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The Effects of Electricity Generation Externalities on Sectoral Output Growth and Welfare in Iran

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Abstract

Environmental problems are one of the most critical issues throughout the world and are considered as negative externalities in economic studies. In the present study, the effects of negative externalities of electricity generation on the output growth of different sectors and household's welfare in Iran's economy have been examined empirically through the use of the Computable General Equilibrium model. In this regard, Iran's 2011 Social Accounting Matrix and GAMS software were used and five scenarios related to the environmental effects of electricity generation were introduced to conduct the analysis. Based on the findings, internalization of electricity generation externalities reduced the output of the agricultural and industrial sectors but increased the services sector output in all scenarios. Additionally, internalization of externalities of electricity generation increased total output and decreased household's welfare.

1. Introduction

During the past half century, a variety of factors, such as world population, global economic growth, technological changes, innovations, introduction of new goods, and changes in consumer preferences have led to a dramatic increase in energy consumption, especially electricity consumption. Although these factors have reduced the direct demand for fossil fuels, such as oil and coal, as energy sources, they have increased the demand for these fuels as sources of electricity. Moreover, recent decade's economic development has raised some central issues, such as sustainable development and environmental problems.

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Considering electricity as one of the main sources of energy which is used by all economic agents, i.e., producers and consumers, the present study is aimed at investigating the environmental effects of power generation on Iran's economy. Accordingly, the actual impacts of the electricity consumption, including both advantages and disadvantages, on Iranian economy and society will be examined. In line with this objective, the present study is an attempt to answer the following research questions: How do negative externalities of electricity generation affect output of different economic sectors of the economy? And, how do these externalities change the household's welfare?

Considering the above, the present paper is organized as follows. In the next section, the theoretical foundations for conducting the present study will be presented and the results of some relevant studies will be discussed in the third section. Then, the research model and the relevant solution method will be explained and the databases will be introducing. Next, descriptive analysis of the results of the model will be done, and, finally, conclusions of the research results will be presented.

2. Theoretical Background

With the debate on sustainable development and environmental issues, the sources of environmental pollution came at a rapid pace with economic and social analysis. Economic agents, such as producers and households, optimized their objective functions solely based on the benefits of the use of goods and services. This has led to significant irreversible damage to the environment over the past century, especially over the past fifty years, and has imposed heavy costs on different nations and their economy. In economic analysis, these types of costs are referred to as negative costs or externalities. As Baumol and Oates (1988) have explained; externalities are unpriced, unintentional and uncompensated side effects which, through the activities of an economic agent, can directly affect welfare of another economic agent.

From the microeconomic point of view, negative externalities can affect utility functions, as well as functions of production, profit and cost of the firm. From the perspective of consumers, externalities show their impacts through the utility function of the individual. Normally, in the absence of externalities, marginal utility of all consumer goods in the basket is positive, and an increase in consumption level of goods will be accompanied with an increase in individual utility. However, the existence of a commodity with a negative externality will lead to the presence of a good with negative marginal utility which, in return, will reduce consumer utility. It is worth mentioning here that introduction of a product with a negative externality changes individual's utility function, but not consumer's budget line. This is related to the nature of the commodity with an externality because externalities have not been considered in market calculations. This can also be the case from the producer's perspective. In the absence of externalities, the firm tries to maximize its production within a specified cost limit. In this case, the firm's production level increases with an increase in the levels of all inputs in the production function. In other words, the marginal product of each input is positive. But, the introduction of a good with a negative externality is reflected as an input in the production function of the firm with a negative marginal product. This occurs when such inputs are not considered in the firm's decision-making process because they cannot affect the firm's decision through the market mechanism (Dadgar, 2012).

As a result, the existence of goods with negative externalities can affect output of firm and welfare of household and can lead to economic inefficiencies. One solution for removing this problem, as proposed by economists, can be consideration of all these issues, through the price system or the market mechanism, in decisions made by economic agents. This way, there will be a hope for achieving higher economic efficiency.

One product which is widely used both as a final product and as an intermediate input, in the process of producing other goods and services, is electricity. Regardless of its usefulness, however, this product can generate negative externalities, especially during its generation process. Taking this into consideration, various methods of electricity generation and their resultant externalities will be discussed as follow.

Nowadays, different methods are used to generate electricity. Among the most crucial factors which affect selection of the type of electricity generation method are geographical and climatic conditions of the area, and economic, technical and related environmental issues. Accordingly, there are three general methods for electricity generation, namely the use of fossil fuels, nuclear energy, or renewable energies.

External effects caused by electricity generation are largely negative. Most of these effects appear in the form of damage to human health, environmental pollution and climate change. Since, external influences change in accordance with the type of production technology, replacing a production method with another can reduce negative externalities associated with power generation through it (Mattmann et al., 2016a; 2016b). The health-related effects of electricity generation generally decrease with an increase in distance from the power generation site. Of course, it should be noted here that this is the direct effects of pollutants on human health and not the effects of climate and environmental changes on the global level (Farber, 1998). The environmental negative externalities associated with the three aforementioned methods of electricity generation have been enumerated in the following paragraphs.

a. Fossil Fuel Plants: Negative externalities caused by fossil fuel power plants often causes climate changes and climate-related greenhouse gas emissions (Foley et al., 2013). Fossil fuel power plants generate emissions of carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOX), particulate matters (PM), liquid, and solid wastes. The fossil-fuel fired power plants produce pollutants that are harmful to health and are the cause of climate change (Jorli et al., 2017). The most important environmental impact associated with fossil fuel fired power plants is air pollution (Samadi, 2017). Dispersion of air pollutants is affected by chemical and physical conditions of the atmosphere. In addition, the majority of pollutants undergo some chemical transformations. It is widely recognized that air pollution from power plants adversely affects public health (Jorli et al., 2017). For example, emissions of sulfur dioxide and nitrogen oxides lead to the formation of acid rain. This can affect natural and artificial materials and cause their degradation. Some of the most obvious issues in this regard are the reduction in the number of fertile agricultural lands and the damage to various buildings and facilities caused by corrosion. Small particles of these pollutants can easily enter the body through the respiratory system and cause some human diseases. For instance, they can directly affect the function of the respiratory system or create a variety of cardiovascular diseases (Welsch, 2016).

Concerning Iran, in 2014, in highest carbon dioxide emissions, with 29.5% of the total carbon dioxide produced in the country, were related to the power plant sector. Furthermore, fossil fuel power plants accounted for 42.3% of the total sulfur dioxide and 33% of the total nitrogen oxides produced in the country in the same year.

b. Nuclear Power Plants: Negative externalities associated with nuclear power have the same potential for radioactive emission into the environment. It is possible that the environment or human beings will be affected by these emissions during the operation of the plant or during disposal of nuclear wastes. In such cases, there is little possibility of radiation. However, a nuclear incident or natural events can cause severe damage to a power plant that leads to the radiation in a considerable scale and has a severe and irreversible impact on humans, plants and animals. Therefore, the magnitude of negative externalities associated with a nuclear power plant depends on the probability of such an unpleasant incident and the economic costs of the probable damages (Welsch, 2016).

c. Renewable Energies: Part of the negative externalities of renewable energies is due to the low efficiency of this type of energy, as compared to the efficiency of fossil fuels and nuclear energy. This means the space occupied by a renewable energy plant should be larger than that for a fossil or nuclear power plant to produce a specific amount of electricity (Wüstenhagen et al., 2007). This can especially be true with regard to three electricity generation technologies, namely hydroelectric, wind and photovoltaic (PV) power, because there is a need for a vast area for all the three technologies. Dam construction projects require a huge amount of excavation for building a hydroelectric power plant. This will destroy the natural landscape, animal life and plant structure, and even in some projects, historical and cultural heritage. PV power may be regarded as a perfect energy source, but life cycle assessment results have revealed that PV power plants have some negative repercussions for the environment and human health. First, PV power plants can cause damage to land and ecosystem. Large-scale PV power plants can also arouse concerns about land degradation and habitat loss. PV power plants have considerable impacts on the wildlife and habitats because constructing such plants use a vast area.

Second, PV power plants have negative effects on beauty of the natural scenery. Finally, solar panels can cause damages for human eyesight which affect every citizen. Therefore, PV power plants affect environment, human health and wildlife, considerably. (Yang et al., 2017).Wind power doesn't make any wastes but it has some externalities. The most attributed externalities to wind power include unpleasant noise emissions, impacts on wildlife, and negative impacts on landscape aesthetics (Krekel and Zerrahn, 2017). Another form of renewable energy which has been developed over the last decade is biomass. Biomass power plants use non-fossilized and organic material originated from plants, animals and microorganisms as fuel in order to produce electricity. As with other types of combustion, biomass fuel combustion emits air pollutants. The amount and type of pollutants depends on both the specific combustion process involved and the extent of controlled burning. Compared with fossil fuels, combustion plants fired with forest residues emit similar levels of nitrogen oxides, but significantly less sulfur dioxide (Carneiro and Ferreira, 2012).

3. Review of Empirical Studies

In this section, some studies on the environmental impacts and costs of electricity industry and energy policies have been reviewed.

Naqvi (1998) introduced a Computable General Equilibrium (CGE) model to show the relationship between energy sector and economic indices in Pakistan. Accordingly, the study has tried to identify the internal links between energy, economy, and equality through making some remarkable changes in the neoclassical standard model.

Akpan and Akpan (2012) reviewed the effect of energy consumption on carbon pollution and economic growth in Nigeria. In line with this, the researcher used a multi-vector error correction model which showed a direct relationship between economic growth and carbon emissions on one hand and between power consumption and carbon emissions on the other hand.

Asiae et al. (2012) examined environmental effects of removing energy subsidies in the industrial sector of Iran. Based on their results, elimination of subsidy led to a change in consumption of various energy sources and to a considerable reduction in carbon dioxide pollution.

In another study, Amadeh et al. (2015) analyzed environmental and welfare effects of subsidy modifications of energy inputs in Iran through the use of a CGE model. The model showed that redistribution of income between households would increase their welfare. On the other hand, the results indicated that price correction of energy inputs could be generally effective in reducing emissions of pollutants.

Meng et al. (2015) also examined the effect of carbon taxes on Australia's environment and employment using a CGE model. Their findings revealed that although carbon taxes could efficiently reduce carbon dioxide emissions, they would lead to economic contractions, for instance a contraction in employment.

Khiabani (2017) developed a Dynamic General Equilibrium Model for examining the effects of energy policies in Iran. The researcher found that eliminating energy subsidies, either once and for all or gradually, was in itself insufficient to stimulate investment and economic growth in the absence of technological progress. Furthermore, the simultaneous effects of eliminating energy subsidies and technology policies led to a strong economic growth stimulus and a significant increase in productive efficiency and a decline in energy intensity.

4. Methodology and Data

CGE model represents a typical economic cycle in the form of a general equilibrium model which can be accessed through the price system. In other words, CGE models include a set of mathematical equations which explain the economy and the interrelationships between its components. There are some considerable advantages in these models. The main advantage of CGE models is that their data requirements can be low and relative to the size of the entire model. To use these models, the researchers only need macro-level data, such as input-output tables related to a specific year. In addition, these models can help in combining a considerable number of different industry subdivisions, and thus reduce the need for multiple data sets.

4.1 Data

The Social Accounting Matrix (SAM) describes transactions done by economic agents involving goods and factors which uses as the CGE model database. SAM is a data matrix. SAM is a square matrix in which each account is represented by a row and a column account. The column represents the cost structure of each economic unit and the row shows the revenue sources of each economic unit.

The main factor in determining the structure of a CGE model is the type of data based on which the research is conducted. The present researchers have benefitted from the 2011 SAM for Iran, developed by the Research Center of the Islamic Consultative Assembly, in conducting the present study.

4.2 Model Structure

In addition to the SAM, which is a database of CGE models, these models consist of four main components, namely price blocks, production activities, institutions, and conditions of economic equilibrium. In fact, these four components show the equilibrium conditions of an economy in the context of the SAM. Furthermore, due to the objectives of the present study and the structure of the 2011 SAM, only three groups of equations will be discussed based on Hosoe et al. (2010). These equations are production activities, institutions which include households and government and investment and savings, and market-clearing conditions.

4.2.1 Production Activities

Firms are assumed to use intermediate inputs in the production process. This assumption complicates the behavior of firms and leads to the division of the production process into two stages. In the first stage, labor and capital are used to generate composite factor, (or value added). In the second stage, composite factor combines with intermediate inputs and develop the gross domestic output. Accordingly, the Cobb Douglas production function was used in the first stage and the Leontief production function was used in the second stage of the production process. These two functions are homogeneous of degree 1 and have a constant return to scale. Considering the Cobb Douglas function, substitution between inputs is possible; however, there is not such a possibility with the Leontief production function is used. Despite this, the Leontief function reduces the complexity of the model and its computational burden.

Accordingly, the profit maximization problem of firm *j* can be represented as follows:

- For the first stage

$$maximiz_{Y_j, F_{h,j}} \pi_j^y = p_j^y Y_j - \sum_h p_h^f F_{h,j} \tag{1}$$

Subject to:

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \tag{2}$$

- For the second stage

$$maximiz_{Z_j, Y_j, X_{i,j}} \pi_j^z = p_j^z Z_j - (p_j^y Y_j + \sum_i p_i^q X_{i,j}) \tag{3}$$

Subject to:

$$Z_j = min\left(\frac{X_{i,j}}{ax_{i,j}}, \frac{Y_j}{ay_j}\right) \tag{4}$$

where π_j^y stands for the profit of firm *j* which leads to the composite factor Y_j in the first stage. Furthermore, π_j^z refers to the profit of firm *j* which leads to the development of the gross domestic product Z_j in the second stage. Y_j is the composite factor which is produced in the first stage and is used by firm *j* in the second stage. $F_{h,j}$ is *h*'s production factor and is used by firm *j* in the first stage. Z_j refers to the gross domestic product of firm *j*, and $X_{i,j}$ is the intermediate inputs used by firm *j* for producing good *i*. p_j^y refers to the price of the j-th composite factor, p_h^f to the price of factor *h*, p_j^z to the price of gross domestic product *j*, p_i^q to the price of composite good *i*, $\beta_{h,j}$ to the elasticity coefficient in composite factor production function, b_j to the scale coefficient in composite factor production function, $ax_{i,j}$ to the coefficient of intermediate input *i* in the Leontief production function for producing the *j*-th good, and ay_j to the composite factor *j* in the Leontief production function for producing good *j*.

Considering all the above, the effect of changes in each of the aforementioned variables on the gross domestic output growth rate can be examined under different scenarios.

4.2.2 Institutions

Institutions usually include three economic agents, namely government, investment and savings or enterprises, and households in general equilibrium models. These three categories will be introduced briefly in the following sections.

- *Government*

Any realistic CGE model must include government. The government collects taxes, including direct taxes, production taxes, and import tariffs and spends parts of these revenues on their consumption and saves the rest. According to the 2011 SAM matrix, the government's equations will be expressed as follows:

$$T^d = \tau^d \sum_h p_h^f FF_h \tag{5}$$

$$T_j^z = \tau_j^z p_j^z Z_j \qquad \forall_j \tag{6}$$

$$T_i^m = \tau_i^m p_i^m M_i \qquad \forall_i \tag{7}$$

$$X_i^g = \frac{\mu_i}{p_i^q}\left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g\right) \qquad \forall_i \tag{8}$$

In the equations (5) to (8), T^d refers to direct tax, τ^d to direct tax rate, FF_h to factor endowment of the *h*-th factor for the household, T_j^z to production tax on the *j*-th good, τ_j^z to production tax rate on the *j*-th good, T_i^m to import tariff on the *i*-th good, τ_i^m to import tariff rate on the *i*-th good, p_i^m to price of the i-th imported good, M_i to imports of the *i*-th good, X_i^g to government consumption of the *i*-th good, μ_i to share of the *i*-th good in government spending ($0 \leq \mu_i \leq 1, \sum_i \mu_i = 1$), p_i^q to price of the *i*-th composite good, and S^g to government savings.

- *Investment and Savings*

Since the CGE model is a static model but investment and savings are dynamic factors, there is an inconsistency problem between the dynamic concept of these factors and the static origin of the CGE model. However, investment has a significantly large share in final demand. To make this concept consistent with a static model, investment has been described as a virtual agent who collects funds from households, government, and the external sector and spends them on purchasing investment goods. This agent's behavior can be represented in the following form of investment demand function:

$$X_i^v = \frac{\lambda_i}{p_i^q}\left(S^p + S^g + \varepsilon S^f\right) \qquad \forall_i \tag{9}$$

$$S^p = ss^p \sum_h p_h^f FF_h \tag{10}$$

$$S^g = ss^g\left(T^d + \sum_j T_j^z + \sum_j T_j^m\right) \tag{11}$$

where X_i^v refers to demand for the i-th investment good, λ_i to expenditure share of the i-th good in total investment ($0 \leq \lambda_i \leq 1, \sum_i \lambda_i = 1$), S^p to household savings, ε to foreign exchange rate, i.e. domestic currency foreign currency, S^f to current account deficits in foreign currency terms or, equivalently, foreign savings, ss^p to household's average propensity to save , and ss^g to government's average propensity to save .

-Household and Welfare

Consideration of government, investment, and savings into the model requires modification of household's behavior equations based on these economic agents. The utility maximization problem facing the household is stated as follows:

$$max_{X_i^p}\, UU = \prod_i \left(X_i^p\right)^{\alpha_i}$$

(12)

Subject to:

$$\sum_i p_i^q X_i^p = \sum_h p_h^f\, FF_h - S^p - T^d \tag{13}$$

UU refers to utility, X_i^p to household consumption of good i, FF_h to household endowment of factor h, S^p to household savings, T^d to direct taxes, p_i^q to price of composite good i, p_h^f to price of factor h, and α_i to coefficient representing the share of goods in utility function, i.e. $\sum_i \alpha_i = 1$, $0 \leq \alpha_i \leq 1$.

By solving household's maximization utility problem, household's demand function for commodity i can be obtained as follows:

$$X_i^p = \frac{\alpha_i}{p_i^q}\left(\sum_h p_h^f\, FF_h - S^p - T^d\right) \tag{14}$$

Household's welfare can be analyzed through taking into account negative externalities of electricity generation. For this purpose, Equivalent Variation (EV) index commonly uses in CGE models. This index measures changes in economic welfare caused by price changes. This index was first introduced by John Hicks (1939). The equivalent variation index can be expressed as:

$$EV = E(P^b, u^p) - E(P^b, u^b) \tag{15}$$

where E is the expenditure function that indicates minimum expenditure level subject to the price vector P in order to achieve the level of utility u. Expression $E(P^b, u^p)$ represents the expenditure function after applying the scenarios, and $E(P^b, u^b)$ represents the expenditure function before applying the scenarios.

4.2.3 Macro Closures and Market-clearing Conditions

A macro closure is a set of assumptions which is used to choose exogenous variables from among all the variables in the model. There are three main macro closures in CGE models which impose some constraints on investment and savings, government, and current account balance.

In this study, the macro closure for investment and savings is a savings-driven closure type. Savings are determined by equations (10) and (11); therefore, savings of each sector are determined in the model, and investment, as an endogenous variable, adjusts itself to establish equality between savings and investment. Regarding government sector, the government's incomes are endogenous. Based on initial values, the combination of government spending is fixed. Government savings is flexible and endogenous. Considering current account balance, two constraints are used; foreign investment which is assumed to be exogenous and exchange rate which is endogenous and determined in the model.

In order to achieve a balance between demand and supply in all markets, it is important to impose the market-clearing conditions. These conditions are as follow:

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j} \qquad \forall_i \qquad (16)$$

$$\sum_j F_{h,j} = FF_h \qquad \forall_h \qquad (17)$$

where, in Equation (16), Q_i is the i-th Armington composite good. The composite good of Q_i is used by the household, the government and the investment agent as well as for intermediate input; the same price p_i^q, is applied to all of them. Equation (17) represents the factor market-clearing condition.

4.3 Model Calibration

Calibration process refers to solving of unknown parameters in the model. This process is done by setting the endogenous variables at a certain value to achieve the observed equilibrium in the SAM. Calibration is concerned with estimating the CGE model parameters, which can be categorized into two groups. The first group of parameters can be calculated by the SAM data. The second group of parameters comes from the relevant previous studies. For instance, Sharifi et al. (2012) considered the elasticity of substitution between capital and labor equal to 1, the elasticity of substitution between intermediate input and composite factor equal to 0 and the elasticity of substitution between imports and domestic goods equal to 3. Also, they considered the elasticity of transformation between exports and domestic goods equal to 1.

The elasticity of substitution between imports and domestic goods and the elasticity of transformation between exports and domestic goods have been 0.5 and 2, respectively in most of the previous studies. Other parameters, including $\beta_{h,j}$, ay_j, and $ax_{i,j}$, however, have been estimated through the use of the SAM data.

4.4 The Extent of Electricity Production Negative Externalities

As it was aforementioned, environment and health scientists have conducted extensive researches on negative externalities of electricity generation. Accordingly, the effects of several environmental pollutants, environmental degradation, and other external factors on environment and human health have been investigated using a variety of biological and environmental functions, and experts have also examined these issues from an economic point of view. Based on the aforementioned studies, generally, negative externalities can be classified into two categories with either local effects or global effects. Global effects of generating electricity are often produced by greenhouse gas emissions which, in turn, are due to the production of carbon dioxide. On the other hand, local and regional effects are produced by other pollutants which are not spread over long distances, such as particulate matter or sulfur oxides. Rabl and Spadaro (2005) did a comprehensive study on the cost-benefit analysis of negative externalities of power generation. These researchers considered both the negative global effects and the negative domestic effects of electricity generation. In this research, they tried to adjust the results of the selected power plants in order to achieving comprehensiveness and generalizability of the research results. Finally, the researchers presented cost range results were for each method of generating electricity.

To consider the result of the aforementioned study results in the present study, power generation's external costs had to be changed into Iranian currency. To do so, those cost ranges were multiplied by exchange rate. However, it is worth mentioning that Rabl and Spadaro conducted their study in 2005 and the SAM data was analyzed in 2011. Therefore, Purchasing Power Parity (PPP) index was used in the present study to convert their calculated cost range in order to time consistency. This index can help researchers to consider the effects of inflation on cost ranges. Calculation results have been provided in the Table (1).

Table 1. The external cost of different electricity generation methods

Electricity generation method	Cost (€$\mathbf{c}/\boldsymbol{kWh}$)	Cost ($\boldsymbol{IRR}/\boldsymbol{kWh}$)
Coal	1.8 - 5.8	360-1159
Oil	1.6 – 4.8	320-959
Natural Gas	1 – 2.5	200-500
Nuclear Power	0.15 – 0.23	30-46
Hydroelectric	≤0.09	≤18
Wind Power	0.09 – 0.12	18-24
Solar Power	0.28 – 0.41	56-82
Biomass	0.07 – 1.9	14-380

Source: Rabl & Spadaro (2005) and Research finding

Considering the above, in any country, including Iran, one range of cost can be calculated for the negative externalities of the entire country's electricity generation, due to the combination of different methods of electricity generation. In order to consideration of the environmental impacts of electricity generation on the Iran's economy, this cost range has to be calculated and applied to the electricity price.

5. Empirical Results

In this section, different scenarios, created in the general equilibrium model based on the structure of power generation, will be presented first. Accordingly, then, based on the presented scenarios, the resulting effects on sectoral output growth, output growth and welfare will be analyzed.

As the SAM which has been used in the present study was related to the year 2011, the electricity generation statistics used for the scenarios, were also selected from the same year. Nine methods of electricity generation were used in Iran in 2011. Among those methods, four of them, namely steam power plant, combined cycle, gas and diesel engines, belong to the category of thermal power plants. The other five methods include hydropower, nuclear power plants, wind power plants, biomass power plants, and PV power plants are in the category of new and renewable electricity generation methods. Considering the above categories and based on statistics on electricity generation in 2011, the aforementioned methods have respectively had a 35.95%, 30.31%, 24.46%, 0.03%, 5%, 0.14%, 0.08%, 0.02%, and 0.01% shares of electricity generation in the country.

To adapt aforementioned data with Table (1), some adjustments are needed. Since the supply of thermal power plants of Iran includes three main types of fuel including natural gas, fuel oil, and diesel, summation of fuel oil and diesel share shows the percentage of electricity that is produced from oil and respectively, for natural gas. According to Tavanir's statistics, natural gas share in electricity generation in thermal power plants is 62% and fuel oil and diesel share is 38%. Based on these figures, the share of each electricity generation method in providing the required electricity for Iran has been shown in Table (2).

Table 2. Share of power plants in supplying electricity

Electricity generation methods	Share of gross power generation (percent)
Natural gas	58.75
Oil	36
Hydro	5
Nuclear	0.14
Wind	0.08
Biogas	0.02
Solar	0.01

Source: Research finding

Considering Tables (1) and (2), the monetary value of negative externalities of electricity generation in Iran has been calculated as a weighted average. Table (1) shows the monetary value of negative externalities caused by each specific power generation method and Table (2) depicts the relevant weight of these methods in Iran. Accordingly, the monetary value of the environmental effects of electricity generation in Iran varies between 233 and 639 Rials per kilowatt-hour. Regarding this range, the average level is about 436 Rials per kilowatt-hour. Consequently, the environmental effects of electricity generation on the three major economic sectors of Iran have been examined under five scenarios. In CGE models, price changes which are caused by policies are not considered at once so that the effects of electricity price shock can be properly examined. To examine the overall effect of the electricity price shock, however, the scenarios have been defined in terms of certain increases, as it can be seen in Sanei and Saadat (2013). These five scenarios are in the form of a series of 25% increases in electricity price based on the external costs of electricity generation. The starting point of the electricity price change is the lower band of the aforementioned cost range. Then it has four 25% increases to reach the upper band, which shape the five scenarios. The results of the model for output growth in the three sectors of agriculture, industry, and services have been shown in Table (3).

Table 3. Percentage of sectoral output growth

Scenarios	Percentage of agriculture output growth	Percentage of industry output growth	Percentage of services output growth
1	-0.158	-0.579	1.669
2	-0.254	-0.952	2.367
3	-0.331	-1.255	2.905
4	-0.464	-1.777	3.803
5	-0.578	-2.22	4.548

Source: Research finding

As shown in Table (3), in all scenarios, an increase in electricity price caused by consideration of external costs of electricity generation has led to a decrease in the output of agricultural and industrial sectors and an increase in the output of the services sector. For instance, if the electricity price increases by 233 Rials per kilowatt-hour, as it is the case for the first scenario, agricultural and industrial outputs decrease by -0.158% and -0.579%, respectively, and the services output increases by 1.669 %. With regard to the forth scenario, a rise in electricity price by 537 Rials per kilowatt-hour has led to a 0.464% decrease in the output of agricultural sector, a 1.777% decrease in the output of industrial sector, but a 3.803% increase in the output of the services sector.

Regardless of a commodity’s externalities and from a social point of view, the market price of the commodity does not represent its actual price. Considering these external effects and internalizing them, the real price or the social value of the commodity will be obtained. This issue has been examined in the present study's research model for electricity price as an intermediate input. Regarding the applied static model, there is no possibility of changing the production technology or the ratio of the use of intermediate inputs and composite factor. In other words, changes in electricity price, based on the CGE model introduced above and the structure of the SAM for Iran's, lead to reallocation of composite factor components, including labor and capital. Therefore, composite factor components move from the agricultural and industrial sectors to the services sector. Based on the model assumptions, thus, factors of production are assumed to be constant. Given the Cobb-Douglas production function in the nest of composite factor, it is only possible to relocate composite factor components between different sectors of the economy. Therefore, the effect of changes in price of intermediate inputs, electricity in this case, will lead to the displacement of composite factor components between economic sectors. Accordingly, as the model results have indicated, internalization of externalities of electricity generation has first increased utilization of capital in the agricultural sector and reduced the employed labor force, which has led to the mechanization of this sector in all scenarios. Second, it has led to a decrease in the use of labor force and capital in the industrial sector, and, Third, an increase in labor force and capital employment in the services sector. Given that intermediate inputs and composite factor are complementary in the short term (constant production technology), and in accordance with the Leontief production function, a certain proportion of them must be used together. Thus, intermediate inputs also move from the agricultural and industrial sectors to the services sector at the same rate. All changes in intermediate inputs and composite factor in the three sectors in the fourth scenario have been shown in Table (4).

Table 4. The percentage rate of changes in production inputs

Percentage of Changes in	Agriculture	Industry	Services
Labor force	-1.469	-2.939	2.699
Capital	0.149	-1.345	4.385
Composite factor	-0.464	-1.777	3.803
Intermediate inputs	-0.464	-1.777	3.803

Source: Research finding

As a result, we see the reallocation and optimization of intermediate inputs and composite factor components arising from the internalization of the electricity generation's externalities. Although the outputs of the agricultural and industrial sectors have decreased, the output of the services sector has increased. Because of services sector's weight in the output of the entire economy, its output growth ultimately leads to the growth of aggregate output, as it has been shown in Table (5). Considering Iran's 2011 economic structure and with regard to changes in the allocation of intermediate inputs and composite factor components, this can indicate that internalization of externalities of electricity generation, can lead to changes in the growth of output for various economic sectors in such a way that the output of the entire economy increases. This is consistent with economic theories of public sector about externalities, which state that internalization of negative externalities leads to moving towards the optimal social production level with a higher production rate than that of the optimal private level.

Table 5. The percentage rate of output growth

Scenarios	1	2	3	4	5
Output growth percentage rate	0.051	0.058	0.062	0.065	0.067

Source: Research finding

Moreover, one of the objectives of the present study has been to observe the effect of negative externalities of electricity generation on household's welfare. Considering this, the results of the model have been presented in Table (6).

Table 6. The percentage rate of changes in household's welfare

Scenarios	1	2	3	4	5
Changes in households' welfare (percentage)	-1.355	-1.985	-2.297	-2.947	-3.47

Source: Research finding

Given the relationships between consumption, demand and utility function of the household, there is a negative relationship between the consumption of a particular good and its price. Therefore, a rise in price of a commodity reduces the demand for consumption of that commodity by the household. In addition, since there is a direct relationship between utility level of the household and household consumption of goods, utility level decreases with a decrease in consumption, and this can, in turn, reduces household's welfare.

6. Conclusion

There have been dramatic changes in the pattern of energy consumption all around the world over the past few decades. Technological changes, development of new methods for producing goods and offering services, and production of new goods have significantly changed consumption and production structure. This has greatly heightened the need for electricity power. Different electricity generation methods, however, can lead to harmful environmental effects and negative externalities, which are usually not taking into account in determining electricity price. In the present study, the effect of negative externalities of electricity generation on outputs of different sectors, total output and household welfare has been investigated in relation to the Iranian economy.

Regarding this, changes in the aforementioned variables were analyzed using the SAM, Version 2011, statistics on electricity generation in 2011, and international information on negative externalities of various methods of electricity generation. The data were then used in a CGE model. Based on the results of the model, internalization of externalities of electricity generation led to a decrease in the outputs of the agricultural and industrial sectors but an increase in the output of the services sector in all scenarios. Furthermore, in all scenarios, internalization of externalities of electricity generation increased the output of the entire economy but reduced household welfare.

As the findings indicated, externalities of electricity generation can have significant effects on Iranian economy, for instance they can have strong effects on output growth in different sectors and household's welfare. Since the effects of these externalities are different in different sectors, the results of this study give policy makers a complete vision about the consequences of environmental policies for Iranian economy. Considering electricity externalities on the sectoral output growth and the overall output growth, the present study's findings can be of great help to policy-makers in developing appropriate environmental policies. These findings can also help them in developing a comprehensive vision of the impacts of the adopted policies on different Iranian economic sectors.

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