Estimating a Cost Effective of Climate Change Adaptation Policy in Algeria: a DCGE Model Analysis

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Summary: The main objective of this study is to find the impacts of the climate change adaptation policy and its associated costs on macro-economic variables such as real gross domestic product, government expenditure, exports, net consumption and sectoral output. This study considered temperature change as an exogenous shock and simulated the effects of adaptation policies over 100 years period based on the 2009 base year Social Accounting Matrix for the Algerian economy. We examined the policy effectiveness by simulating scenarios with and without adaptation options. We investigated the findings of this study using our CGE model called Algerian Integrated Climate and Economy and interpreted to establish whether the adaptation policy is effective in terms of reducing the climate change monetary impact. Our findings indicate that the optimum level of adaptation varies over time with continued economic growth and the costs of adaptation tend to increase as well. Findings show that over the hundred-year projection period, the optimum level of adaptation tends to be within the range of 11 to 29 percent of gross damages. The associated costs of adaptation varies from 27 million to 1,235 million DZD. This indicates that the optimal adaptation policy is effective for Algeria.

Keywords: Climate change, CGE Model, SAM, Adaptation policies.

Jel Classification Codes : Q54, C68, E16

I- Introduction:

Climate change is among the most serious global concern on environmental issues (DFID, 2002).It is a major global challenge not only due to the predictable rise in temperature and sea levels, but also due to its associated impacts on the social, ecological, and economic systems. It is a complex phenomenon with profound impacts on virtually every aspect of life on earth. Therefore, climate change demands research from multiple dimensions and disciplines to identify the appropriate policies to reduce its negative impacts.In addition, the impacts will be noticeably different among different sectors of a country. To assess the costs and benefits of climate change adaptation policy at a local or country level, it is essential to build a comprehensive model specific to the region and to match with the local economic structure. The growing risk of climate change related damages demands strong as well as appropriate measures and actions from policymakers so as to adapt to the changed climatic conditions and minimise the risk.For instance, in 2008 the German government has devised ―German Adaptation Strategy to Climate Change‖ (in German terms, Bundesregierung, 2008) to reduce the climate change vulnerability and increase the adaptive capability (Arndt & Volkert, 2011, pp. 311-337). Moreover, policymakers are accountable to validate the effectiveness of these projects to their electorates. Therefore, economic impacts as well as cost-benefit analysis of intended adaptation actions are to be performed prior to suggesting an adaptation policy specifically at the local levels.

Climate change involves more than environmental issues in Algeria. It will also adversely affect economic growth and human wellbeing.

With this background, the cost-benefit analysis for adaptation actions is necessary for devising appropriate adaptation policy. This study investigates whether from economic perspective adaptation action is beneficial or not for Algeria considering the associated costs. It also introduces ideas and concepts to achieve long-term solutions of the climate change problems so that the government can introduce an efficient adaptation framework to reduce the adverse consequences related to climate change.

The general aim of this study is to analyse how Algeria could counter balance the negative impacts of climate change. Thus, this study investigates the adaptation choices as an alternative for Algerian climate policy and their comparative dimensions to reduce future impacts and vulnerabilities of the agriculture sector. To this end, this study proposes the following specific objectives:

a) To determine the optimal level of adaptation for a period of one hundred years since 2009.

b) To estimate the climate change adaptation cost for associated optimal adaptation levels of objective (a).

c) To examine the impacts of climate change and adaptation policies on the agricultural sector as well as on the overall economy.

II– Empirical Literatures:

Recently, huge number of researchers, policy planner and environmentalist applied the dynamic Computable General Equilibrium (CGE)model to examine the effects of climate change, its adaptation cost and impact on the economy of a country. This is especially done in assessing the impacts of reforms on macroeconomic variables and adaptation cost management for agricultural sectors.

From this extensive review of background literatures, we conclude that computable general equilibrium (CGE) model is widely used to minimise climate change adaptation costs. It also focused on the global impact on economy especially on the agricultural sector. However,Berrittella, Hoekstra, Rehdanz, Roson,&Tol, 2007and many others utilise CGE model for their researches on climate change adaptation policy options in agriculture to determine optimum climate adaptation cost(Berrittella, Hoekstra, Rehdanz, Roson, & Tol, 2007, pp. 1799-1813).

O'Ryan et.alfocused on the key inter-relations amidst the financial, social and environmental components of the maintainable development triangle. They used the CGE model ECOGEM-Chile to model the extensive economy effects of numerous environmental, community and joint strategies for the Chilean economy. Thus, precise engagement of community strategies would advance environmental policy understanding, while decreasing poor income distribution inequalities (O'Ryan, de Miguel, Miller, & Munasinghe, 2005, pp. 447-472).

John et.alshowed that crop harvests, grassland and forest output would be affected as a result of the impacts of climate changes on the global agricultural sector and would have significant economic consequences. They examined the collective impacts on crop, grassland and forests due to climate changes, rising levels of carbon dioxide (CO_2) concentration, and variations in troposphere ozone, and assessed their consequences on adaptation costs for the global and regional economies. They also highlighted scenarios where there is partial or insignificant effort to regulate these substances, and policy scenarios that limit CO_2 emissions and ozone precursors (John, Sarofim, Paltsev, & Prinn, 2006, pp. 503-520).

Deke et.alanalysed how the physical and biological arrangements are affected due to climate change in numerous areas of the planet. The adaptive capabilities within a region as well as across regions dictate the extent of economic damages for human systems on earth. They used an economic General-Equilibrium model and an Ocean-Atmosphere model in a regional and sectoral disaggregated framework to analyse climate change adaptation in different regions of the world (Deke, Hooss, Kasten, Klepper, & Springer, 2001).

Herteldiscussed the works on applied general equilibrium analysis of agricultural and resource policies. He started from the basic principles and moved onto the assessment of benefits of this methodology for examining sectoral policies. He analysed queries about disaggregation of commodities, households, regions and factors of production (Hertel, 2002, pp. 1373-1419).

Böhringer and Löschelinvestigated the application of computable general equilibrium (CGE) models for evaluating the effects of strategies and policy intervention on policy-relevant environmental, social (institutional) and economic indicators. They found that the operational CGE model used for energy–economy– environment (E3) investigations comprehensively cover the central economic indicators. Environmental indicators, for example energy-related emissions with direct connections to economic activities are extensively covered, while indicators for complex natural science representation such as water stress or biodiversity loss are barely represented. Social indicators are also poorly covered mostly due to fact that these parameters are inherently vague and incommensurable (Böhringer & Löschel, 2006, pp. 49-64).

Liu et.alfocused on current studies in macro-econometric estimation and designed a method to parameter estimation for a widely used global CGE model for climate change adaptation cost. The set of optimal elasticity values is found by maximizing an approximate likelihood function proposed in the model, in the context of a back-costing exercise. Additionally, they perform two statistical tests. The first test compares the standard GTAP elasticity vector with the estimated trade elasticity vector. The null hypothesis of equality is rejected among the two sets of trade elasticities. The second test investigates the well-known "rule of two" hypothesis which sets the elasticity of substitution across imports by sources to twice the elasticity of substitution among domestic goods and imports (Liu, Arndt, & Hertel, 2004, pp. 626-649).

Tolused CGE model to estimate the potential impacts of climate change in economic terms on agriculture, forestry, unmanaged ecosystems, sea-level rise, human mortality, energy consumption, and water resources. Estimations are obtained using GCM based scenarios from globally comprehensive and internally consistent works. An underestimate of the uncertainty is assumed. Following the meta-analytical approaches described here, new impact studies can be incorporated. A 1ºC increase in the global mean surface air temperature would have a positive effect on the OECD, China, and the Middle East, and a negative effect on other nations (Tol, 2002, pp. 47-73).

Bosello et.alperformed an economic assessment of climate change impacts by the study of four major crop families covering more than 80% of agricultural outputs in Nigeria. The results are obtained by modelling land productivity in a computable general equilibrium system to represent Nigerian economy until 2050. It also incorporates detailed land usage scenario by differentiating different agro ecological zones based on productivity. Indecision and uncertainty regarding future climate are captured, using yield changes computed by a crop model as input and covering the whole range of variability produced by an envelope of one RCM and ten GCM runs.After 2025, in the medium term, climate change is unmistakably negative for Nigeria with production losses, rise in crop prices, higher dependency on foreign food imports and GDP losses in all the simulation runs (Bosello, Campagnolo, & Eboli, 2013).

III-Methodology:

From the past literature, we have identified some crucial theories to develop a conceptual framework for this study with a view to accomplishing its objectives. For example, we have used theory of transitions to develop the concepts of the optimum adaptation path.We developed a country specific (Algeria) dynamic computable general equilibrium model to examine the impacts of climate change on the economy (with and without adaptation policy).

III.1 Detailed Data Sources

This study uses data for all sectors of the economy collected from recent I-O tables issued in 2009. From the I-O table of 2009, we have used the data on Intermediate Inputs, Final Goods and Services, Production, Total Demand, Total Supply, Export and Import, Labor and Capital used and Indirect taxes. In order to construct a SAM for 2009, a time-series data for the year (2009) are used.

Besides that, typical SAMs also require additional data such as total household income (by income category), factor of payments in total, total amount of government revenues and expenditures (including inter-government transactions), institutional distribution of income, and transfer payments (both for production sectors and households). It is also combined with the national accounts and Household Income and Expenditure Survey (HEIS) data within a consistent framework for expenditures and savings patterns. Specifically, the secondary time series data is used to construct the SAM for 2009 are HEIS and National Office of Statistics Data.

III.2 Modelling Method

In order to achieve the aims of the study, we have used the computable general equilibrium model which is based on the general equilibrium framework. The general equilibrium framework has been chosen for this study because CGE models have the ability to represent sectoral and regional scopes of the impacts and policy responses in a comprehensive way. Hence, it can consider sector specific and global/regional/local climate damage functions in the most straightforward manner.

III.3A CGE Model for Algerian Economy

This section presents a Computable General Equilibrium (CGE) model that is developed as an appropriate method for assessing the economy-environmental effects of adaptation policies in the Algerian economy. We name it as Algerian Climate and economy (ACE) model. In our study, we have divided the Algerian Economy into 15 sectors of interest to model the agricultural versus rest of the productions based on Algerian Input Output (I-O) table. We considered two factors of production, labor and capital. The institutions in the model represent Government, Firms, Households, and Rests of the world and capital account. The next subsection discusses basic structure of the model.

III.4Structure of the Model

This section presents mathematical modelling of the ACE model. In its mathematical form, the CGE model consists of a set of nonlinear simultaneous equations where the number of equations is equal to the number of endogenous variables. The model equations, divided into blocks for prices, production and commodities, institutions, climate change and system constraints. Explanatory boxes are added for each block of equations. According to our study objectives, we considered five different blocks of equations.**See Appendices**.

IV-FINDINGS:

The main objective of this study is to find the impacts of the climate change adaptation policy and its associated costs on macro-economic variables such as real gross domestic product (RGDP), government expenditure, exports, net consumption and sectoral output. The agricultural sector of the Algerian economy is our focused sector as it is directly affected by the climate change. In this chapter, we investigated the findings of this study using our CGE model called Algerian Integrated Climate and Economy (AICE) and interpreted to establish whether the adaptation policy is effective in terms of reducing the climate change monetary impact. We also simulated the effects of adaptation policy on different sectors as well as on the overall economy using the developed CGE model.

IV.1 Policy Scenarios

Our study focused only on Algeria, even though analogies can be easily applicable to some other countries. The focus was on how climate change impacts are translated into monetary damages and how these damages can be reduced via adaptation.

Under CGE framework, there are several types of Integrated Assessment Models (IAMS). Among the climate change related global impact model, well-recognised models are: Dynamic Integrated Climate and Economy (DICE) model which was introduced by Nordhaus (1991) and its extended AD-DICE model that considered adaptation as a decision variable. Moreover, the regional version of this model is called Regional Integrated Climate and Economy (RICE) model and its extension for adaptation is the AD-RICE model (de Bruin, Dellink and Tol). This model analyses at a regional level not distinguishing sectors or economic and non-economic categories(De Bruin, Dellink, & Tol, 2009, pp. 63-81).

In this study, we considered AD-DICE as well as AD-RICE models as our base models and then reconstructed a specific model which only considered one country (Algeria) with its own economic data and tried to find out locally optimum policy without considering any externalities and spillover effects of the global activities and policies. We assumed populations are constant over time, and all parameters are non-zero. In our model, the values of the elasticity of substitution was exogenously taken from GTAP data base (Xiao-guang & Verikios, 2006). For consistent growth rate, we took the real GDP growth rate data from World Bank estimates for Algeria.

This study considered temperature change as an exogenous shock and simulated the effects of adaptation policies over 100 years period based on the 2009 base year Social Accounting Matrix (SAM) for the Algerian economy. We examined the policy effectiveness by simulating scenarios with and without adaptation options. To achieve this, at first we make a business as usual referred here as Base Case Scenario (BCS) simulation when no adaptation policies are engaged. Also, this situation does not consider monetary value of the climate change damages in economic figures. Thus, we figure out the economic costs of the climate change without any adaptive policy and compare its impacts on the economy. Then we introduce our optimum adaptation policy into the simulation and see whether it is effective in terms of reducing the climate change related damages.

Therefore, we consider the following three scenarios:

i. Base Case Scenario (BCS)

ii. Climate Impact with No Adaption (CINA)

iii. Climate Impact with Adaption Actions (CIAA)

IV.1.1 Base Case Scenario (BCS)

The first scenario of this study is a base case or business as usual scenario. In this scenario, we consider that the country‘s economic developments will not be affected by the climatic change and will continue following the existing trend.

IV.1.2 Climate Impact with No Adaption (CINA)

This scenario considers what will be the worst-case economic condition when the projected climatic parameters change having its associated impacts; but the policymakers, economic agents, and stakeholders do not respond and hence do not take any adaptation policy and so there is no investment for adaptation.

IV.1.3 Climate Impact with Adaptation Actions (CIAA)

This scenario represents the case when policymakers engage optimum adaptation actions and bear the associated costs for adaptation. Thus this case highlights the economic impacts of adaptation. Also the comparative analysis of CINA and CIAA fulfills our objective to measure the effectiveness of adaptation policy in terms of its economic impacts.

IV.2 Description of Simulations

In this study, we estimate the climate change impacts over a period of hundred years. We divide these 100 years into 6 different time segments, each having 20 years duration and these time segments are independent of each other. We consider 2009 as the benchmark year or base year for this study. Therefore, all the simulations start from this benchmark year and end on 2109. Table 1shows time segments 1 to 6, starting on 2009 and ending on 2109. **See Appendices**.

IV.3 Objective One: Optimum Level of Adaptation

To achieve the first objective of this study (i.e. optimum level of adaptation), we follow the AD-RICE model (de Bruin et al 2009), which defined the optimum level of adaptation using equation as follows.

$$AL^{*}_{j,t} = \left(\frac{\omega_t \cdot M_t}{\gamma_{2,j} \cdot \gamma_{1,j}}\right)^{\frac{1}{\gamma_{2,j-1}}} \qquad (4.1)$$

Where, $(\omega_t . M_t)$ is the value of the gross damage that we have found from the Algerian model, and the rest of the parameters are adaptation coefficients.

The temperature change trend indicate that in the year 2009, the temperature has increased by 0.71 degree Celsius compared to 1900. However, in the year 2109, the projected change is 3.3 degree Celsius compared to 1900 or 2.05 degree Celsius compared to the year 2009. The projection also shows that the trend is linear and the rate of temperature change remains nearly constant over time.

Hence, from our model, we estimated the optimum adaptation level i.e. the value of equation (4.1), for the period of 2009 to 2109. With continued economic activities along with increased gross damage values, the optimum level of adaptation is projected to increase over time (without considering any mitigation policies).

The results shows that the optimum level of adaptation will be increasing with growing economic activities along with associated climate change monetary damage values. In 2009, if adaptation policy was to be taken, the optimum level of adaptation would have been 0.11 or 11% of the total damage. In 2109, the optimum level of adaptation increases to 29%. The overall results show that the optimum level of adaptation increasingly depends on corresponding damage and economic growth.

IV.4 Objective Two: Costs of Adaptation

To achieve the second objective of this study (i.e. to measure the costs of adaptation when adaptation is at its optimum level), we follow the AD-RICE model (e.g. de Bruin et al 2009), which describes the optimum costs of adaptation by the equation (4.2) as follows.

$$AC_t = \gamma_1 . AL_t^{\gamma_2} .\ Y_t \qquad (4.2)$$

For each time segment, we estimate the cost of adaptation for the optimum level. The cost of adaptation varies with the corresponding optimum level of adaptation along with respective gross damage values.

The results establish that the costs of adaptation are only a very small percentage of the estimated real GDP. Interestingly, the result presents that the early action costs are as little as % (0.005892 for year 2009), whereas if the action is taken at a later stage, the cost increase exponentially as % of GDP. The results indicate that an early action could potentially reduce the overall cost of adaptation.

For Algerian economy, Hydrocarbure as well as services are the highest contributing sector in terms of their contribution to the GDP. However, our study focuses only on agriculture; therefore we disaggregated this sector among 10 different subsectors to get each sector wise results. These results further indicate that olive oil (0.396726 for the segment 2009) was the highest contributing sector in agriculture (in terms of the production value). Thus, the cost of adaptation is also high whereas for wheat (0.021563 for the segment 2009) it was the lowest. These values increase consistently over the entire simulation period of the hundred-year period starting from 2009 to 2109. However, the rate of change for each crop is not same. For example, in the year 2009, the costs of adaptation for wheat was 22.546 thousand DZD, whereas, the costs of adaptation for food crops was a little higher, 23.647 thousand DZD. In the last time segment, (2109), costs of adaptation for wheat (1142.647 thousand DZD) is higher than the costs of adaptation for food crops (1098.673 thousand DZD). This is because of the elasticity of substitution for each crop is different.

Costs of adaptation corresponding to the optimum adaptation level continuously vary with time. These are the continuous costs towards a steady stabilized adopted economy. It is concluded from the results that the cost of adaptation is very small as the percentage of GDP for the agricultural sector. However, the increasing trend indicates the early adaptation action costs are as minimal as percentage of GDP (0.000341 for the segment 2009), whereas if the action is to be taken at a later stage the cost increases significantly as the percentage of GDP (0.012891 for the segment 2109).

IV.5 Comparison of BCS, CINA and CIAA scenarios

This study simulated each of the three scenarios (base case scenario, climate impact without adaptation and with adaptation actions) to investigate the impacts of adaptation policy in terms of the associated costs on the economy. The following sections depict the numerical results derived from the Algerian climate and Economy (ACE) model. This study examines the impacts of the adaptation policy on real GDP, productions of commodities, government expenditure etc.

1The Effect on Real Gross Domestic Product (RGDP)

In general, the value of RGDP increase over time for all three cases as the economic activities progress with time. However, the RGDP is lower for CINA and CIAA cases than BCS. This is because BCS does not consider any adverse effect of climate change.**See Appendices(table 2)**.

Among CINA and CIAA we find that RGDP is consistently higher for CIAA even though it takes adaptive actions having associated costs. On the other hand CINA does not include any additional cost of adaptive actions, however, its RGDP is lower due to the loss in economy for climate change related damages. The result indicates that the adaptation is effective in reducing the loss of RGDP due to climate change.**See Appendices(table 2)**.

IV.5.1 Loss of RGDP due to climate change

Table 3.show the RGDP monetary losses for CINA and CIAA compared to BCS RGDP. It is the difference between the BCS and CINA, CIAA RGDP values. This scenario results indicate that if no policy is taken, the loss of real GDP will be increasing at a higher rate over time. On the other hand, when adaptation measures are taken, the rate of loss in RGDP is stabilized to a near constant value, as evident from the last four time segment RGDP values for CIAA scenario. **See Appendices**.

IV.5.2 Effectiveness of the climate change adaption

The RGDP gains achieved for climate change adaptation (CIAA) compared to that of without adaptation (CINA). It is the difference between RGDP with and without adaptation policy. It is clearly evident that climate change adaptation policy is beneficial or effective in terms of the monetary value of real RGDP. From the results, we conclude that without investment for adaptation, climate change will cause remarkable losses in the RGDP (almost 5.7% of RGDP). On the contrary, adaptation policy can significantly reduce the losses and thus economically beneficial. The values also establish that the benefits of adaptation is increasing at a higher rate over the time.

The comparison between costs and benefits of adaptation. It is evident that the benefits of adaptation are higher than the costs of adaptation for each time segment. Moreover, benefits of adaptation tends to increase at a higher rate than the rate of increase of the costs over time. It implies that the benefit over cost ratio will continue to increase over the time.

IV.5.3 The Effects on Economic Outputs/Productions of Commodities

For all three scenarios, the value of output for each crop is now compared in order to determine whether adaptation policy is effective or not and to what extent. We consider both sector specific and aggregate level outputs to do this.

Economic output is highest for the BCS as this case assumes that growth trend will be unaffected by climate change impact. In comparison, outputs for CINA and CIAA are less than that of BCS but only by a small margin, whereas the CIAA outputs are a little higher than that of CINA. The sectors are divided into four groups based on their output volumes i.e. i) less than 2,000, ii) between 2,000 to 10,000, iii) between 10,000 to 100,000 and iv) higher than 100,000 DZD million.

IV.5.4 Climate change impact on output considering residual damages

Residual damages are calculated by subtracting the CINA, CIAA outputs from that of BCS scenario.In other words, the productions of each sector tends to decrease by the amount of the residual damages. These damages are compared for CINA and CIAA cases. It is clearly evident that for each sector, adaptation policy has reduced the residual damages compared to that of the CINA scenario. It is also evident that each sector projects damages commensurate to its ratio in the total production or output with the exception of olive oil sector which shows highest resilience to climate change related damages compared to its percentage contribution to the Algerian economy.

IV.5.5 Benefits of climate change adaptation

Taking into account of the optimum adaptation action, the simulation results show that CIAA residual damage is consistently lower i.e. the productions of each sector for CIAA are higher than that of CINA scenario. The results indicated that the adaptation policy is effective in terms of the outputs for each sector. It is further clarified from the results to shows the difference between the production values of two scenarios (CINA and CIAA).

IV.5.6 Climate change effects on the overall agricultural sector

This study accumulated the production values of all agricultural subsectors to find out the benefits of adaptation for the overall agricultural sector.**See Appendices(table 4)**

It is evident that with continued economic activities the production of each sector tends to increase over time for all three scenarios. As discussed before BCS output is fictitious as it does not consider any climate change projections. Therefore, it is also the highest. Comparing CINA and CIAA, we find that CIAA productions for the overall agricultural sector is higher than that of CINA. Hence, it can be concluded that the adaptation policy is effective in terms of the outputs for agricultural sector.

IV.5.7 The Effects on Government Expenditure

The government expenditure is a must to implement a public policy. Thus, to enforce adaptive actions, government has to bear the costs of adaptation. The estimated values of government expenditures before and after taking adaptation policy. In this scenario, there is no costs of adaptation was considered. The general trend for all cases show that with continued economic activities the government expenditure increases linearly over time. However, in case of CIAA, government expenditure is higher than that of no adaptation (BCS and CINA cases) by the amount of the costs of adaptation. **See Appendices(table 5)**.

V-Conclusion:

From the above findings, it is evident that the adaptation policy would be effective for Algeria in terms of the costs and benefits. However, the next chapter will focus on a discussion of these findings and try to relate with other studies and theories relevant to the present study.

Optimum Level of Adaption

This study shows that, with continued economic activities along with increased gross damage values, the optimum level of adaptation tends to increase over time. Without taking any mitigation policy, the country's economic activities continue to emit GHGs at a higher rate because of the expanding/growing economic activities and are supposed to accelerate the climate change negative impacts on the economy. As a result, the optimum level of adaptation increases over time.

Costs of Adaptation

This study showed an increasing trend for the cost of adaptation over the hundred years. Growing economic activities as well as emissions would cause optimum level of adaptation to increase. Therefore, the costs of adaptation would also increase both for sector wise or overall economy considerations.

Impacts of the Climate Change with and without Adaptation

The general objective of this study was to investigate the impacts and costs of the climate change on the agricultural sector as well as on the overall economy with and without adaptation policy. Our results showed that, benefits of adaptation are higher than the costs of adaptation for each time segment. Moreover, benefits of adaptation tend to increase as a higher rate than the rate of increase for the associated costs over time. This implies that the benefit-cost ratio will continue to increase with the time period. The positive values for every sector indicated that, adaptation is effective in terms of sectorial production, as the production without adaptation policy is less than the production with adaption policy, for each of the 15 sectors. From the findings, it is evident that the adaptation policy would be effective for Algeria in terms of the costs and benefits.

This study focused on the entire economy by dividing it into fifteen different sectors among which ten sectors are only agricultural, as our special focus was on agricultural impact investigation. We have estimated the costs of climate change with and without adaptation action for each agricultural commodity separately. In addition, the results showed that for every sector the benefit tend to be higher than the associated costs.

Contribution

The study has revealed the macroeconomic effects of adaptation policies on the Algerian economy. Specifically, this study will enhance the current knowledge by setting up a long-term national climate change adaptation policy framework for Algeria in response to the Algerian National Policy on Climate Change (2009). This study contributes to filling the research gap regarding the costs of adaptation for each crops within the agricultural sector. The study formed guidelines for policymakers to make macroeconomic decisions based on precise knowledge of the overall impacts of adaptive measures**.** Although the ultimate target groups are principally Algerian policymakers, however, a wide range of people/organisations are expected to benefit from the scientific outcome of this research.

-Appendices :

Table 1: Time Segments for this Study

Time segment 1	Year 2009
Time segment 2	Year 2029
Time segment 3	Year 2049
Time segment 4	Year 2069
Time segment 5	Year 2089
Time segment 6	Year 2109

The source : Prepared by researchers

Table 2: Comparison of RGDP (in DZD million) for BCS, CINA and CIAA

	2009	2029	2049	2069	2089	2109
BCS	493663.9	513965.2	535184.6	5441361.9	568538.1	600756.4
CINA	491925.914	510954.401	529119.541	525242.614	549686.275	564925.561
CIAA	492119.249	511516.476	530563.672	527795.635	548926.011	574960.636

The source : Prepared by researchers

Table 3: Loss of RGDP Due to Climate Change (in DZD million)

Time segment	2009	2029	2049	2069	2089	2109
CINA	1737.986	4010.799	8065.059	16119.286	24851.825	35830.839
CIAA	1544.651	3448.724	6620.928	12566.265	18612.089	25795.764

The source : Prepared by researchers

Table 4: Overall Agricultural Sector Outputs for Different Scenarios (in DZD million)

Time segment	2009	2029	2049	2069	2089	2109
BCS	46683.66	49377.59	50894.47	52877.58	55149.98	57216.33

CINA	46609.33	49227.02	50692.19	51711.96	54533.43	56313.79
CIAA	46618.97	49262.56	50755.02	52656.3	54772.03	56575.95

The source : Prepared by researchers

Table 5: Government Expenditure for BCS/CINA (AL=0.0) and CIAA (AL*)(in DZD M million)

Time segment	2009	2029	2049	2069	2089	2109
EG(AL=0.0)	66100.108	70155.33	72544.326	75135.197	77948.33	80736.99
EG(AL *)	66127.122	70231.277	72712.14	75674.95	78970.531	81971.628
Difference	27.014	75.947	167.814	539.753	1022.201	1234.638

The source : Prepared by researchers

<u>A-Price Block</u>

Import Price

$$PM_c = pwm_c(1 + tm_c) \cdot EXR \tag{3.1}$$

Export Price

$$PE_c = pwe_c(1 + te_c) \cdot EXR \ (3.2)$$

Absorption

$$PQ_c QQ_c = [PD_c QD_c + PM_c QM_c](1 + tq_c) \tag{3.3}$$

$$PX_c \cdot QX_c = PD_c QD_c + PE_c QE_c \tag{3.4}$$

Activityprice

$$PA_a = \sum_{c \in C} PX_{ac}\, \theta_{ac} \tag{3.5}$$

Value addedprice

$$PVA_a = PA_a - \sum_{c \in C} PQ_c\, ica_{ca} \tag{3.6}$$

, **B-Production and trade block**

Activity production function

$$QA_c = ad_a \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \tag{3.7}$$

Factor demand

$$WF_f WFDIST_{fa} = \frac{a_{fa} PVA_a QA_a}{QF_{fa}} \tag{3.8}$$

Intermediatedemand

$$QINT_{ca} = ica_a QA_a \tag{3.9}$$

Output function

$$QX_c = \sum_{a\epsilon A} \theta_{ac} \, QA_a \tag{3.10}$$

Composite supply (Armington) functions

$$QQ_c = aq_c \left(\delta_c^q QM_c^{-p_c^q} + (1-\delta_c^q) QD_c^{-p_c^q}\right)^{\frac{-1}{p_c^q}} \tag{3.11}$$

Import-domesticdemand ratio

$$\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c}\frac{\delta_c^q}{(1-\delta_c^q)}\right)^{\frac{1}{1+p_c^q}} - 1 < p_c^q < \infty \tag{3.12}$$

Composite supply for non-imported commodities

$$QQ_c = QD_c \tag{3.13}$$

Output transformation function

$$QX_c = at_c \left(\delta_c^t QE_c^{p_c^t} + (1-\delta_c^t) QD_c^{p_c^t}\right)^{\frac{1}{p_c^t}} \tag{3.14}$$

Export-domesticdemand ratio

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c}\frac{(1-\delta_c^t)}{\delta_c^t}\right)^{\frac{1}{p_c^t - 1}} - 1 < p_c^t < \infty \tag{3.15}$$

Output transformation for non-exportedcommodities

$$QX_c = QD_c \tag{3.16}$$

C-Institution block

Factor income

$$YF_{hf} = shry_{hf} \sum_{a\in A} WF_f WFDIST_{fa} QF_{fa} \tag{3.17}$$

Non-governmentdomestic institution

$$YH_h = \sum_{f\in F} YF_{hf} + tr_{h,gov} + EXR \cdot tr_{h,row} \tag{3.18}$$

Household consumption demand

$$QH_{ch} = \frac{\beta_{ch}(1-mps_h)(1-ty_h)YH_h}{PQ_c} \tag{3.19}$$

Investmentdemand

$$QINV_c = qinv_c \cdot IADJ \tag{3.20}$$

Government revenue

$$YG = \sum_{h\in H} ty_h \cdot YH_h + EXR \cdot tr_{gov,row} + \sum_{c\in C} tq_c\,(PD_cQD_c + PM_cQM_c) + \sum_{c\in CM} tm_cEXR \cdot pwmc_c \cdot QM_c + \sum_{c\in CE} te_c\,EXR \cdot pwe_c \cdot QE_c + ygi \quad (3.21)$$

Government expenditures

$$EG = \sum_{h\in H} tr_{h,gov} + \sum_{c\in CE} PQ_c \cdot qg_c \quad (3.22)$$

D-System constraints block

Factor markets

$$\sum_{\propto\in A} QF_{fa} = QFS_f \quad (3.23)$$

Composite commoditymarkets

$$QQ_c = \sum_{\propto\in A} QINT_{ca} + \sum_{h\in H} QH_{ch} + qg_c + QINV_c \quad (3.24)$$

Current account balance for ROW

$$\sum_{c\in CE} pwe_c \cdot QE_c + \sum_{i\in I} tr_{i.row} + TASV = \sum_{c\in CM} pwm_c \cdot QM_c + irepat + yfrepat_f \quad (3.25)$$

Savings-Investment balance

$$\sum_{h\in H} mps_h \cdot (1 - ty_h)YH_h + (YG - EG) + EXR \cdot FSAV = ygi + EXR \cdot irepat + \sum_{c\in C} PQ_c \cdot QINV_c + WALRAS \quad (3.26)$$

Price normalization

$$\sum_{c\in C} PQ_c \cdot cwts_c = cpi \quad (3.27)$$

E- Climate Change Block

$$GD_t = \alpha_i \Delta T_t^2 \quad (3.28)$$

$$T_t = \alpha_j T_{t-1} + \alpha_k EM_t \quad (3.29)$$

$$EM_t = \Omega . Y_t(1 - \mu_t - AL_t) \quad (3.30)$$

$$\frac{AC_t}{Y_t} = \gamma_1 . AL_t^{\gamma_2} \quad (3.31)$$

$$\frac{GD_t}{Y_t} = \omega . M_t \quad (3.32)$$

$$\frac{GD_t}{Y_t} = \alpha_1 \Delta T_t + \alpha_2 \Delta T_t^{\alpha_3} \quad (3.33)$$

$$\frac{GD_t}{Y_t} = \frac{RD_t(GD_t - AL_t - AB_t)}{Y_t} + \frac{AC_t(AL_t - AB_t)}{Y_t} \quad (3.34)$$

$$RD_t = (1 - AL_t). GD_t \quad (3.35)$$

$$C_t = Y_t - RD_t - AC_t - MC_t \tag{3.36}$$

$$U_t = \sum_{t=1}^{Z} \rho_t . (C_t) \tag{3.37}$$

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