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The Effect of Climate Change on Economic Growth (Application of DCGE Model for Iran)

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Abstract:

Climate change is one of the most important issues affecting different economic sectors. Although this phenomenon has had a larger effect on the agricultural sector due to the heavy dependence of agriculture on weather conditions as compared to the other economic sectors, other economic sectors such as the industry, mining and service sectors are also influenced by weather changes due to their intra-sector dependence on the agricultural sector. Accordingly, the effect of climate change on the economic growth of Iran was examined in this research using the Dynamic Computable General Equilibrium (DCGE) model. Our investigation revealed that the decrease in the precipitation in the twenty-year horizon (2011 to 2030) will reduce consumption in all sectors. Moreover, while production in the agriculture and mining sectors declines, it escalates with a descending trend in the industry and service sectors. Based on our findings, as a result of the decreased investment in the other sectors, investment in the agriculture, industry, and mining sectors decreases, whereas it rises in the service sector. Given the research results and the challenge of climate change facing this country, the Iranian government must devise a master practical plan to adapt to and confront this phenomenon and reduce its adverse effects.

1- Introduction

Climate is the average weather conditions in a particular area during a specific period of time. According to the definition by the Intergovernmental Panel on Climate Change (IPCC), climate change occurs if the weather indices of a region deviate from the long-term expected behavior (based on the recorded and observed information on the area) and the changes are irreversible. This definition applies to any change caused by human activities or the natural instability of the climatic system. This change differs from short-term climatic fluctuations.

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In recent decades, climate change has affected many parts of the world, and the effects of these changes are expected to escalate in the coming decades. Iran has not been excluded from these vast changes, which are evident in many parts of this country (Khaledi et al., 2015). This phenomenon influences the country's economic sectors such as the production sector, income of production agents, and income of the institutes. This influence is more marked on the sectors that interact on a higher level with the agricultural sector (Khaleghi et al., 2015).

One of the most important consequences of climate change, which is also one of the major global challenges, is the decrease in precipitation and the increase in temperature, which significantly affect agricultural crops (Parhizkari et al., 2014).

Today, long-term forecasts of the climate variables including temperature and precipitation, awareness of climatic fluctuations, and preparedness for the destructive consequences of these changes have captured the attention of researchers (Moradi et al., 2015). In general, the increase in the sea levels and the earth's temperature and the occurrence of drastic weather fluctuations and drought could be considered the consequences of climate change. Most experts consider climate change to be one of the most important environmental challenges of the past century. They believe that this challenge will have serious economic consequences (Redsma et al., 2009). Nicholas Stern, the prominent economist of the World Bank, discussed the effects of climate change on the global economy in a report published on October 29, 2006. He noted that weather changes can seriously affect economic growth and it can drive one-fifth of the global economy to bankruptcy.

A review of literature shows that few studies have been conducted on the effects of climate change on the macroeconomic variables of the developing countries such as Iran with the aim of simultaneously studying the effects of this phenomenon on all economic sectors, and studies have been mainly focused on the agricultural sector.

One of these studies in Iran is the research by Khiz (2012) who investigated the effects of drought on Iran's economy using the computable general equilibrium (CGE) method. His findings revealed that drought can reduce the gross domestic product (GDP), the regional gross domestic product (GDPR) of all provinces, total employment, and employment in most provinces.

Madani and Khaleghi (2015) estimated the variation of the production of the agricultural sector as a result of climate change using the social accounting matrix in Iran. They found that as a result of Iran's predicted climate change, agricultural production will decrease by 5.37% and 11.67% from 2000 to 2025 and from 2025 to 2050, respectively.

In a similar study in the foreign countries on the effect of climate change on the agricultural sector, Ben Zaied (2013) investigated the effects of precipitation and annual temperature on the agricultural sector of Tunisia using the dynamic panel data method. Their findings revealed that the annual temperature and

annual precipitation had a negative and positive effect on the production of cereals and the total agricultural production of Tunisia, respectively.

In a study titled "Analysis of the Effect of Climate Change on Economic Growth Using the Dynamic Computable General Equilibrium Model", Eboli et al. (2010) concluded that the impact of climate change varies across the sectors and countries, but it mostly causes damage to the developing countries.

Gebreegziabher et al. (2011) used the CGE model to investigate the effects of climate change (temperature and precipitation) on the Ethiopian economy and found that within a five-year period, the predicted decrease in agricultural productivity will reduce the average revenue of the agricultural sector by 30% as compared to the possible consequences of no climate change.

Elshnnawy et al. (2015) examined the effects of climate change on the economic growth of Egypt using the DCGE model and reported that climate change will negatively affect economic growth as well as the agricultural development of this country.

Chalise et al. (2017) used the CGE model to investigate the economic effects of weather changes on the agricultural sector of Nepal and stated that climate changes will adversely affect the productivity of the agricultural sector due to a decrease in production and this negative effect will extend to the economy of this country. Their findings also indicated that the rural households of Nepal, who mostly make a living through farming, will suffer poverty due to the anxiety caused by the weather changes and this will undermine the social welfare system of this country.

Babatunde et al. (2017) studied 154 articles from 67 journals to examine the preventive actions for preventing climate change and political interventions. Their analyses revealed the cardinal importance of the CGE model for solving the problems of preventing climate change on the national, regional, and global levels. The most important studies in this field have been carried out in China, the United States, India, and Australia, which are mainly concerned about issues such as carbon tax, greenhouse gases emission, renewable energies, and absorption and storage of carbon. Finally, the DCGE and the ABM (agent-based model) models were recommended for studying the existing gap in the literature.

Considering the previous investigations and the effects of climate change on the agricultural sector, especially in the developing country, the overarching goal of this research is to study the effects of climate change on Iran's economic growth using the DCGE model.

2- Research Method

The information base of the general equilibrium models is the Social Accounting Matrix (SAM), which reflects the circular flow of cash between different sectors, agents, and institutes in a market-based economy. SAM is a

square matrix designed to have an equal number of rows and columns. The columns show the receipts (income) and the rows show the payments (expenditures). According to this definition, the total income in all accounts must be equal to the total expenditure in all accounts. In other words, the income of a given economy must be equal to its total expenditures. The most important attribute of this matrix is the integration of all economic sectors with similar functions into an overall framework.

Since the SAM is a descriptive tool for presenting the details of the economy of a country, it is useful for general equilibrium analyses because it provides information on the production sectors and the relationship with the outside world. It also shows the relationship between income generation and consumption.
The research model was implemented using the social accounting matrix of the Iranian economy in 2011.

2-1- Production Equations

In the general equilibrium model, the use of the workforce and investment, as the inputs for production by the economic sectors is considered one of the primary estimation assumptions. To implement the model, in addition to the inputs it is assumed that the sectors also use the intermediate inputs in production. This assumption complicates the behavior of the firms and divides the production process into the first and second phases.

Phase one involves the combination of the investment and workforce inputs, resulting in the value added creation. The production function in this phase is the Cobb-Douglas function, which is expressed as Equation (1).

$$VA_{j,t} = b_{j,t} \prod_{h} FD_{hj,t}^{\beta_{hj,t}} \qquad (1)$$

In phase two, the value added created in phase one is mixed with the intermediate commodities and the production equations are generated as Equations (2) and (3) assuming the Leontief technology.

$$X_{ij,t} = ax_{ij,t}.Y_{j,t} \qquad \forall i \qquad (2)$$

$$VA_{j,t} = ay_{j,t}.Y_{j,t} \qquad \forall j \qquad (3)$$

where *i* and *j* are the sector or commodity indices, *h* denotes the initial production factors (workforce and capital), $VA_{j,t}$ is the value added of the *j*-th sector at *time t*, $b_{j,t}$ is the effectiveness parameter in the production function of the *j*-th sector at time *t*, $X_{ij,t}$ is the production of the *i*-th sector used as the intermediate input at time *t* by the *j*-th sector, $Y_{j,t}$ is the gross output of the *j*-th sector at time *t*, $ax_{ij,t}$ is the minimum demand for the intermediate input of the *i*-th sector for the

production of the single gross output of the *j*-th sector at time *t* (the input-output coefficients), $ay_{j,t}$ is the minimum demand for the value added in producing a single gross output at the time *t*, $\beta_{hj,t}$ is the share parameter of the production function or the production elasticity of the *j*-th sector at time *t* in relation to the *h*-th input (for $1 \leq \beta_{hj,t} \leq 0$ and $\sum_h \beta_{hj,t} = 1$).

2-2- Consumption Equations

2-2-1- Private Sector Consumption

In this section, first, it is assumed that the consumers select their commodity bundle to maximize utility. The utility of the households depends on their consumption of the commodities of each sector. Here, the utility function is assumed to be a Cobb-Douglas function that is maximized with regard to the budget restriction (which is assumed to be equal to the net income of the household).

Accordingly, the demand function for each commodity is expressed as Equation (4).

$$C_{i,t}.PQ_{i,t} = \lambda_{ci,t}\left(YH_t - DTAX_t - HSAV_t\right) \qquad \forall i \qquad (4)$$

where $C_{i,t}$ is the household's consumption of the commodity produced by the *i*-th sector at time *t*, $HSAV_t$ is the household's savings at time *t*, $DTAX_t$ is the direct tax at time *t*, YH_t is the household's income at time *t*, and $\lambda_{ci,t}$ is the share parameter of the utility function or the share of each commodity of the household's commodity bundle ($1 \leq \lambda_{ci,t} \leq 0$ and $\sum_i \lambda_{ci,t} = 1$).

2-2-2- Public Sector's Consumption

The public sector's consumption is an exogenous variable and a function of the total public sector's consumption.

$$G_{i,t}.PQ_{i,t} = \lambda_{gi}.GDTOT_{t,t} \qquad (5)$$

where $G_{i,t}$ shows the government expenditures in the *j*-th sector at time *t*, $\lambda_{g_{i,t}}$ is the share of the government expenditures of each sector at time *t*, and $GDTOT_t$ is the total public consumption at time *t* (exogenous variable).

2-3- Investment Equations

In each sector, the investment demand function is obtained using Equation (6), based on which investment in each sector is a function of the total investment.

$$ID_{i,t}.PQ_{i,t} = \mu_{i,t}.INVEST_{t,t} \qquad (6)$$

where $ID_{i,t}$ shows the demand for investment in the *i*-th sector at time *t*, $INVEST_t$ is the total investment at time *t*, $PQ_{i,t}$ is the composite commodity price in the *j*-th sector at time *t*, and $\mu_{i,t}$ is the investment share of the *i*-th sector at time *t* ($1 \le \mu_i \le 0$ and $\sum_i \mu_i = 1$).

2-4- International Trade

In this section, it is assumed that the small country hypothesis is true. In other words, it is assumed that the country has a small economy and its activities do not considerably influence the prices in the international markets. Hence, the prices of exports and imports are constant in foreign currency. The relations between the prices of export and import in the foreign and local currencies are expressed via Equations (7) and (8).

$$PE_{i,t} = pwe_{i,t}.EXR_t \quad (7)$$

$$PM_{i,t} = pwm_{i,t}.EXR_t \quad (8)$$

where $PE_{i,t}$ is the local price of the exports in the *i*-th sector at time *t*, $PM_{i,t}$ is the local price of the imports in the *i*-th sector at time *t*, $pwe_{i,t}$ is the global price of exports (exogenous variable) in the *i*-th sector at time *t*, and $pwm_{i,t}$ is the global price of exports (exogenous variable) in the *i*-th sector at time *t*.

2-5- Dynamics Equations

Since the present research investigates the effect of climate change on the macroeconomic variables of the agricultural sector within a specific period of time, it is necessary to make the model dynamic and alter it by adding equations to the previous set of equations. To make the model dynamic, the growth of investment in the sectors and the government and household expenditures were added to the model assuming that the value of each variable in each period equals the value of that variable in the previous period plus the annual increment.

The data on the growth rate of these variables were obtained from the Statistical Center of Iran and the Central Bank of Iran.

$$PQ_{j,t+1}.C_{j,t+1} = PQ_{j,t}.C_{j,t}.(1+r) \quad (9)$$

$$PQ_{j,t+1}.G_{j,t+1} = PQ_{j,t}.G_{j,t}.(1+r) \quad (10)$$

$$PQ_{j,t+1}.ID_{j,t+1} = PQ_{j,t}.ID_{j,t}.(1+r) \quad (11)$$

where r is the average growth of expenditures in the private and public and investments, which is obtained based on the statistics published by the Central Bank of Iran in different years.

2-6- Method of Studying the Effect of Climate Change Using DCGE

It is possible to study the effect of climate change on the macroeconomic variables of the agricultural sector using DCGE by applying a shock to one of the parameters of this sector. Agricultural sector productivity is among the parameters influenced by climate change (Al-Shenawi et al., 2015). For instance, precipitation levels can influence the productivity of the agricultural sector. In the Cobb-Douglas production function, in the first phase of production, the b parameter is known as the index of partial productivity of the production factors,. The ultimate goal can be accomplished by identifying the relationship between this parameter and the climate variable. Hence, the relationship between precipitation level and agricultural sector productivity is calculated by Equation (12).

$$\mathrm{TFP} = Rain^{\beta} \qquad (12)$$

It is worth stating that the time series of the period from 1996 to 2010 was used to estimate the above relation. The precipitation information was extracted from the Iran Meteorological Organization and the productivity index information was obtained from the National Iranian Productivity Organization. In addition, the above equation was estimated using Eviews Software Package.

It should be noted that it was tried to assess the effects of other climate variables such as temperature on productivity and present results based on temperature changes. However, due to the lack of a significant relationship between temperature and productivity, only the effect of precipitation, as a climate variable, was studied in this research.

3- Results

In the present research, the DCGE model was employed to investigate the effects of climate change on the economic growth of Iran. To this end, the effect of precipitation, as one of the climate variables, on the productivity of the agricultural sector was calculated to estimate its effect on the macroeconomic variables of the agricultural sector and other economic sectors such as the industry, mining, and service sectors using the DSGE model. The results of studying the effect of precipitation on the agricultural sector productivity suggest that 1% change in precipitation will reduce the productivity of the agricultural sector by 0.79%. It has been shown that precipitation will be decreased by 9% by 2030, and thus it will be decreased at the rate of 0.3% per year. Therefore, the productivity of the agricultural sector will be lost by 0.237% on average per year. Moreover, the effect of the productivity of the agricultural sector (the technology

coefficient of the Cobb-Douglas function) following climate changes on the macroeconomic variables of the agriculture, industry, mining, and service sectors was explored and the results are presented in the following.

Table 1- Changes in production due to climate change (percent)

	Sectors	(First five year)	(Second five year)	(Third five year)	(Fourth five year)
Production	Agricultural sectors	-1.558	-2.546	-3.516	-4.469
	Industrial sectors	1.264	0.853	0.448	0.050
	Mining sectors	-5.127	-4.057	-3.005	-1.969
	Service sectors	0.457	0.404	0.354	0.305

Source: Research finding

The production of agricultural crops, as one of the subsectors of the agricultural sector, shows a descending trend due to the considerable effect of the changing precipitation patterns. This descending trend creates the problem of food insecurity in the dairy farming sector, as one of the other subsectors of the agricultural sector. It also adversely affects the livestock production. This trend will result in the loss of overall productivity of the agricultural sector so that the production of this sector will be decreased by 4.469% at the end of the study period. The decrease in the production of the agricultural sector influences the productions of other sectors. For instance, the production of the mining sector decreases, but the production of the industry and service sectors escalates with a descending trend. The fluctuations of some of the variables in some sectors are consistent with the agricultural sector. In other words, these sectors have a positive inter-sector relationship with the agricultural sector, and these sectors consume the products of the agricultural sector (as the intermediate input) more than the other sectors.

Table 2- Changes in Consumption due to climate change (percent)

	Sectors	(First five year)	(Second five year)	(Third five year)	(Fourth five year)
Consumption	Agricultural sectors	-3.168	-3.791	-4.410	-5.025
	Industrial sectors	-1.648	-1.603	-1.524	-1.447
	Mining sectors	-4.255	-3.639	-3.028	-2.424
	Service sectors	-0.454	-0.399	-0.343	-0.287

Source: Research finding

As a result of the decreased production of the agricultural sector, the demand for the production factors (workforce and capital) drops, and since the households rely on the production factors, their earnings are decreased, leading to a decrease in their purchasing power. As a result of the loss of the households' purchasing power, consumption declines, and the decrease in the consumption in the

agricultural, industrial, mining, and service sectors is 5.025, 1.447, 2.424, and 0.287%, respectively.

Table 3- Changes in investment due to climate change (percent)

	Sectors	(First five year)	(Second five year)	(Third five year)	(Fourth five year)
Investment	Agricultural sectors	-2.693	-3.285	-3.875	-4.462
	Industrial sectors	-1.131	-1.050	-0.971	-0.893
	Mining sectors	-3.717	-3.097	-2.483	-1.876
	Service sectors	0.105	0.161	0.217	0.274

Source: Research finding

Climate change can affect all the areas and issues associated with the agriculture and natural resources, education and research, and entrepreneurship and employment in the other sectors, and it can lead to the decline of investment in these sectors. In addition, with a decrease in the production of the agriculture sector and the amounts received by the owners of the production factors, lower-income households are negatively affected by this decrease more than the high-income households because most consumers of the products of this sector are low-income households. In other words, the decrease in production leads to economic inequality, which eventually results in a decrease in the investment in the agricultural, industrial, and mining sectors. However, investment in the service sector escalates probably as a result of the decrease in investments in other sectors.

Table 4- Changes in export due to climate change (percent)

	Sectors	(First five year)	(Second five year)	(Third five year)	(Fourth five year)
Export	Agricultural sectors	-4.027	-7.399	-10.645	-13.770
	Industrial sectors	4.263	3.287	2.329	1.387
	Mining sectors	-5.788	-4.569	-3.372	-2.194
	Service sectors	7.222	6.558	5.912	5.283

Source: Research finding

With a decrease in production and investment in the mining and agricultural sectors as a result of climate change, exports declined by 13.770% and 2.194% in these sectors, respectively. However, due to the increase in the production and the decrease in the consumption in the industry and services sectors, export in these two sectors increased by 1.387% and 5.238%, respectively, with a descending trend at the end of the study period.

Table 5- Changes in import due to climate change (percent)

	Sectors	(First five year)	(Second five year)	(Third five year)	(Fourth five year)
Import	Agricultural sectors	0.324	2.029	3.756	5.504
	Industrial sectors	-1.575	-1.459	-1.343	-1.227
	Mining sectors	5.573	4.241	2.937	1.659
	Service sectors	-1.546	-1.424	-1.303	-1.183

Source: Research finding

The agricultural sector is closely related to the other sectors and supplies food to the employees of other economic sectors. Hence, with a decrease in the production of this sector, imports are increased to meet the demand for food in the country. In addition, as a result of the loss of the production of the mining sector, imports escalate in this sector because the rate of the decrease in consumption under the influence of climate change is lower than the rate of production in this sector. However, in the industrial and service sector, importation is decreased due to the increase in production and the decrease in consumption.

4- Conclusions and Suggestions

According to the research results, the climate changes in the future years will substantially challenge the sources of production in the agricultural sector, as one of the sectors influencing the Iranian economy. Hence, the control and management of the consequences of this phenomenon can partially prevent these damages and the total destruction of the production capacities of this sector.

Despite the determining role of investment in the economy, the results of this research suggest that the investment in the agricultural, industrial, and mining sectors will be decreased during the given period due to the consequences of the climate change. Hence, it is recommended to adopt policies such as fixing the prices of commodities in these sectors and increasing the credits given by banks to motivate the private sector to invest in these sectors.

Finally, given the population growth and the future decrease in production as a result of climate change, the food security of the society will be probably endangered. Hence, we should prioritize ensuring food security by using trans-terrestrial capacities and joining the World Trade Organization.

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بررسی اثرات تغییر اقلیم بر رشد اقتصادی
(رهیافت الگوی تعادل عمومی قابل محاسبه پویا در ایران)

چکیده:
تغییرات آب و هوا یکی از مهم‌ترین مسائلی است که بخش‌های مختلف اقتصاد را تحت تأثیر قرار داده است. با اینکه بخش کشاورزی به‌دلیل وابستگی شدید به عوامل آب وهوایی، نسبت به سایر بخش‌های اقتصادی از این پدیده تاثیرپذیری بیشتری داشته است اما دیگر بخش‌های اقتصادی نظیر صنعت، معدن و خدمات نیز به دلیل وابستگی درون‌بخشی با بخش کشاورزی، نیز از تغییرات آب و هوا متأثر می‌باشند. بر همین اساس در پژوهش حاضر به بررسی اثر تغییر اقلیم بر رشد اقتصادی ایران با استفاده از مدل تعادل عمومی قابل محاسبه پویا پرداخته شده است. نتایج مطالعه نشان داد که با در نظر گرفتن میزان کاهش بارندگی در افق بیست ساله (۲۰۳۰-۲۰۱۱)، مصرف در تمامی بخش‌ها کاهش می‌یابد اما تولید در بخش‌های کشاورزی و معدن کاهش ولی در بخش صنعت و خدمات با روند کاهشی افزایش می‌یابد. همچنین نتایج نشان داد که سرمایه‌گذاری در بخش‌های کشاورزی، صنعت و معدن کاهش می‌یابد اما در بخش خدمات سرمایه‌گذاری افزایش می یابد که ناشی از کاهش سرمایه‌گذاری در سایر بخش‌هاست. با توجه به نتایج پژوهش و مواجه شدن کشور با چالش در برابر تغییرات اقلیم، اتخاذ یک برنامه جامع و کاربردی توسط دولت جهت تطبیق و مقابله با این پدیده برای کاهش اثرات منفی آن، امری ضروری می‌باشد.

کلمات کلیدی: تغییر اقلیم، مدل تعادل عمومی قابل محاسبه پویا، رشد اقتصادی، ایران.