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Research Article

Studying the Effects of Climate Change on Macro Economy Sectors using Recursive Dynamic Computable General Equilibrium Approach: Evidence from Iran

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ABSTRACT

In this study the effects of shocks caused by climate change scenarios (IPCC1, IPCC2 and IPCC3) on Iran's macro-economic sectors (agriculture sector value added, industry sector value added, services sector value added and total welfare) was studied. For this purpose, required data was gathered from central bank of Iran, statistical centre of Iran and Iran Meteorological Organization during 1988-2018. Also, for data analysing the new Recursive Dynamic Computable General Equilibrium (RDCGE) model and Impulse Response Functions (IRF) were applied. Results indicated that climate change reduces the value added of agriculture sector and industry sector while increase the value added of services sector. Also, climate change reduces the total welfare. In addition, between three studied scenarios, IPCC1, IPCC2 and IPCC3 have the highest effect on value added of studied sectors respectively. Finally, according to negative effects of climate change especially on agriculture sector, suitable water resources management through: increasing water efficiency in agriculture sector (as the high consumed sector), applying modern irrigation methods, evaporate reduction form dam's surface were suggested.

Keywords: Climate change; Economic sectors; Total welfare; RDCGE; IRF

INTRODUCTION

According to Special Report on Emissions Scenarios (SRES), it is suggested that fossil fuels are still one of the main sources of world energy resource until the middle of recent century and accumulated CO_2 due to this fact; will increase 40% to 110%. In total scale the outcome of this issue is increasing earth temperate 1.5°C to 4.5°C, increasing sea level and happening huge weather fluctuations. In addition in regional and local scales, climate change has significant effects on quantity and template of rainfalls, amount of evaporation and transpiration, surface runoff and consequently the probe of happening hydrological threshold phenomenon [1]. Also, notice to huge and contract effects of climate with other productive sectors, environmental factors and human society, today climate change is known as one of the main environmental challenges of 21st century which has serious economic outcomes [2]. According to estimated various degree of earth temperature in different studies, increase in earth temperature until 2°C will encountered with loss in World's GDP between 1% to 7% and increase in earth temperature until 3°C will encountered with loss in World's GDP between 1% to 14% and if this increscent raises to 5°C, its economic loss will be equal to 2.5% to 30% of World's GDP and its whole payer will developing countries by Kahn. On the other hand, recently the Iran's average rainfall is equal to 250 mm which is less than one-third of World's average rainfall (860 mm). In addition the rainfalls distribution is very inharmonious and in many regions the amount of evaporation and transpiration is more than annual rainfall (Iran meteorological organization, 2018). In addition, the estimations of Intergovernmental Panel on Climate Change (IPCC) for climate change in Iran under the A1 scenario indicates the increase in Iran average temperature equal to 2°C until the 30 years later and 3.5°C to 4°C until the 100 years later which rainfall will significantly reduce (IPCC, 2018). On the other hand, many researches about the effects of climate change on economic sectors have been carried out using static computable general equilibrium and in most advanced case with dynamic computable general equilibrium models. But dynamic computable general equilibrium models divided in two categories: interim and recursive. The interim models are based on optimum growth theorem which assumed that economic agents have the ability of complete prediction while this doesn't correct many economic circumstances, especially in developing countries. Hence many economic experts believe that recursive models are

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more trustable [3]. Therefore, in this research the effects of shocks caused by climate change scenarios (IPCC1, IPCC2 and IPCC3) on Iran's macro-economic sectors (agriculture sector value added, industry sector value added, services sector value added and total welfare) will study using new RDCGE approach. The rest of the paper is arranged as follows.

Literature review

Arndt C, et al. (2011) developed a stochastic economy-wide framework for analysing economic impacts from climate change and potential adaptation policies in Ethiopia [4]. They found that if climate change affects the rate of technical change and the rate of accumulation of capital, the implications become significant over time. Furthermore, analysis of the variability of the components of GDP indicates that aggregate consumption always has a higher coefficient of variation than the other macro aggregates. Investigated the long-term global impacts on crop productivity under different climate scenarios using the Agricultural Model Inter-comparison and Improvement Project (AgMIP) approach [5]. The paper provides horizontal model inter-comparison from 11 economic models as well as a more detailed analysis of the simulated effects from the Common Agricultural Policy Regionalized Impact (CAPRI) model to systematically compare its performance with other AgMIP models and specifically for the Chinese agriculture. The results for China indicated that the climate change effects tend to be smaller than the global impacts. Elshennawy studied country-level computable general equilibrium analysis for climate change impact and adaptation analysis by incorporating forward-looking expectations for Egypt up to 2050 [6]. They found that in the absence of policy-led adaptation investments, real GDP towards the middle of the century will be 6.5% lower than in a hypothetical baseline without climate change. Also, a combination of adaptation measures, that include coastal protection investments for vulnerable sections along the low-lying Nile delta, support for changes in crop management practices and investments to raise irrigation efficiency, could reduce the GDP loss in 2050 to around 2.6%. Study analysed specific adaptation measures for the road and rail sectors in Austria using a computable general equilibrium model [7]. They found that when analysing adaptation measures for the road and rail sectors, without capturing any indirect effects, benefit cost ratios imply a clear benefit only for the rail sector. Climate change-induced GDP and welfare losses are reduced by 55% and 34% and lead to positive employment effects. Tol and Notes (2018) studied the economic impacts of climate change and the policy implications of the results. They found that the initial impacts of climate change may well be positive. However, in the long run the negative impacts dominate the positive ones. Negative impacts will be substantially greater in poorer, hotter, and lower-lying countries. Study shows combined global climate, crop and economic models to examine the economic impact of climate change-induced loss of agricultural productivity in Pakistan. Results showed that climate change-induced loss of wheat and rice crop production by 2050 is 19.5 billion dollars on Pakistan's real gross domestic product coupled with an increase in commodity prices followed by a notable decrease in domestic private consumption [8].

METHODOLOGY

In this study we model the effects of shocks caused by climate change scenarios (IPCC1, IPCC2 and IPCC3) on Iran's macro-economic sectors (agriculture sector value added, industry sector value added, services sector value added and total welfare). Below (Table 1) illustrates the applied climate change scenarios of this study.

Table 1: IPCC scenarios using MAGICC/SCENGEN model.

Scenarios	Average temperature /Average rainfall	Change during 2000-2030 (%)
IPCC 1	Average temperature	7.27
	Average rainfall	-12.4
IPCC 2	Average temperature	7.27
	Average rainfall	-12.2
IPCC 3	Average temperature	5.03
	Average rainfall	-12.3

In addition for data analysing we apply a Recursive Dynamic Computable General Equilibrium (RDCGE) model. Also, the CGE equations related to production, households, government, saving, investment and foreign trade have been represented as follow [3].

$$VA_j = b_j \prod_h FD_{hj}^{\beta_{hj}}$$

$$X_{ij} = ax_{ij} Y_j \equiv$$

$$VA_j = ay_j Y_j$$

$$FD_{hj} = \frac{\beta_{hj}.PN_j}{W_h}.VA_j$$

$$PS_j = ay_j.PN_j + \sum_i ax_{ij}.PQ_1$$

$$Y_{hoh} = \sum_h W_h.FS_h + GOVTH + REMIT.EXR$$

$$C_i.PQ_1 = \lambda_{ci}(Y_{hoh} - TAX_{dir} - SAV_{hoh})$$

$$TAX_{ind.j} = tx_j.PS_j.Y_j$$

$$TAX_{dir} = td.\sum_h W_h FS_h$$

$$TARIFF_j = tm_j.PM_j.M_j$$

$$Y_g = TAX_{dir} + \sum_j TAX_{ind.j} + \sum_j TARIFF_j + E_{oil}$$

$$G_i.PQ_i = \lambda_{gi} GDTOT$$

$$ID_i.PQ_i = \mu_i.INVEST$$

$$SAVING = (SAV_{hoh} + SAV_g + EXR.SAV_f)$$

$$SAV_{hoh} = s_{hoh}.Y_{hoh}$$

$$SAV_g = s_g.Y_g$$

$$SAVING = INVEST$$

$$PE_i = pwe_i + EXR$$

$$PM_i = pwm_i + EXR$$

$$Q_i = \gamma_i(\alpha_{mi}.M_i^{\rho_{mi}} + \alpha_{di} + D_i^{\rho_{mi}})^{\frac{1}{\rho_{mi}}}$$

$$M_{iq} = (\frac{\gamma_i^{\rho_{mi}}.\alpha_{mi}.PQ_i}{(1+tm_i).PM_i})^{\frac{1}{1-\rho_{mi}}}.Q_i$$

$$D_i = (\frac{\gamma_i^{\rho_{mi}}.\alpha_{di}.PQ_i}{PD_i})^{\frac{1}{1-\rho_{mi}}}.Q_i$$

$$Y_i = \theta_i(\beta_{ei}.E_i^{\rho_{ei}} + \beta_{di}.D_i^{\rho_{ei}})^{\frac{1}{\rho_{ei}}}$$

$$E_i = (\frac{\theta_i^{\rho_{ei}}.\beta_{ei}(tx_i + PS_i)}{PE_i})^{\frac{1}{1-\rho_{ei}}}.Y_i$$

$$D_i = (\frac{\theta_i^{\rho_{ei}}.\beta_{di}(tx_i + PS_i)}{PD_i})^{\frac{1}{1-\rho_{ei}}}.Y_i$$

$$\sum_j FD_{hj} = FS_h$$

$$Q_i = C_i + G_i + ID_i + \sum_j X_{ij}$$

$$\sum_i pwe_i.E_i + SAV_f + REMIT = \sum_i pwm_i.M_i$$

$$PINDEX = \sum_i \omega_i PQ_i$$

E oil:Oil export revenue of g overnment

Yg:Total income of government

PMj:Domestic price of import

Mj:Import quantity

GDTOT:Total government expenditure

SAVg:Saving of government

Gi:Government expenditure

SAVf:Foreign saving

IDi:Investment

SAVING:Total saving

Invest:Total investment

PEi:Export domestic price

Qi:Composite good

Di:Domestic produced well

PDi:Price of domestic good

Ei:Export quantity

PINDEX:Price Index

TARIFFj:Tariff of Import

VAj:Value Added of sector j

FDhj:Demand for production factor h by sector j

Yj:Gross output of sector j

Xij:Production of sector i which uses as intermediate input by sector j

PNj:Value added price of sector j

Wh:Wage of production factors

PSj:Price of supply

PQi:Price of composite good

Yhoh:Household income

FSh:First factor h supply

GOVTH:Government transferring payment to households

REMIT:Net abroad received funds

EXR:Exchange rate

Ci:Consumption quantity of households from i sector goods

TAXdir:Direct tax on households' income

SAVhoh:Saving of households

TAXind.j:Indirect tax of each sector

i و j:Sectors indices

h:Production factors index (labor and capital)

bj:Efficiency parameter in production function

β_{hj}:Share parameter in production function or production elasticity of sector j to input h

ax_{ij}:Input-output technical coefficient

ayj:Minimum coefficient of requirement to value added for producing 1 unit of gross output

λ_{ci}:Share in utility function parameter or share of each good in household consumption

tx_j:Sale tax rate

td:Direct tax rate

tm_j:Import tariff rate

λ_{ci} :Parameter of government expenditure share in each sector

S_{hoh}:Medium propensity to saving of private sector

S_g:Medium propensity to saving of public sector

μ_i:Parameter of investment share for sector

pwe_i:Price of world export

pwm_i:Price of world import

γ_i :Parameter of efficiency in Cobb-Douglass production function

α_{mi}:Parameter of share in Armington

Table 3: Calibrated quantities and parameters of RDCGE model.

Function	Parameter/Elasticity		Industry sector	Agriculture sector	Service sector
Consumption	Good share		0.184	0.231	0.585
	Households marginal propensity to consumption		0.633	0.633	0.633
Cobb-Douglass production	Transfer or efficiency		1.423	1.826	1.903
	Share of production factors	Labor	0.113	0.29	0.343
		Capital	0.887	0.71	0.657
Leontief marginal production	Share of marginal intermediates	Industry	0.288	0.067	0.119
		Agriculture	0.011	0.369	0.009
		Service	0.169	0.106	0.147
	Share of value added		0.531	0.458	0.72
Armington composite good	Substitution elasticity		1.4	1.4	1.4
	Share of import		0.461	0.276	0.078
	Transfer		2.201	1.833	1.231
Convert function	Convert elasticity		1.2	1.2	1.2
	Share of export		0.524	0.882	0.934
	Transfer		2.003	3.342	4.476
Constant Proportion of agriculture production to total production				0.02	
Constant Proportion of agriculture import to total agriculture production				0.015	
Constant proportion of agriculture export to total export				-	
Constant proportion of agriculture price index to total CPI				-	
Constant proportion of agriculture producer index to total PPI				-	
Constant proportion of rural labor to total labor				-	
Constant proportion of agriculture investment to total investment				-	
Constant proportion of agriculture sector energy to total energy consumption				-	

α_{di}: Parameter of share in Armington

ρ_{mi}: Power of Armington function or elasticity of substitution

η_i: Armington function elasticity

θ_i: Parameter of transfer function efficiency

β_{ei}: Parameter of share in transfer function

β_{di}: Parameter of share in transfer function

ρ_{ei}: Power of transfer function or parameter of transfer elasticity

σ_i: Transfer elasticity

ω_i: Weight of price for each sector

Furthermore, in order to RDCGE calibrating the Iran's Social Accounting Matrix (SAM) will use which has been represented in (Table 2).

Table 2: Iran's macro social accounting matrix in year 2011 (Thousand RLS).

Accounts	Production	Production factors
Production	3,744,722,627	0
Production factors	6,209,271,377	0
Inputs	129,223,564	6,212,806,622
Saving	0	0
Foreign sector	1,412,387,674	20,267,642
Total input	11,495,605,243	6,233,074,264

Notice to entering climate change variable in agriculture production function, in this study the Dommartin method which is the most known methods in this field was applied [9]. This method categorized the region climate based on rainfall and temperature as follow:

$$T = \frac{P}{I+10} \quad (1)$$

Which: P, I, and T represent the average annual rainfall (mm), average annual temperature (centigrade) and Dommartin index, respectively. Therefore, the Cobb-Douglas production function for agriculture sector could is as follow [4].

$$\text{VA}= (\text{b(T)}^{*}\ \text{B})^{\alpha} * \text{K}^{\gamma} * \text{L}^{\omega}$$
$$with \qquad \alpha + \gamma + \omega = 1 \quad (2)$$

Where VA, L, K, B, T and b represent the agriculture sector value add, labor, capital, land (cultivated surface), climate change index and efficiency parameter, respectively. Also, □, □ and □ are elasticity of production function. Therefore, the first equation of CGE function for agriculture sector is as follow [10].

$$\text{VA}_j = b_j \prod_h FD_{hj}^{\beta hj} \; ; \; j = a, h = K, B, L, \beta = \alpha, \gamma, \omega$$

$$\text{VA}_a = b_a (T)^{\alpha} * FD_{Ba}^{\alpha} * FD_{Ka}^{\gamma} * FD_{La}^{\omega} \quad (3)$$

Where, a and FD represent the agriculture sector and demand for production factor by agriculture sector, respectively. Then the change in production of agriculture sector due to climate change variable will enter to the SAM matrix and its effect on other economic sectors will investigates. Furthermore, the required data was gathered from central bank of Iran, Iran statistical centre and Iran Meteorological Organization during 1988-2018. Finally the Matlab software was applied in order to data analysis.

RESULTS AND DISCUSSIONS

In order to calibrating RDCGE model, the Iran's SAM (2011) was used. (Table 3) represents the results of RDCGE calibration using SAM (2011) and base scenario (IPCC1).

The Impulse Response Functions (IRF) of Iran's macro-economic sectors (agriculture sector value added, industry sector value added, services sector value added) and total welfare to a positive shock of climate change through the studied scenarios of IPCC1, IPCC2 and IPCC3 have been illustrated in (Figures 1-6).

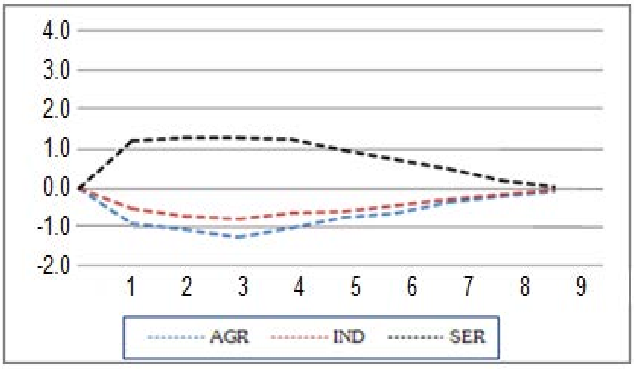

Figure 1: IRF AGR, IND and SER sectors to IPCC1 shock.

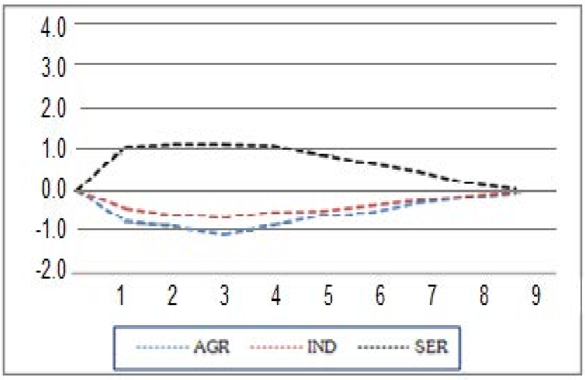

Figure 2: IRF AGR, IND and SER sectors to IPCC2 shock.

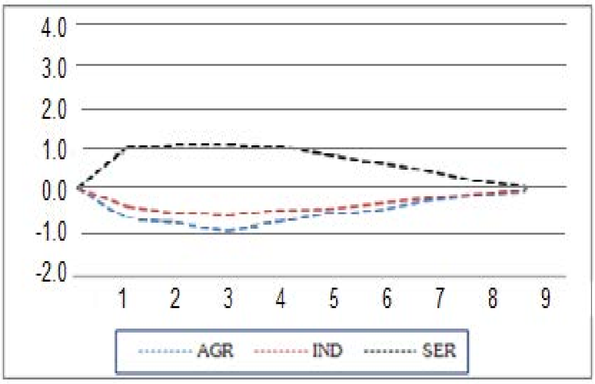

Figure 3: IRF AGR, IND and SER sectors to IPCC3 shock.

(Figures 1-3) illustrate the Impulse Response Function (IRF) of agriculture, industry and services sectors to climate change based on IPCC1, IPCC2 and IPCC3 scenarios. Results of (Figure 1) indicate that a positive shock of climate change based on IPCC1 decreases the value added of agriculture sector 0.97%, 1.09% and 1.26% in period 1, 2 and 3, respectively and neutralizes gradually. Also it cause to reduction in the value added of industry sector 0.62%, 0.81% and 0.89% in period 1, 2 and 3, respectively and neutralizes gradually. Furthermore, it cause to increase in the value added of services sector 1.02% and 1.11% in period 1 and 2, respectively and neutralizes gradually.

Results of (Figure 2) indicate that a positive shock of climate change based on IPCC 2 decreases the value added of agriculture sector 0.94%, 0.99% and 1.13% in period 1, 2 and 3, respectively and neutralizes gradually. Also it cause to reduction in the value added of industry sector 0.64%, 0.78% and 0.81% in period 1, 2 and 3, respectively and neutralizes gradually. Furthermore, it cause to increase in the value added of services sector 0.98% and 1.02% in period 1 and 2, respectively and neutralizes gradually.

Results of (Figure 3) indicate that a positive shock of climate change based on IPCC3 decreases the value added of agriculture sector 0.88%, 0.93% and 0.99% in period 1, 2 and 3, respectively and neutralizes gradually. Also it cause to reduction in the value added of industry sector 0.66%, 0.73% and 0.76% in period 1, 2 and 3, respectively and neutralizes gradually. Furthermore, it cause to increase in the value added of services sector 0.97% and 1.01% in period 1 and 2, respectively and neutralizes gradually.

(Figures 4-6) illustrate the Impulse Response Function (IRF) of total welfare to climate change based on IPCC1, IPCC2 and IPCC3 scenarios. Results of (Figure 4) indicate that a positive shock of climate change based on IPCC1 decreases the total welfare 0.49%, 0.61% and 0.71% in period 1, 2 and 3, respectively and neutralizes gradually. Also, results of (Figure 5) indicate that a positive shock of climate change based on IPCC2 decreases the total welfare 0.44%, 0.49% and 0.54% in period 1, 2 and 3, respectively and neutralizes gradually. Finally, results of (Figure 6) indicate that a positive shock of climate change based on IPCC3 decreases the total welfare 0.39%, 0.43% and 0.46% in period 1, 2 and 3, respectively and neutralizes gradually.

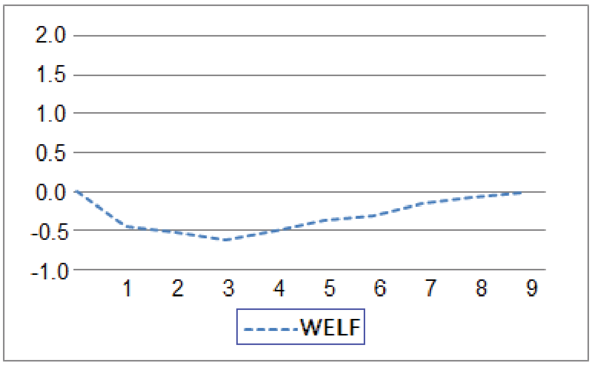

Figure 4: IRF Total welfare to IPCC1 shock.

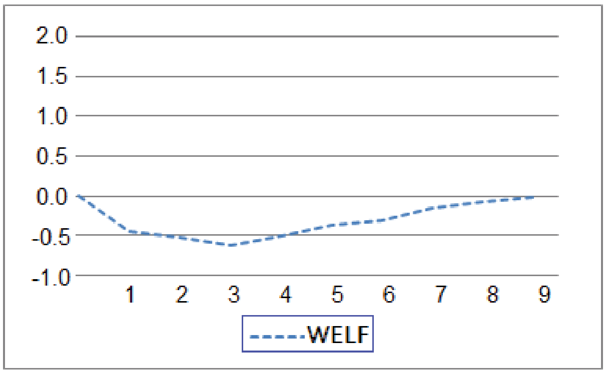

Figure 5: IRF total welfare to IPCC2 shock.

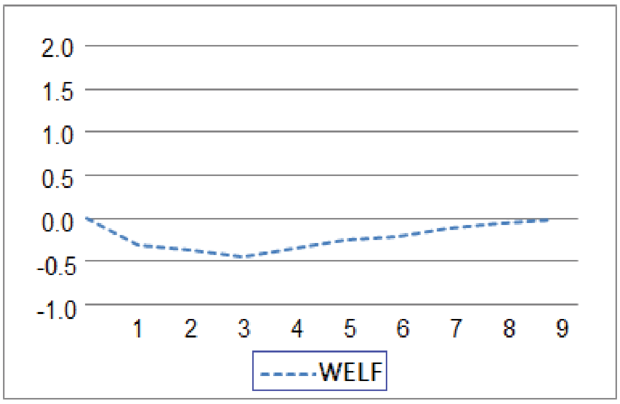

Figure 6: IRF total welfare to IPCC3 shock.

CONCLUSION

In this research the impacts of shocks caused by climate change scenarios (IPCC1, IPCC2 and IPCC3) on macro-economic sectors of Iran include of agriculture sector value added, industry sector value added, services sector value added and total welfare was studied. The required data gathered from central bank of Iran, Iran statistical centre and Iran Meteorological Organization during 1988-2018. Also, for data analysing Recursive Dynamic Computable General Equilibrium (RDCGE) and Impulse Response Functions (IRF) were applied. Results indicated that climate change reduces the value added of agriculture sector and industry sector while increase the value added of services sector. Because the import of agricultural products will increase due to the reduction in domestic agricultural products affected from the climate change and consequently the value added of commerce related activities and value added of services sector will increase. Also, climate change reduces the total welfare. Also, between three studied scenarios, respectively, IPCC1, IPCC2 and IPCC3 have the highest effect on value added of Iran's economic sectors. Finally, according to negative effects of climate change especially on agriculture sector, suitable water resources management through: increasing water efficiency in agriculture sector (as the high consumed sector), applying modern irrigation methods, evaporate reduction form dams' surface etc. are suggested.

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