TOWARDS A LOW CARBON ECONOMY IN TURKISH ENERGY POLICY: NUCLEAR AND RENEWABLE VS. FOSSIL FUELED PLANTS IN POWER GENERATION

Levent Aydın*

Türkiye Enerji Politikasında Düşük Karbon Ekonomisine Doğru: Elektrik Üretiminde Fosil Yakıtlı Güç Santrallerine Alternatif Nükleer ve Yenilenebilir Enerji

Bu makalenin amacı fosil yakıtlı güç santrallerine alternatif olarak nükleer ve hidroelektrik güç santrallerinin kurulmasının ekonomik ve çevresel etkilerinin hesaplanmasıdır. Bu politika seçeneğini analiz etmek için spesifik olarak Türkiye ekonomisi için dinamik, çok sektörlü ve uygulamalı genel denge modeli geliştirilmiştir. Modelin temeli ORANI-INT modeline dayanmaktadır. ORAN-INT modeli bir enerji modeli olmadığından dolayı üretim fonksiyonuna enerji ikamesi dahil edilerek gerekli düzenleme yapılmıştır. Üretim yapısı elektrik ve elektrik-dışı olmak üzere iki şekildedir. Hidroelektrik santrallerinde %20 artış ve 4800 MW kapasiteli iki nükleer santral inşa edilmesiyle Gayrisafi Yurtiçi Hasıla (GSYH)'da simülasyon-1 de %0,7 ve simülasyon-2 de %1,1 artış sağlanmaktadır. Hasılanın artmasına ilave olarak yurtiçi, yeni ve fosil olamayan kaynakların kullanılması ile enerji bağımlılığı azalarak Türkiye'nin dış ticaret açığı iyileşmektedir.

Anahtar sözcükler: *Elektrik üretimi; nükleer enerji; karbon salınımı; HGD modeli; Türkiye*

* Department of Ecoonomics, Kırıkkale University, Kırıkkale/Turkey
e-mail: leventaydin60@gmail.com ; www.leventaydin.net.tr

Introduction

Turkey is not a rich country in terms of the hydrocarbon (crude oil and natural gas) potential to be used for generation of electricity. Therefore it has a strategy for developing the two nuclear power plants and a few hundred small hydro power plants to be constructed in the long run. Moreover there is the need for Turkey to discover new and renewable energy resources. However, new and renewable resources other than hydro will not be sufficient to produce the large amounts of electricity in the coming decades even if major efforts were made to develop them.

Eventually, the power generation strategy Turkey must adapt should be ~~a~~ based on constructing nuclear and hydro power plants for coming decades in order to minimize her foreign dependency of natural gas and carbon dioxide (CO_2) emissions. Constructing nuclear and hydro power plants not only means reduction in the importation of natural gas and CO_2 emissions but also means sustainable economic growth, provision of high quality jobs and better technological development. Hence, Turkey attempts to cover its power generation gap as well as minimize its dependence on foreign energy resources, mainly natural gas. One of the Turkish energy policies is to designate hydro and nuclear power as an essential source of energy, meeting at least one-fifth of her power needs within the next decades.

The aim of this research is to evaluate the economic and environmental impact of constructing new nuclear and hydro power plants as an alternative to fossil-fired power plants. In order to analyze this policy option we specifically developed dynamic, multi-sectoral and applied general equilibrium model for Turkish economy. The structure is mainly based on ORANI-INT model. Due to the fact that ORANI-INT model is not an energy model, it was modified by incorporating energy substitution into CES production function. The production structure is divided into two types: electricity and non-electricity.

Data is compiled from the I/O tables of Turkish economy with reference year of 2002. Both sectors and commodities for this data were aggregated into eight (8) sectors and commodities. These are agriculture, coal, oil, gas, oil products, energy intensive industries, electricity, other industries and services. The electricity sector further disaggregated into 5 sectors (coal-, oil-, gas fired, and nuclear and hydro power generation) and its commodities with additional data of Turkish power sector.

It was speculated that hydro power generation is to be increased about twofold the average annual production from 62 billion kWh to 118 billion kWh in the next decade. There was good investment environment for constructing small hydro power plants.

Turkey agreed with Russia for Akkuyu nuclear plant last year and signed a memorandum of understanding with Japan for the initiation of discussion on the Sinop nuclear plant at the end of last year. As part of its economic targets for 2023, the centennial of the modern republic, Turkey hopes to cut its dependence on foreign supplies in natural gas and aims to have at least three nuclear power plants with a total installed capacity of 5,000 megawatts while also intensifying efforts in developing methods for renewable energy production around the country.

The policy scenarios are to diversify fuel sources as well as supply routines and origin and they also aims to reduce dependence on the importation of natural gas and coal for power generation while increasing the share of the country's renewable hydro and nuclear power. In the long term, it is expected that nuclear and hydro power makes significant contribution to economic growth in the country. We used real GDP, trade balance and CO_2 emission as a macroeconomic variable and sectoral output to evaluate the advantages of nuclear and renewable power plants over the alternative use of fossil fuel.

The rest of the paper is organized as follows: Section 2 provides a brief overview of Turkey's power generation sector. Section 3 describes modeling approach and data. Section 4 presents the results of analysis and section 5 provides the concluding remarks and some policy recommendation.

Overview of Power Generation in Turkey

Table-1 demonstrates the importance of Turkey's electricity sector. Rapid economic growth led to rapid growth in electricity demand. Between 1990 and 2009, the average annual growth rates of electricity generation and demand were both around 6.7% while generation capacity grew by about 5.5%. During the same period, per capita generation capacity and net electricity consumption grew annually by about 4% and 5%, respectively. The need for reform arises from the rapid growth of demand and the need to ensure continuity in electricity supply. As seen in Table 1, electricity supply and demand have been in balance over the years. According to the TEIAS report, in order to meet the demand that is projected to grow by

7.0% on average during the ten-year period 2007 to 2018, investments in power generation should be increased (TEIAS, 2008).

Table 1- Development Of Power Generation In Turkey

	1990	**2000**	**2007**	**2008**	**2009**
Population (thousands)	56,473	67,845	70,586	71,517	72,561
Installed capacity (MW)	16,318	27,264	40,836	41,817	44,761
Gross generation (GWh)	57,543	124,922	191,558	198,418	194,813
Supply (GWh)	53,500	122,052	181,782	189,429	185,886
Demand (GWh)	56,812	128,276	190,000	198,085	194,079
Net consumption (GWh)	46,820	98,296	155,135	161,948	156,894
Per capita installed capacity (Watt)	289	402	579	585	617
Per capita gross generation (KWh)	1,019	1,841	2,714	2,774	2,685
Per capita supply (KWh)	947	1,799	2,575	2,649	2,562
Per capita demand (KWh)	1,006	1,891	2,692	2,770	2,675
Per capita net consumption (KWh)	829	1,449	2,198	2,264	2,162

Source: Electricity Generation & Transmission Statistics Of Turkey, TEIAS

The power generation market in Turkey is a rapidly growing market due to the strong economic growth, rapid urbanization, extension of electrification to the whole country rising per capita electricity consumption (OECD, 2002).

In order to establish a financially strong, stable and transparent electricity market the provision of a special law has been targeted for a continuous and sufficient, high-quality, and environment friendly supply of electricity at a low cost to the consumers as well as the maintaining of an independent regulatory and supervisory framework, Electricity Market Law

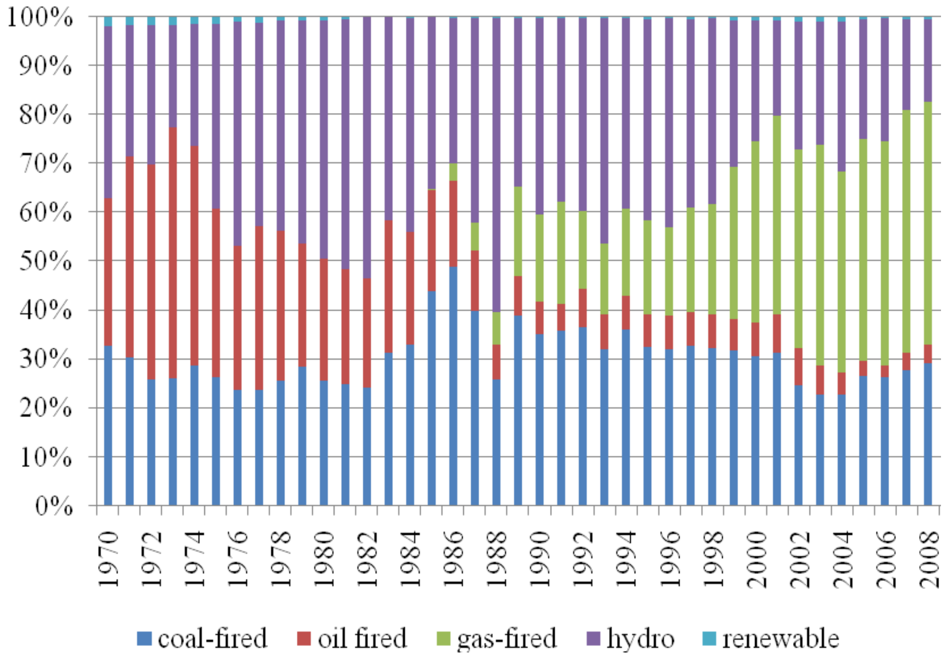
No. 4628 came into force as issued in the Official Gazette dated 3rd March, 2001 (Hepbasli, 2005).

One fundamental section of Law 4628 was to separate the former Turkish Electricity Transmission and Generation Corporation (TEAS) into separate bodies for generation (Electricity Generation Corporation, EUAS), distribution and trading (Turkish Electricity Trade and Contracting Corporation, TETAS), and transmission (Directorate-General of Turkish Electricity Transmission, TEIAS). The idea behind unbundling these assets was to ease their eventual privatization. Indeed, this move was another step in the process that started in 1994 when TEK (Turkish Electricity Corp.) was split into Turkish Electricity Generation and Transmission Corporation (TEAS) and Turkish Electricity Distribution Corporation, (TEDAS) (responsible for generation/transmission and distribution respectively). The privatization also give rise to the splitting of TEDAS into 21 regional distribution companies controlling market share in electricity distribution across Turkey (Uzlu et al., 2011).

In the context of Electricity Market Law, the private sector applications began in accordance with the regulation related to the procedures and the principles of signing the Water Usage Rights Act for production activities in the electricity market since 2003. All of the hydroelectric power related projects developed at various stages until this year as required by the 4628 Electricity Market Law along with the enacting electricity market regulation and the regulations of Agreement for the Right to Use Water. These projects have been open to the appeal of the private sector (McKeigue, 2009).

Power generation projects mostly face financial, political, technical, and environmental challenges. Until recent years, these issues have been exaggerated in Turkey. In the past Turkey implemented strict government planning and control of all aspects of its economy, however, recently it has made substantial progress to open its markets and reduce government control of foreign trade and outside investment in power. Additionally, many publicly owned industries have been privatized since 2001. At the moment it is clear that Turkey must have immediate and substantial investment in its electricity generating infrastructure if the country is to sustain its recent economic growth (McKeigue, 2009).

Over the past half-century, Turkey's electricity generation has grown dramatically, with an average annual growth rate of nearly 5 %. As seen in Figure-1, during this time, generation of natural gas has grown faster than hydro and coal-fired power. The key challenges in power generation for Turkey are high rate of natural gas dependency abroad. This dependence is undertaken due to the heavy foreign payment obligation incurred.



Source: WEC-TNC, 2011

Figure 1- Share of power generation by fuel types (1970-2009)

As known carbon emission generated from power sector may be mitigated in two different ways: (1) efficiency by reducing the amount of electricity generated, and (2) conservation by reducing the emissions associated with low- and zero-carbon electricity generation technologies such as renewable energy, carbon capture and storage, and nuclear power. Nuclear power and small hydro power option has been located in Turkish energy policy in recent years.

Modeling Approach and Simulation Design

Model structure and data

A dynamic Computable General Equilibrium (CGE) model for Turkey's economy is constructed for analyzing energy and carbon abatement policies by means of constructing new nuclear and hydro power plants. The model was developed from the Australian model, originally presented in ORANI (Dixon et al, 1984, 1982) and has its core dynamic CGE model described in ORANI-INT model [10, 11]. Currently, in the standard ORANI model, there are no inter-fuel, nor fuel-factor (energy-primary factor) substitution. Therefore the original ORANI-INT model structure has been modified in a number of ways to make it suitable for analyzing energy and climate change issues. In this context, model is a one region, dynamic Applied General Equilibrium (AGE) model which highlights the relationships between energy production and use, and CO_2 emissions by means of incorporating inter-fuel (fossil fuels) and power generation technology (coal-, oil-, natural gas-fired, hydro and nuclear power) substitutions. The main focus is on the energy sector and its linkage to the economy.

The model database is compiled from the 2004 Turkey Input-Output Table (TURKSTAT, 2008) and Turkey's energy statistics (WEC-TNC, 2004). The 64 sectors in Turkey's economy are first aggregated to 8 production sectors, which were considered essential for this analysis. In the model, all production sectors were divided into two main categories to represent different production structures: electricity sector and non electricity sectors. Electricity sector was further disaggregated into electricity generation and electricity distribution. The electricity is generated from oil-fired, coal-fired, gas-fired, nuclear and hydro power. The electricity generation industry is able to substitute alternative power generation technologies in response to changes in relative costs. The output of the power sector is an aggregate of the power generated from each of these technologies.

The production structure of power generation sectors in the model is illustrated by the nested structure as shown in Figure-1. The nested structure of power generation can be expressed in equation (1).

$$(1)\quad Z^{1}_{j,t} = Min_{c\in COM}\left\{CES\left[\frac{X^{1}_{c,s,j,t}}{A^{1}_{c,s,j,t}}\right], CES\left[\frac{K_{j,t}}{A^{K}_{j,t}}, \frac{L_{j,t}}{A^{L}_{j,t}}, \frac{N_{j,t}}{A^{N}_{j,t}}\right]\right\}$$

The power generation sectors is given as j={oil-,coal-,gas-fired, hydro, nuclear}, c={all commodities} and variable A^1 denotes the intermediate input, A^K, A^L, A^N, respectively, capital saving, labour saving, agricultural land saving and technological change.

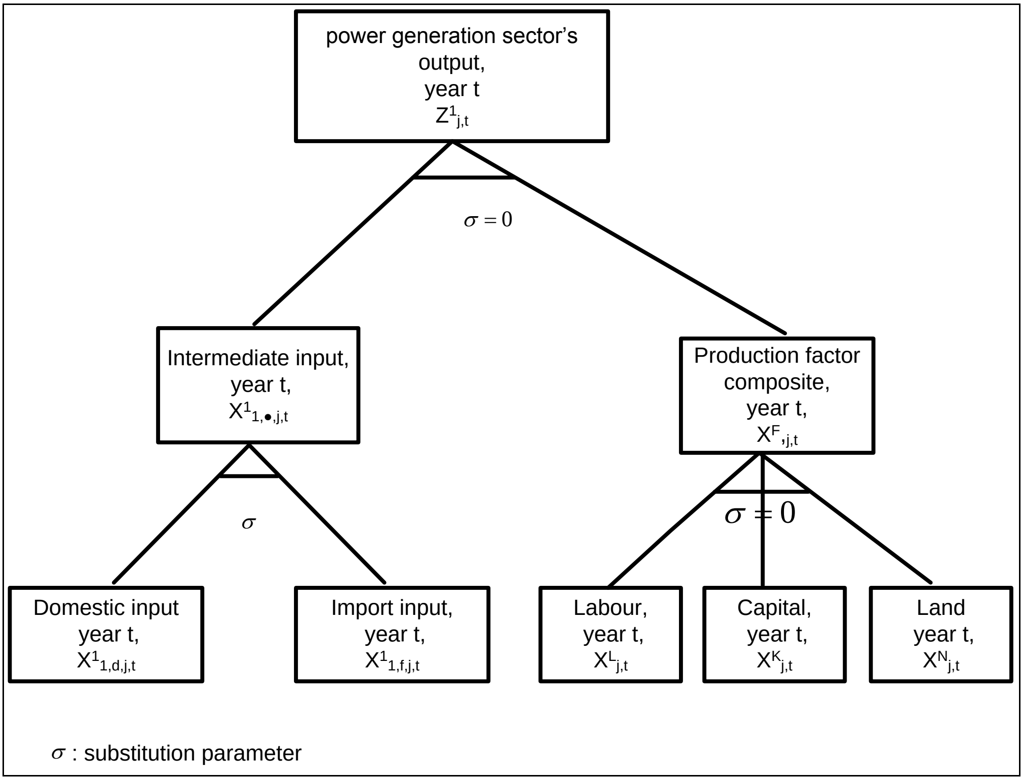


Figure 3-Production structure of power generation

As shown in Figure 4, all electricity generated from various technologies is transferred to the end-use electricity sector. The output of the end-use electricity is aggregated for each power technologies and fixed rates of intermediates inputs except electricity and primary factor composite. The nested production of end use electricity production can be expressed by equation (2).

$$(2)\quad Z^1_{j,t} = Min\{\mathrm{CES}_{c\in nonelect}\left[\frac{X^1_{c,s,j,t}}{A^1_{c,s,j,t}}\right], \underset{j\in elect}{\mathrm{CES}}\left[\underset{j\in sources}{\mathrm{CES}}\left(\frac{X^1_{c,s,j,t}}{A^1_{c,s,j,t}}\right)\right], CES\left[\frac{K_{j,t}}{A^K_{j,t}}, \frac{L_{j,t}}{A^L_{j,t}}, \frac{N_{j,t}}{A^N_{j,t}}\right]\}$$

In this equation j={end use electricity} and variable A represents technological change both intermediate inputs and factors. Moreover, in Figure 2, power generated from nuclear and hydro energy sources are designed as a separate sector so as to analyze economic and environmental effects of these sources as an alternative to fossil sources.

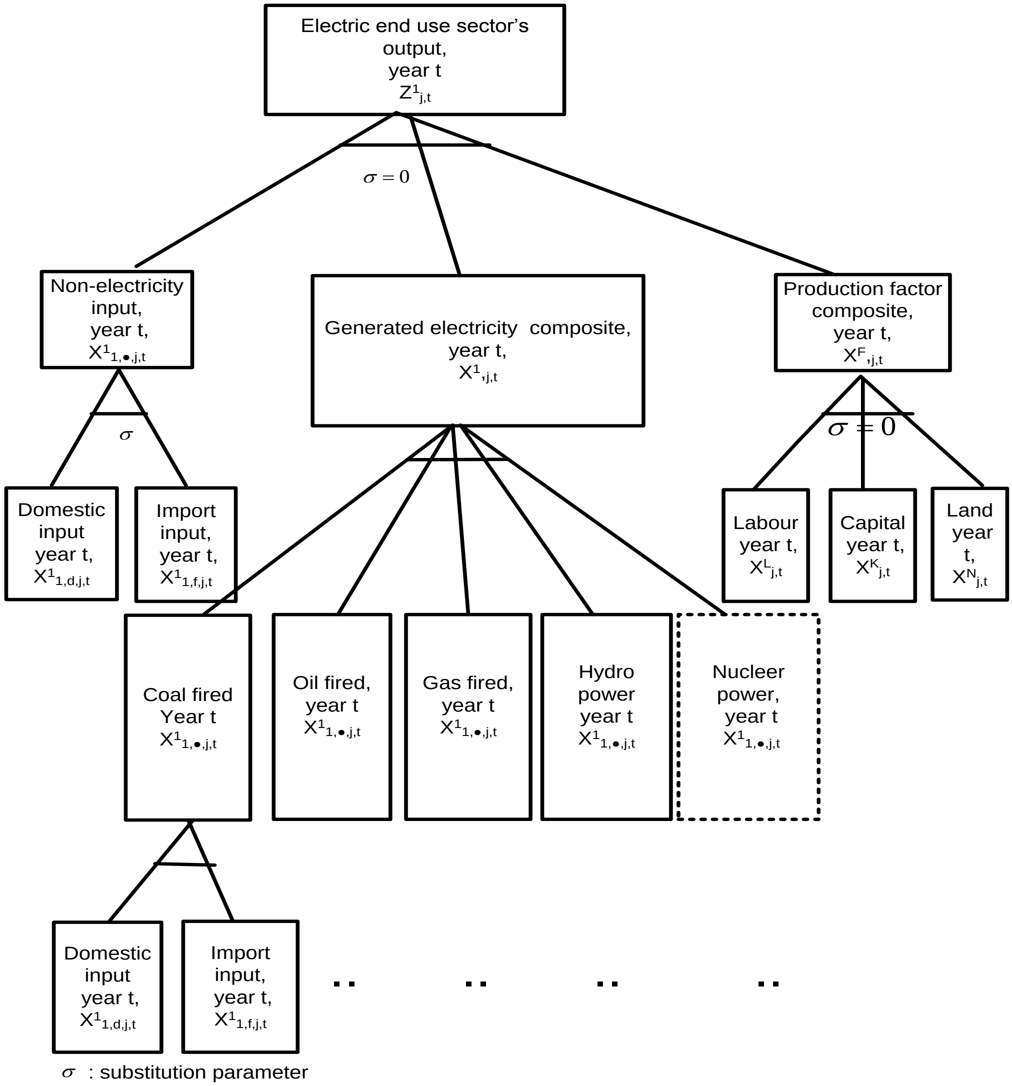


Figure 4- Production structure of end use sector

The production structure for non-electricity sectors in the model is represented by the nested structure of energy composite (coal, oil products, gas) and primary factor composite (land, labor, capital) as shown in Figure 5. Equation (3) indicates the nested structure of non-electricity production.

$$Z^{1}_{j,t} = \underset{c \in nonenergy}{\text{Min}} \left\{ \underset{s \in source}{\text{CES}} \left[\frac{X^{1}_{c,s,j,t}}{A^{1}_{c,s,j,t}} \right], \left[\underset{e \in energy}{\text{CES}} \left\{ \underset{s \in source}{\text{CES}} \left(\frac{X^{1}_{e,s,j,t}}{A^{1}_{e,s,j,t}} \right), CES \left[\frac{K_{j,t}}{A^{K}_{j,t}}, \frac{L_{j,t}}{A^{L}_{j,t}}, \frac{N_{j,t}}{A^{N}_{j,t}} \right] \right\} \right] \right\} \quad (3)$$

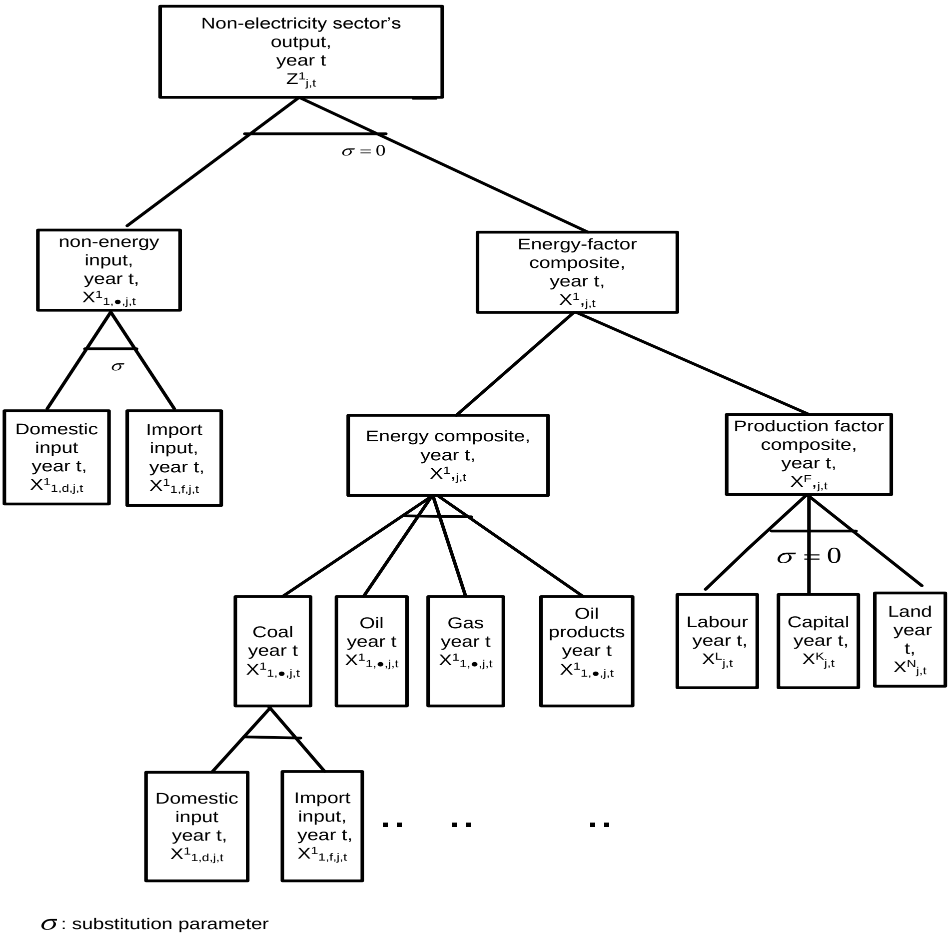


Figure 5- Production structure of non-electricity sectors

The household in the model was assumed to have a Stone-Geary utility function, which is used to aggregate the composite good demanded by the household. The household consumption is modeled as inter-temporal consumption leading to the discrete time elaboration of Lluch's (1973) Extended Linear Expenditure System (ELES). All households were assumed to be identical and they are infinitively lived to eliminate inter-generational transfers. The utility-maximizing household allocates its budget to equalize the marginal utility of consumption across time. The equilibrium condition[1] for the distribution of aggregate discretionary[2] expenditure can be given as:

$$(4) \quad \frac{MU_{t+1}}{MU_t} = \frac{\tilde{C}_t}{\tilde{C}_{t+1}} = \left[\frac{1+\rho}{1+B_{d,\,t}}\right] \qquad t=1,\ldots,T\text{-}1$$

Household budget constraint is given as

$$(5) \quad \tilde{\Omega} = \sum_1^T \left\{\frac{\tilde{C}_t}{\Pi_{u=0}^{t-1}[1+B_{d,t}]}\right\}$$

where $\tilde{C}_t$ is the above subsistence expenditure and MU is marginal utility, ρ is time preference rate. The household takes is given by all the prices as well as $B_{d,\,t}$ (nominal rate of return on domestic bonds). As implied by equation (1), if the bond rate is grater (smaller) than the time preference rate, subsistence expenditure will be raising (falling) (Malakellis 1998).

Even though the household takes $\tilde{\Omega}$, the present value of expected stream of disposable income is given, Ω, the present value of the aggregate income stream ($\Omega = Q\tilde{\Omega}$) is endogenous and Q is the number of household to the economy as a whole and it is determined indirectly by an economy-wide budget constraint. Borrowing and lending by households are constrained by a terminal condition that requires the net-foreign-liabilities to GDP ratio to stabilize by the end of the planning period (Malakellis, 2010).

---

[1] Here the method of Lagrange multipliers was used to derive a solution to the household intertemporal optimization problem.

[2] Stone-Geary utility function leads only to a portion of each period's expenditure is discretionary. See more information. (Neary, 1997).

$$(6) \quad \frac{D_t}{GDP_t} = \frac{D_{t+1}}{GDP_{t+1}} \qquad t= T\text{-}1$$

where D is the value of net foreign liabilities, GDP is the gross domestic product.

B3: Capital demand

As regards capital formation, capital is assumed to be produced with inputs of domestically produced and imported commodities. As far as investments are concerned, investors make two decisions: 1) Choose the optimal level of capital held by the firm so as to equalize marginal revenue product and marginal cost of capital. The marginal cost of capital is given by the following equation:

$$(7) \quad P^{(K)}_{j,t} = \varphi_{j,t-1} P^{(Y)}_{j,t-1} + \delta_j P^{(Y)}_{j,t} - \left(P^{(Y)}_{j,t} - P^{(Y)}_{j,t-1}\right) \qquad j= 1,\ldots,8 \quad t=2,\ldots,T$$

where $P^{(K)}_{j,t}$ is the capital rental rate, $P^{(Y)}_{j,t}$ is the cost of constructing a unit of capital, $\varphi_{j,t}$ is the rate of return and, δ_j is the depreciation rate of capital (Malakellis, 1998).

The first term in the right hand side (equation 3) is the opportunity cost of the capital-services producing asset. The investment costs incurred in year t for an asset come in stream year t+1. Second term represents depreciation costs and final term captures capital gain or losses. Secondly, investors choose the optimal mix of inputs to construct their capital. Investment demand equations which are derived from the solution to the investor's two-part cost minimization problem. A unit of fixed capital for use in sector j is constructed according to a two-tier technology. At the bottom level, the total cost of imported and domestic goods i is minimized subject to the CES production function:

$$X^{(2)}_{i,\bullet,j,t} = CES\left(X^{(2)}_{i,d,j,t}, X^{(2)}_{i,f,j,t}\right) \qquad i=1,\ldots,8 \quad j=1,\ldots,8 \quad t=1,\ldots,T$$

while at the top level the total cost of commodity composites is minimized subject to the Leontief production function:

$$(8) \quad Y_{j,t} = \mathrm{Min}\left\{\frac{X^{(2)}_{1,\bullet,j,t}}{A^{(2)}_{1,\bullet,j,t}}, \ldots, \frac{X^{(2)}_{8,\bullet,j,t}}{A^{(2)}_{8,\bullet,j,t}}\right\} \qquad j=1,\ldots,8 \quad t=1,\ldots,T$$

where $X^{(2)}_{i,\bullet,j,t}$ is the demand for composite good i by sector j for the purpose of creating capital in year t and $A^{(2)}_{1,\bullet,j,t}$ is the technical change parameter.

equation (9) was used to model export demand by specifying an inverse relationship between $X_{i,t}^{(4)}$, the foreign demand for domestic commodity, and $P_{i,t}^{(4)}$ the fob foreign currency price of that commodity.

$$(9)\ X_{i,t}^{(4)}=F_{i,t}^{(4q)}\left\{\frac{P_{i,t}^{(E)}}{F_{i,t}^{(4p)}}\right\}^{\eta_i} \qquad i=1,\ldots,8\ t=1,\ldots,T$$

where η_i is the elasticity of foreign demand and slack variables, $F_{i,t}^{(4q)}$ and $F_{i,t}^{(4p)}$ are included to allow for horizontal (quantity) and vertical (price) shifts in export demand functions.

Equation (10) determines the government demand. The default setting with both shift variables, $F_{i,s,t}^{(5)}$ and $F_t^{(5)}$ in the model is for the level and composition of real government to be exogenous.

$$(10)\ \frac{X_{i,s,t}^{(5)}}{C_t^{(R)}} = F_{i,s,t}^{(5)}F_t^{(5)} \qquad i=1,\ldots,8\ s=d,f\ t=1,\ldots,T$$

Government consumption was assumed to move together with household consumption in the absence of shocking shift variables of the above equation (Malakellis, 1998).

To close the model, there was need to choose which variables are to be exogenous and which are to be endogenous. In GEMPACK software, closure is a list of exogenous variables. Variables for which model has no formal theory are typically exogenous. These include technical and taste changes, government consumption, foreign demand, risk factors, foreign currency prices of imports, population, and the exchange rate which serves as the "numerier" in the model.

The model is replicated "T" times by indexing all variables in the model with respect to time, where "T" is the length of time horizon (in years). Specific investments specified in the model (hydro and nuclear power sector) and aggregate household expenditures are exogenous in the model. The model equations are dynamic: they express relationships among variables at different points in time.

Carbon dioxide emissions arising from the combustion of fossil fuels such as coal, natural gas, and petroleum products were accounted for. We assumed that carbon dioxide emissions are closely related to energy consumption. We assign user, fuel, and source specific emissions coefficients (CO_2 per dollar, at 2004 value) and prorate the fuel specific 2004 national CO_2 inventories among users. This produces the CO_2

emissions matrix by fuel commodities, commodity sources and users. Table 2 shows CO_2 emissions from 3 fuels (domestic plus imported): coal, natural gas, oil.

	Domestic			Imported		
	Coal	Gas	Oil Products	Coal	Gas	Oil Products.
Agriculture	0	0	10	0	0	3
Energy intensive industries	0	0	4	1	1	1
Coal fired power plants	48	0	0	11	0	0
Oil fired power plants	0	0	10	0	0	3
Gas fired power plants	0	0	0	0	29	0
Other industry services	14	0	42	8	5	11
Households	4	3	20	5	4	5
Total	65	3	86	26	39	23

Source: GTAP 6 database (Dimaranan, 2005)

Table 2- Turkey's CO_2 Emissions By User (2004, Million Tons)

Simulation design

For policy simulation, the model is solved over 25-year time horizon and results are reported as percent deviations from the baseline scenario. In setting up the simulation, There was need to specify the closure for the model and the set of relevant shocks for the exogenous variables.

In the "balanced growth" baseline scenario were used as the control scenario, the economy converges to a balanced 6 percent[3] average annual growth asymptotically, all real variables grew at 6 percent per annum and all prices are stationary.

It was assumed that past behavior of agents is exogenous and it is taken as given in the model, owing to the fact that a 1-year gestation lag was specified in the capital creation process. The amount of capital that the sectors have at disposal in year 1 is characterized by a short-run equilibrium in which the supply of sectoral capital stock cannot be altered. However it

[3] OECD statics indicate a 6% average annual GDP growth for the last decade. (OECD country statistical profile, 2010) downloadable at http://stats.oecd.org/index.aspx?queryid=2357#.

was assumed that the supply of sectoral capital stocks is allowed to change so as to equalize the rate of return on capital after year one. An arbitrage condition that relates to risk adjusted sectoral rates of return to the interest rate are enforced by making the capital stock shifter variable exogenous (Malakellis, 2011)

Many variables model have no formal theory and, typically, the values of these variables are specified exogenously. These variables are technical change, consumer tastes, indirect and carbon tax tools, risk factors, foreign prices, foreign interest rates, transfer overseas, population, and aggregate real government expenditures. The Model was implemented and solved by using GEMPACK[4] software (Harrison and Pearson, 1996, Harrison and Pearson, 2002)

To analyze the results of simulation, it is convenient to divide the 27 years time horizon of the experiment into three sub-intervals. The period of 2004 to 2009 is the pre-shock years. The second sub-interval analyzed includes the year 2010, the year in which the hydro power plant shock is initially implemented. The supply of hydro power plant was annually increased by 7%. Next, the transition from year to the long run represented by the period of 2011 to 2030 is discussed (see Table 3 and 4).

Table 3- Outlines Of Scenarios

Baseline	No change from baseline share of power generation
Small hydro power policy[5]	New regulations and legislation about small hydropower gives a strong motivation to explore the potential of hydropower as a renewable energy source, which has not been utilized sufficiently so far. It should be seriously considered as a major contributor to meet significant portion of all electricity demand from now on. Share of hydro in power generation increases between 2012-2020 due to the increases in private investment for small hydro power

[4] Gempack is Developed by the Centre of Policy Studies, Monash University, Australi**a.**

[5] The installed capacity will increase to 57,551MW in 2010 and to 117,240MW in 2020. The installed hydropower capacity is anticipated to increase to 18,943MW in 2010 and to 34,092MW in 2020. Thus, an additional 1000MW of hydro capacity should be added to the system annually over the next 20 years.

Nuclear power policy	Turkey came to an agreement with Russia for the Mersin plant and signed a memorandum of understanding with Japan for the initiation of formal talks on the Sinop plant in 2010. As part of its economic targets for 2023, the centennial of the modern republic, Turkey hopes to end its dependence on foreign supplies in the field of energy and aims to have at least three nuclear power plants with a total installed capacity of 4,800 megawatts

Table 4- Simulations

Code	Description
Baseline scenario	Assuming a "balanced growth," allowing all real variables to grow by 6% annually over the time horizon.
Simulation-1	In this scenario the nuclear and hydro power plant investments are assumed as specific investment in the simulations in order to increase investment exogenously. Investment in hydro power plants increases by 20% between 2010 to 2020 and constructing in first nuclear power plant with a capacity of 4,800 MW. The first unit is expected to be built and start operations within seven years of construction. The cost of investment is estimated to be around $20 billion.
Simulation-2	Second nuclear power plant with a total capacity of 4,800 MW is added to the first scenario to start operations in 2020 and its cost is the same as the first nuclear power.

Results and discussion

This section presents the results obtained from the two different policy simulations carried out using CGE modeling designed in this research. The impact of nuclear and hydro power shock to selected macroeconomic indices and amount and prices of raw electricity was discussed, followed by a discussion on the impact of the shocks on carbon emission. The long run results of the two simulations are identical since second nuclear plant in year of 2020 is only added to the second simulation.

Impact on macro indicators and output

Figure 6 shows the path of real GDP. As can be seen from Figure 6 expanding power generation in favor of domestic resource (nuclear and hydro) have significant positive impact on Turkey's economic performance in the long run though this impact in the short run gets limited. Throughout the twenty-year projection period, while GDP is on average 0.7% higher than the baseline in simulation-1, it is 1.1% higher than the baseline in simulation-2.

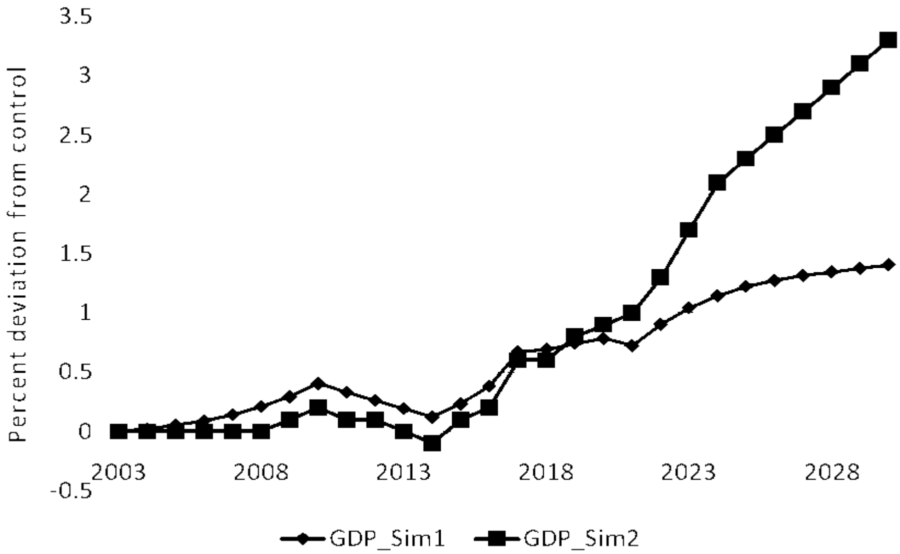


Figure 6- Change in real GDP

The impact of constructing nuclear power plant and expanding hydro power capacity on the price of raw electricity is more marked. The price change is on average about 4.8% lower than the base case over the twenty-year simulation period while price change is on average about 6% lower than the base case. The impact on the electricity price increases mostly in 2021, the tenth year of the projection period. The reverse is true for the amount of raw electricity in both first and second simulations. There is a negative correlation between electricity price movements and changes in the amount of raw electricity (Figure 7).

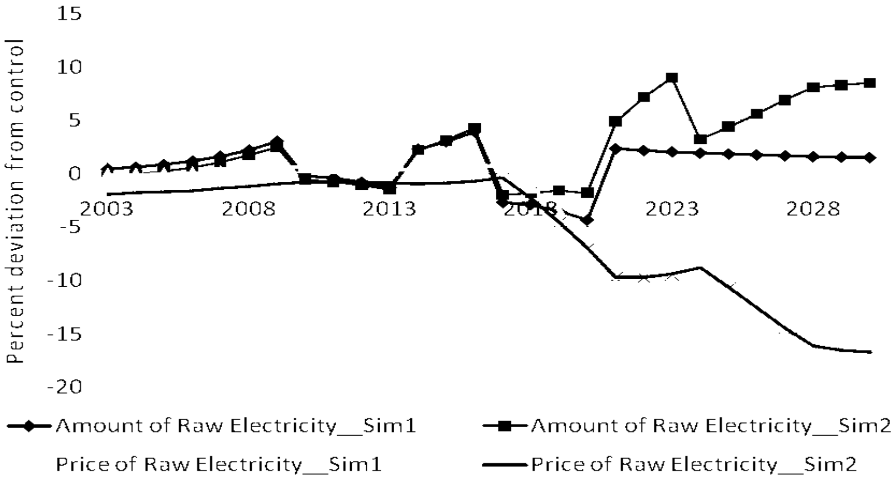
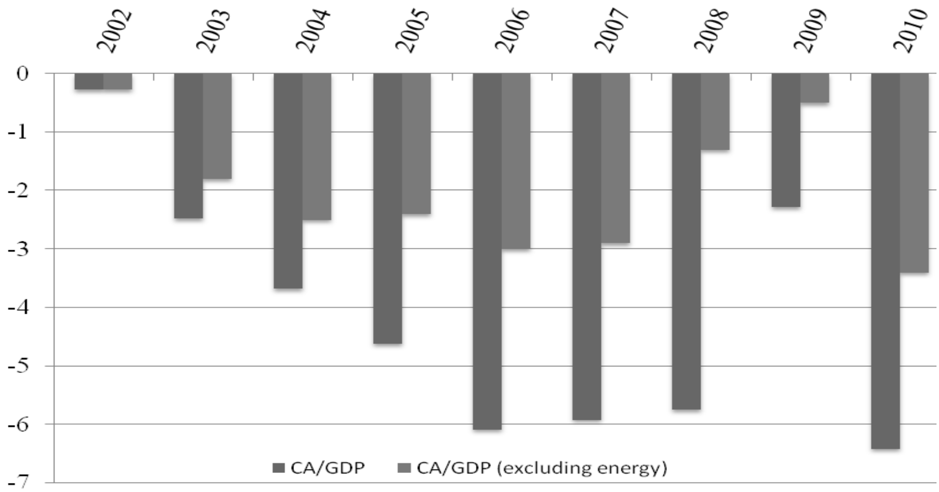


Figure 7- Change in price and amount of raw electricity

In last decades Turkeys' economy has been one of the fastest growing emerging economies. Fiscal discipline and a tight fiscal policy have contributed substantially to low inflation, as well as to the strong growth performance. In addition to its sound fiscal policies, Turkey made important progress in foreign trade sector. In 2010 while imports reached 186 billion dollar, exports reached USD 114 billion dollar and trade deficit was 72 billion dollar. Although Turkey has implemented a comprehensive structural reform agenda in energy sector in the recent years, more than half of the current account deficit comes only from the imports of energy goods like crude oil and natural gas. According to Turkeys' Central Bank data, the current account deficit as a percent of GDP in 2010 is 6.4%, while it is 3.4 % in case of excluding energy imports. (Figure 8)

It is clear that the impact of energy imports on current account deficit is very strong and it will continue to be effective for the next decades because of high crude oil prices.



Source: CBRT

Figure 8- Current account deficit as percentage of GDP

The balance of trade (or net exports) is defined as the difference between the monetary value of exports and imports of output in an economy over a certain period. It is the relationship between a country's imports and exports (Sullivan and Sheffrin, 2003) A positive balance is known as a trade surplus if it consists of exporting more than is imported; a negative balance is referred to as a trade deficit or, informally, a trade gap. An economic measure of a negative balance of trade means that country's imports exceed its exports.

Changes in Turkeys trade balance turns out to be very important for understanding the dynamic adjustment of the economy to changes in the price of a major input such as crude oil (15% of total imports) and changes in domestic prices under fixed exchange rates.[6]

As seen from figure 9, results of simulations indicate that trade deficit will widen by about 600 million TL on average in the next decade as higher oil prices drive up the cost of imported oil and inflation. Owing to the increasing share of indigenous energy production, trade deficit will start to narrow by average about 400 million TL in simulation-1 and about 400 million TL on average in simulation-2 beyond 2020.

[6] Exchange rates are assumed to be fixed in the model. Even though Turkey has switched to flexible exchange rate system since 2001, there have not been big fluctuations in recent years. http://www.tcmb.gov.tr [19]

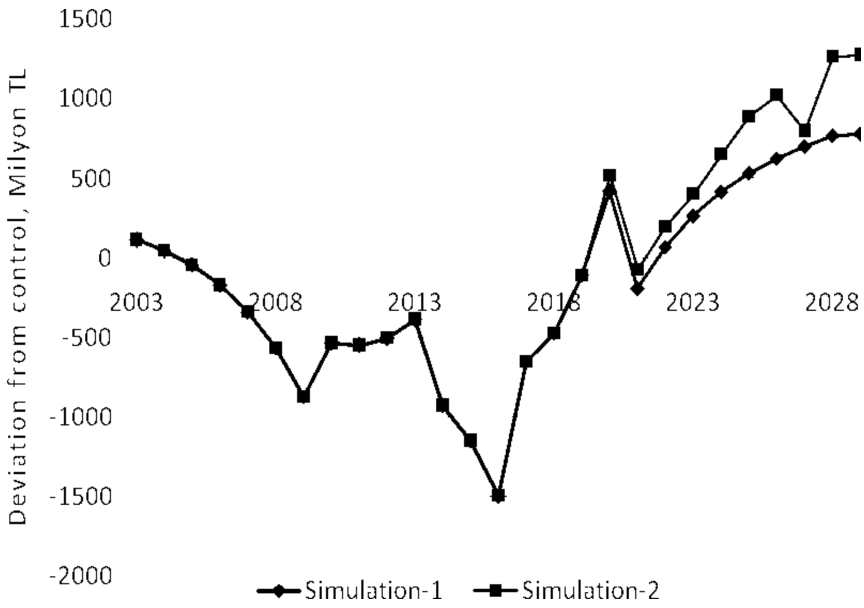


Figure 9- Trade balance

The sectoral output of simulation-1(see Figure-10) and simulation-2 (see Figure-11) show that extending power generation in favour of renewable energy sources improves the security of energy supply for Turkey. The output of oil-fired, coal-fired and gas-fired power generation fall by about 15-17 per cent per annum as shown in these figures. This is as a result of the lack of fossil fuel resources which reduce its dependency on fuel and natural gas imports through domestically available renewable energy

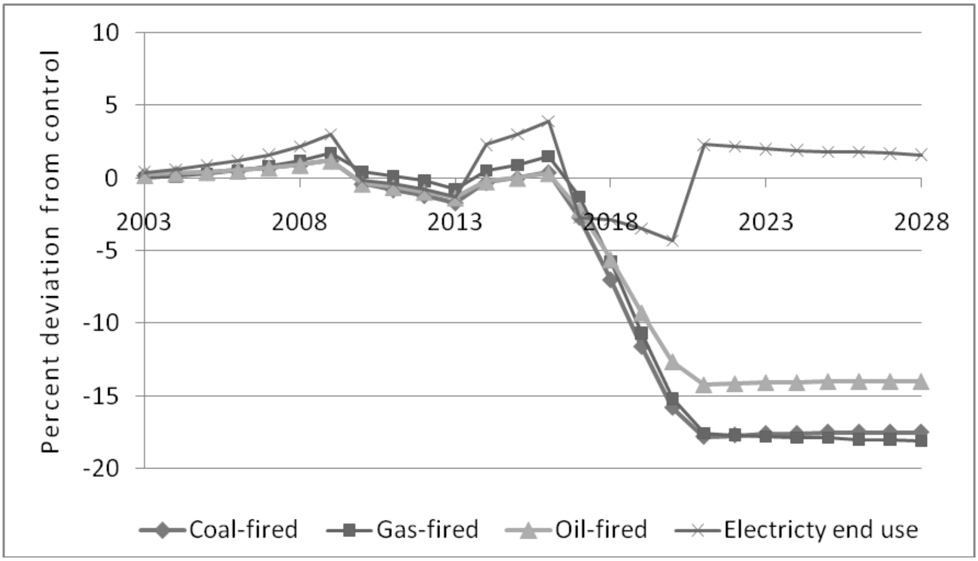


Figure 10- Change in output of fossil fired power generation in simulation-1.

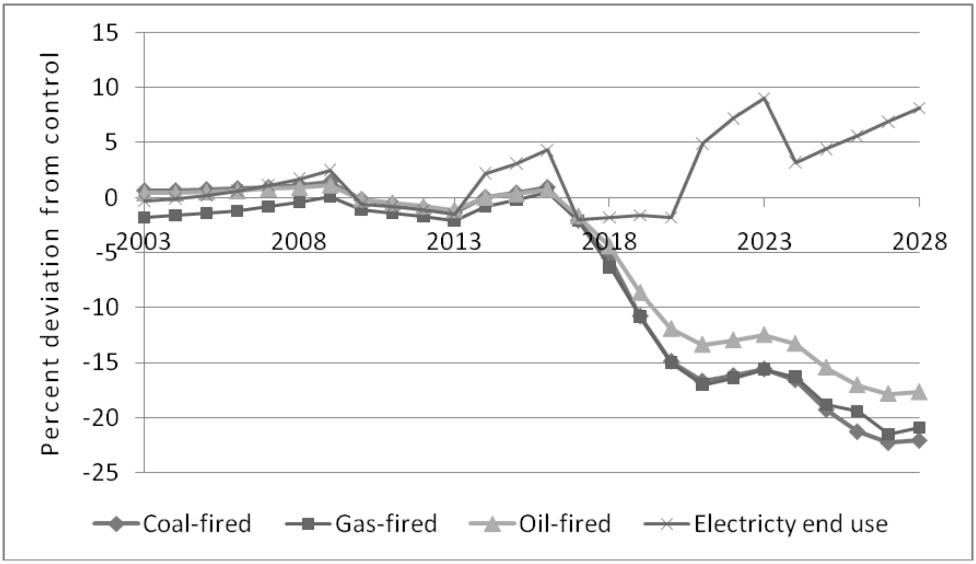


Figure 11- Change in output of fossil fired power generation in simulation-2.

Impact on carbon emission

This section examines whether the expanding hydro power and constructing nuclear power generation in the next two decades will have any significant effect on carbon emission growth rate in Turkey's economy. As known, carbon emissions are closely related to energy consumption. This consumption mainly arises from the burning of fossil fuels such as coal, gas and oil products. Therefore we assume that the rate of carbon emission for fossil fuel commodities in each period is the sum of the carbon emissions of all sources (domestic and imported) and all users (firms, household, investor and government).

The two paths of Turkey's carbon emissions resulting from two power generation scenarios are depicted in Figure 12. Throughout the whole projection period, carbon emissions are on average 3.9% lower in simulation-1 than the baseline and 4.3% lower from the baseline in simulation-2.

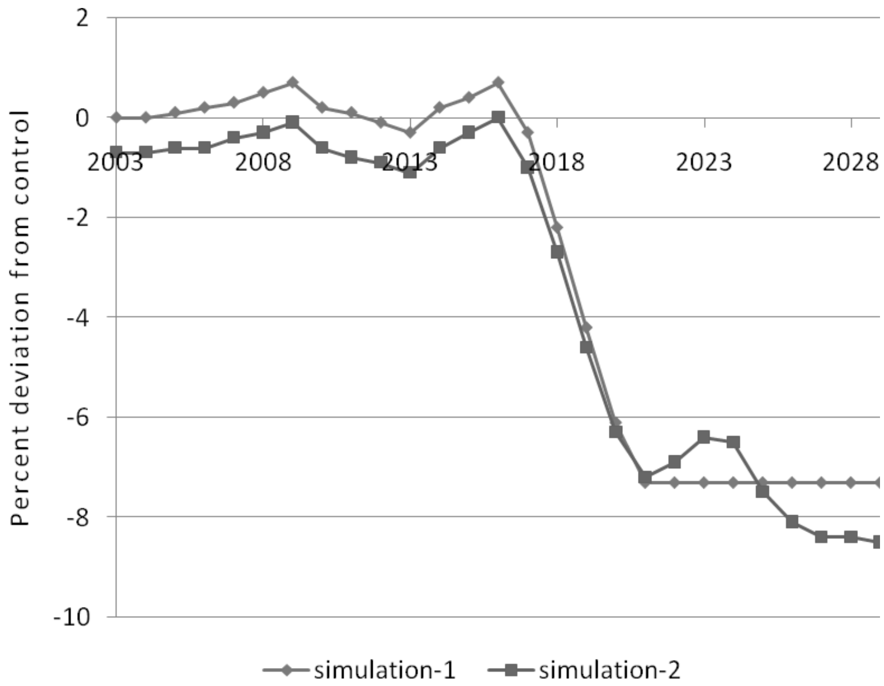


Figure 12- The change of carbon emissions

Conclusion

Turkey is one of the highest energy import dependent countries in the world, high prices of oil and natural gas are likely to have very harmful effects on Turkey's economy by causing a reduction in output and deterioration of trade balance and thereby causing a deficit in current account balance. Although Turkeys' economy has been one of the fastest growing emerging economies, the current account deficit has become major issue since the early 2000. While the most of the imported oil has been used in transportation, imported natural gas has been used in (more than 50%) power generation. Thus, increase in investment to expand hydro power and constructing nuclear power plants would contribute to the solution of current account deficit issue.

On the other hand, some economist asserts that a trade deficit representing an outflow of domestic currency to foreign markets is not necessarily a bad situation because it often corrects itself over time. But, a deficit has been reported and growing in Turkey for the last decade, which has some economists worried.

Addressing Turkey energy security and global climate change issue mainly arising from carbon emission is a major challenge for policy makers. Policy maker should take into consideration without giving up economic growth; nuclear and hydro energy is the most important option among others which can play a significant role in securing, carbon-free and competitive supply of energy on a large scale.

One should keep in mind that this model measures only deviation from the baseline as to the costs and benefits of these policies. There are many further potential advantages or disadvantages of nuclear and hydropower in the context of power generation. But they have not been captured in this analysis.

References

Dimaranan BV, McDougall RA. Global trade, assistance, and production: The GTAP 6 Data Base, Center for Global Trade Analysis. Purdue University; 2005.

Dixon PB, Parmenter BR, Russell JR. Extending the ORANI model of the Australian economy: adding foreign investment to a miniature version, Chapter 12 in H. E., Scarf, and J. B. Shoven (eds.), *Applied General Equilibrium Analysis*, Cambridge University Press; 1984.

Dixon PB, Parmenter BR, Sutton J, Vincent DP. ORANI: *A Multisectoral Model of the Australian Economy*, Amsterdam, North-Holland.1982

Harrison W, Pearson KR. Computing Solutions for Large General Equilibrium Models Using GEMPACK, *Comp. Econ.*, 1996; 9(2):83-127

Harrison WJ, Pearson KR. An Introduction to GEMPACK: GEMPACK Document GPD-1", Centre of Policy Studies, Monash University, Clayton, Melbourne, Australia. 2002

Hepbasli A. (2005). Development and restructuring of Turkey's electricity sector: a review *Renewable and Sustainable Energy Rev.*, 9:311–343

Lluch C. The Extended Linear Expenditure System: *Euro. Econ. Rev.*, 1973; 4:21-32

Malakellis M. (1998) Should Tariff Reductions be Announced? An Intertemporal Computable General Equilibrium Analysis, *Econ. Rec*., (225):121-138

Malakellis M. Integrated Macro-micro-modeling Under Rational Expectations with an Application to Tariff Reform in Australia, Physica-Verlag. 2010

McKeigue J., Cunha AD, Severino D. (2009). Turkey Opens Electricity Markets as Demand Grows, Power; Business and technology from the global generation industry, http://www.powermag.com/gas/Turkey-Opens-Electricity-Markets-as-Demand-Grows_1934.html last accessed in 10.07.2011.

Neary JP. R.C. Geary's Contributions to Economic Theory', in Conniffe D., (ed.), *Geary R.C., 1893-1983: Irish Statistician*, Oak Tree Press, Dublin; 1997

OECD, 2002. OECD Reviews of Regulatory Reform Regulatory Reform In Turkey, crucial Support for Economic Recovery OECD. Published by: OECD Publishing, ISBN: 9789264176010

Sullivan A, Sheffrin SM. *Economics: Principles in action*. Upper Saddle River, ew Jersey 07458: Pearson Prentice Hall. 2003, p. 462.

TEIAS, Directorate-General of Turkish Electricity Transmission Internet Available: http://www.teias.gov.tr last accessed 12.07.2011

The Central Bank of the Republic of Turkey (CBRT), www.tcmb.gov.tr (last accessed 12.07.2011)

Turkish Electricity Transmission Corporation Research Planning and Coordination Department (TEIAS). Turkish electrical energy 10- year generation capacity projection (2007-2018). Ankara, Turkey; 2008 [in Turkish].

Turkish Statistic Institute (TURKSTAT). The Supply-Use and Input-Output Tables, 2002, Ankara. 2008.

Uzlu E, Akpınar A, Kömürcü MI. (2011). Restructuring of Turkey's electricity market and the share of hydropower energy: The case of the Eastern Black Sea Basin Renewable Energy 36.

World Energy Council-Turkish National Committee (WEC-TNC), *Turkey Energy Report* 2009. Ankara (Turkey): WEC-TNC; 2010 [in Turkish].

World Energy Council-Turkish National Committee (WEC-TNC). *Energy Statistics,* Ankara (Turkey): WEC-TNC; 2004 [in Turkish].