**10**

Notes: For investments starting as of January 1, 2015. The new investment incentives system defines certain investment areas including coal mining and coal fired power generation as "priority" areas and grants them with the regional support measures defined for Region 5, regardless of the region of investment. If the fixed investment amount in priority investments is TRY 1 billion or more, tax reduction will be applied by adding 10 points on top of the "rate of contribution to investment" available in Region 5. If priority investments are made in Region 6, the regional incentives available for this particular region shall apply.

[a] In accordance with the measure, VAT is not paid for imported and/or domestically provided machinery and equipment within the scope of the investment encouragement certificate.

[b] Customs duty is not paid for the machinery and equipment provided from abroad (imported) within the scope of the investment encouragement certificate.

[c] Calculation of income or corporate tax with reduced rates until the total value reaches to the amount of contribution to the investment according to envisaged rate of contribution.

[d] The measure stipulates that for the additional employment created by the investment, employer's share of social security premium on portions of labor wages corresponding to amount of legal minimum wage, will be covered by the Ministry.

[e] Refers to allocation of land to the investments with investment incentive certificates, if any in that province in accordance with the rules and principles determined by the Ministry of Finance.

[f] Interest support, is a financial support instrument, provided for the loans with a term of at least one year obtained within the frame of the investment encouragement certificate. The measure stipulates that a certain portion of the interest/profit share regarding the loan equivalent of at most 70% of the fixed investment amount registered in the certificate will be covered by the Ministry.

[g] The measure stipulates that for the additional employment created by the investment, employee's share of social security premium on portions of labor wages corresponding to amount of legal minimum wage, will be covered by the Ministry. The measure is applicable only for the investments to be made in Region 6 within the scope of an investment encouragement certificate.

[h] The measure stipulates that the income tax regarding the additional employment generated by the investment within the scope of the investment encouragement certificate will not be liable to withholding. The measure is applicable only for the investments to be made in Region 6 within the scope of an investment encouragement certificate.

income region while in the low income region it rises by 0.2 percentage points. Due to the deceleration of the economic activity, there is a fall in aggregate investment and consumption expenditures, yet these effects are found to be comparably small. These observations suggest that owing to substitution effects, domestic production activity helps recovery of the aggregate economy; and in the final analysis, the gains in pollution abatement are relatively noteworthy. More detailed sectorial and regional summary of these results are documented in Tables 8 through 11.

4.2.2. Eliminate investment subsidies on coal

Coal mining is further subsidized under the Regional Investment Incentives Scheme (see Table 12 for a detailed outline of the scheme). Accordingly, investment expenditures on coal mining are supported by the central government to boost coal production across regions. Via reduced income or corporate taxes, the existing scheme subsidizes the cost of investments at a rate of 30% in the high income region, and by 35% in the low income region. In this scenario, in addition to eliminating producer subsidies in coal production (Scenario 1) we further eliminate the investment subsidization programme in the coal sector. The results are tabulated under the "scenario 2" part of Tables 6 through 11, and also portrayed in Figs. 2 through 4.

We find the macro-effects of the scenario quite small. GDP loss by 2030 is only 0.5% suggesting that substitution effects on the reallocation of capital across the remaining sectors dominate. Yet, the abatement on CO2 emissions continue and in comparison to the base path the combined scenario brings about a 5.4% reduction in aggregate CO2(eq) emissions (in 2030). In the high income region reduction of CO2 emissions from coal burning reach to 42.7% and in the low income region it reaches to 42.6%. Total abatement of energy related CO2 emissions reach to 42.5 million tons (Fig. 3), and the ratio of CO2 from energy to GDP is reduced further to 0.382 kg/$ (Fig. 4).

It has to be noted that the model results obtained through the scenario pathways are ultimately limited to adjustments implied within the *domestic* economy. As discussed above, the current account deficit is an important fragility indicator for Turkish economy and energy imports is responsible for a significant share of this deficit. Therefore, any policy which alters the energy mix in Turkey is expected to have an impact on the resolution of the current account deficit. Yet, the model's closure rule specifies that even though the balance on the current account is endogenous to the model, it nevertheless depends on the inflows of foreign capital (in the form of workers' remittances, profit transfers, portfolio and foreign direct investments, and net debt flows) which are exogenously given as ratios to the GDP over the dynamic pathways. This specification sets the boundaries of adjustment in the current account balance. This is clearly an undesirable feature of our dynamic results; and yet, in the absence of any evidence on how a fiscal policy of elimination of coal subsidies night affect foreign capital inflows we had to abstain from making *ad hoc* assumptions on the nature of adjustments in the current account.

5. Conclusion and policy implications

In this paper we assessed the impact of the current arsenal of energy policy instruments (in particular coal subsidies) on macro-indicators and environmental outcomes, specifically CO2 emissions in Turkey. Consequently, the implications of the removal of coal subsidies are explored. The findings suggest that elimination of production and investment subsidies for coal results in a slight reduction of GDP (by 0.5% as of 2030) but a substantial decrease in CO2 emissions both in the low and high income regions. Considering that a relatively small coal sector benefits from significant subsidies, the elimination of these motives alone will considerably benefit the environment.

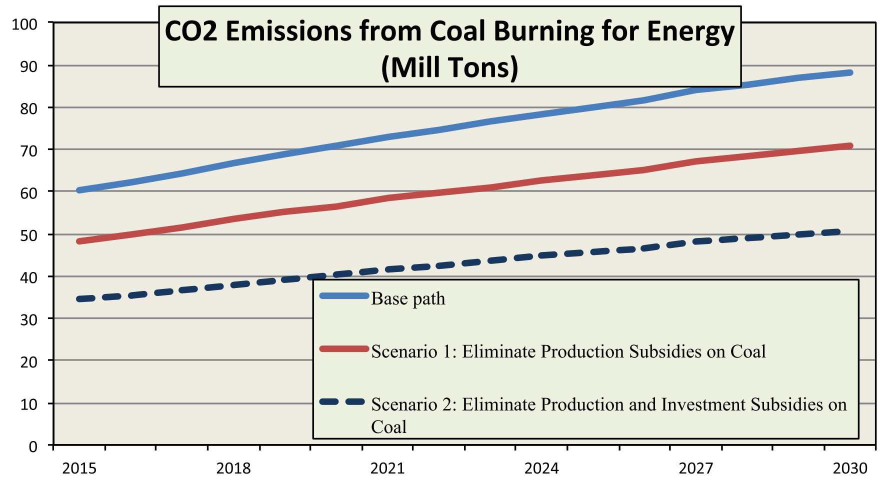

Fig. 2. CO2 emissions from coal burning for energy (mill tons).

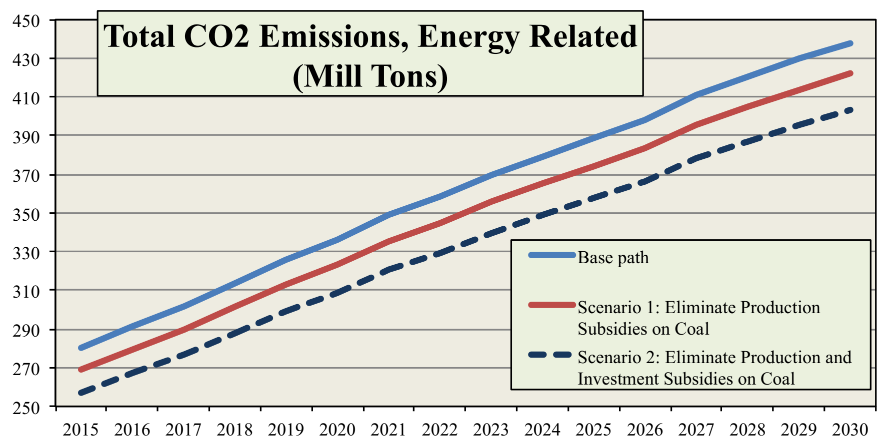

Fig. 3. Total CO2 emissions, energy related (mill tons).

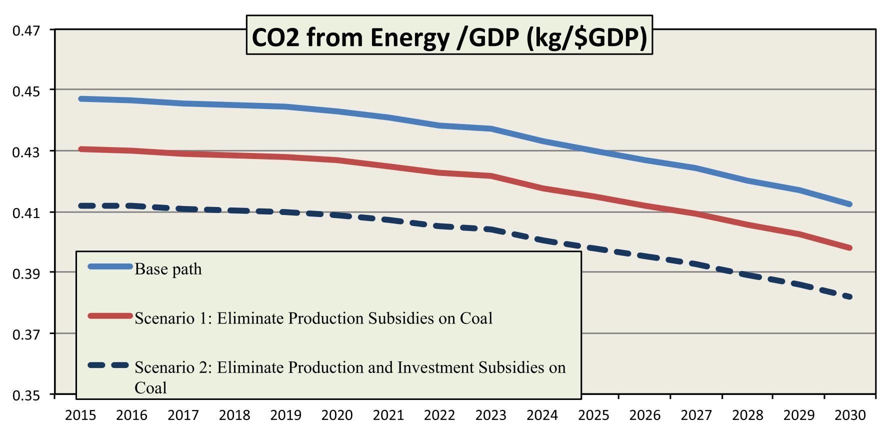

Fig. 4. CO2 from energy/GDP (kg/$ GDP).

On the other hand, while Turkey has ambitious plans for deployment of renewable energy, these are likely to be compromised by the continued existence of subsidies to coal-fired power generation and coal mining including the recently introduced regional development package with investment support and loan guarantees. Debate over subsidy reform is hindered by lack of transparent data in the magnitude and impacts of these subsidies. Since coal subsidies work against the competitiveness of renewable energy technologies, locks the energy sector in to the continuation of fossil-fuel-based systems, and jeopardizes investment decisions of renewable energy investors (Bridle and Kitson, 2014), elimination of coal subsidies and redirecting these funds towards renewable energy, green jobs, or CO2 mitigation in general will likely prove efficiency and social welfare improvement.

Apart from the ambitions to increase coal utilization in the country, Turkish environmental policies currently rely on gasoline and fuel taxes. However, the impacts and economic effects of the taxation/subsidization policies are not analytically investigated, and there is an acute need for development of such a framework. In fact, in the absence of any viable substitute energy sources, it is clear that polices based only on the fiscal motives of excise taxation will not suffice to achieve significant results for mitigation, and they ought to cover many other innovations of policy such as earmarking of the pollution tax monies and encouraging mitigation investment towards reduced energy intensities (Acar et al., 2014). Hence, there is a strong need for the construction and utilization of analytical models that can account for the general equilibrium effects for environmental policy analysis, especially under the discipline of dynamic general equilibrium. We believe that our model sheds light on the effectiveness of such policies and their potential impacts in the future.

As an extension of this work, viable policy alternatives can be put forward in order to help the greening of the economy. Coal subsidies could be transferred to the development of renewable energy and green jobs while the environmentally harmful impacts could be mitigated. Coal subsidy phase-out would decrease CO2 emissions, decrease the fiscal burden, and has the potential to generate green jobs and green energy. Switching from subsidization of coal to development of renewables promises a win–win–win strategy for a cleaner environment, for decreased dependence on fuel imports, and expansion of renewables. Besides, alternative public policy intervention mechanisms could be developed to accelerate technology adoption and achieve higher employment, energy security, and sustainable growth patterns.

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