Impact of climate change on food security in Ethiopia: A computable general equilibrium micro-simulation analysis

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Abstract: Climate change affects food production and distribution, it lessen production in straight line, and distribution of incomes indirectly. Ethiopian economy is extremely sensitive to temperature and precipitation variability. Its exposure in turn impacted all dimension of food security. Some studies have been applied on economic-wide impact of climate change using general equilibrium modeling. Yet, those studies were not bespoke to examine global climate change impact on food security of individual household. Using macro-micro analysis decisions made at macro level could integrate with individual household characteristics. This paper employed static CGE model linked with micro-simulation, which basically follows top down approach. From supply side standpoint CGE result suggests, food security decreases by 8.28%, and 13.21% in CGCM2 and PCM scenario, respectively. In demand side simulation result shows 5.57% decline in food security, proxy by consumption expenditure under CGCM2 scenario and 9.04% in PCM, respectively. Government consumption is exceptional macroeconomic variable which had shown growth for climate change induced economy. Nevertheless, real GDP, private consumption, investment, absorption, import and exports have been declined both in CGCM2 and PCM simulation scenarios. Micro-simulation result explains household consumption must rise by 2.6% to move out from food insecurity gap. In addition, food insecurity has seen sever for urban insecure households of climate change induced economy. It increases by 0.89% in PCM and rises by 0.79% for CGCM2. Following the finding authors recommend that policy interventions that shrink consumption expenditure inequality needed. Furthermore, national level policies which play down climate change impacts have to be endorsed.

Key words: Computable General Equilibrium, Micro-simulation, Food security, CGCM2, PCM
1. INTRODUCTION

Climate change is not merely deviation from “standard” climactic conditions. It is the mother of all externalities larger, more complex, and more uncertain than other environmental problem. Every farm and household emits some greenhouse gases which in turn affects everything and everyone (Apata T.G. et al., 2009). Many African economies hard hit by climate change, it aggravate existing food insecurity in the region (Dinar A. et al., 2006).

Ethiopia known to be economically underdeveloped, its economy depends mainly on agriculture. It is often seen that even minor change in climate brings huge impact on Ethiopian economy because; its economy is extremely sensitive to climate change proxies. Moreover, Ethiopia become progressively more dependent on food aid in most densely populated highlands (Kassie M. et al., 2011). Although, Ethiopia has planned to build Climate Resilient Green Economy which intends to reach middle-income status before 2025 (FDRE, 2011). Country’s vulnerability to climate change in turn affects all dimensions of food security: food availability, food accessibility, food utilization & food stability (Gebreegziabher Z. et al., 2011).

Food insecurity due to climate change is critical area that needs analysis and sound policy alternatives. Previous studies (Ferede, Belayneh, & Hanjra, 2013); (Kebede W., 2012) used dynamic CGE to measure impact of climate change on food security. However, those studies were not bespoke to recognize macro-micro impacts. Therefore, this study was investigated impact of climate change on food security using CGE model linking with micro simulation, which captures household heterogeneity. It had applied to examine less-research question of economy wide-household level impact of climate change on food security in Ethiopia. Basically, the paper has principal objective of investigating static impact of climate change on availability and accessibility dimension of food security. With supportive objectives of examining household food security status in Ethiopia and examine severity of household food insecurity for urban and rural households.

2. METHODOLOGY

2.1. Data source

The main data source of this research is 2005/2006 Social Accounting Matrix (SAM) which was constructed by Ethiopian Development Research Institute (EDRI) together with institute of
development studies of the University of Sussex. Micro-simulation analysis has been done using Ethiopian household consumption expenditure survey data collected in 2004/2005 by CSA.

**Conceptual Framework**

Conceptual framework has built adopting works done by (Sassi M. & Cardaci A., 2012). It has two parts, first impact of climate change on crop productivity estimated based on study (Deressa T. & R. Hassan, 2009) crop productivity change coefficient. Accordingly, changes in crop productivities for climate change used as parameter inputs in CGE model simulation. Secondly, changes in some macro variables (composite commodity output and consumption expenditure) were used as an indicator for food availability and access dimension respectively. In the figure below the frame work for this research work is presented.

*Figure 2.1: Conceptual frame work*

*Source (Sassi M. & Cardaci A., 2012)*
Food availability, measured composite food production and change in consumption expenditure let food access to adjustment. The author modified the framework; by letting value added function CES and intermediate input Leontief.

2.2. Model description

Economy of Ethiopia is stratified into 5 different agro ecological zones based on pattern of land use and moisture; agro ecological division form 14 household groups, 99 activity accounts which includes 65 regionally segregated agricultural activities, one aggregate forestry and agricultural activity, 21 manufacturing(industrial) and 12 service related activities. With 91 commodity accounts; which agriculture share 45 commodity 25 marketed and 20 own-consumed), industrial sector attributes 30 marketed commodity items while remaining 16 commodities 2 owned and 14 marketed services produced by service sector. With 22 commodity groups and 46 activities including 35 regionally segregated agricultural sectors. In addition 15 factors of production are identified which includes labor, agricultural land, livestock in each agro ecological division, and employment in industry and service sectors.

This study basically follows CGE model linking with micro-simulation. It was adopt standard CGE model of International Food Policy Research Institute (Lofgren H. etal., 2002). Which follows neo-classical modeling tradition originally presented by (Dervis K., J. de Melo, & S. Robinson, 1982). The model belongs to Static strand of CGE literature, to evaluate impact effect of climate change on food security. Here, is presentation of general description of model with focal equation focusing on assumptions that are needed to build Computable General Equilibrium and specification of how food security variables were placed in the model:

2.2.1. Production and Trade Block

This block covers four categories: domestic production and input use; domestic output to home consumption, domestic market, and exports; aggregation of supply to domestic market (imports and domestic output sold domestically); and definition of demand for trade inputs that is generated by distribution process. Production is carried out by activities that are assumed to maximize profits subject to their technology, taking prices (for their outputs, intermediate inputs, and factors) as given. It works in a perfectly competitive venue. Then, CGE model includes first-order conditions for profit-maximization by producers. Firms maximize profits under the
restriction of their production technology, for given prices. The nested-CES production function consist factor input from SAM. Intermediate deliveries demand nest Leontief technology which yield commodity output in the production process. All the output is not consumed, allocated between some for export and other goes for domestic sales governed by constant elasticity of transformation (CET) function and this, captures any time or quality differences between the two products. In addition, allowing small country assumption, Ethiopia faces horizontal world demand curve for export at fixed world prices. Extending small country assumption Ethiopia faces perfectly elastic world supply at fixed world food price for imperfect substitution between imported and domestically produced goods. Constant returns to scale are assumed, with no excess profits can reaped. Implies that factors receive income where marginal revenue equals marginal cost based on endogenous relative prices.

The size of output from an activity in CGE model will determine using equation

\[ QA_a = a_a^a \left( \delta_a^a QVA_a^{-\rho_a^a} + (1 - \delta_a^a) QINTA_a^{-\rho_a^a} \right)^{1/\rho_a^a} a \in ACE \]  

Where: \( a \in ACES(A) \) is set of activities with CES function at the top of technology nest, \( a_a^a \) is efficiency parameter in CES activity, \( \delta_a^a \) is CES activity share parameter and \( \rho_a^a \) is CES activity function exponent. In this block per capita food production percentage change with climate change scenario gives extent to which climate change affects supply side food security.

**Output Transformation (CET) Function**

Domestic marketed output is allocated either for domestic sale or export with an assumption of imperfect transformability between destinations expressed using output transformation function. The output transformation function revealing allocation of domestically produced output \( QX_c \) for domestic market and export market has specified in Equation (2) below with CET assumption.

\[ QX_c = \alpha_c^c \left( \delta_c^c QEC_c^{\rho_c^c} + (1 - \delta_c^c) QDC_c^{\rho_c^c} \right)^{1/\rho_c^c} c \in (CES \cap CD) \]

Where, \( \alpha_c^c \) is a CET function shift parameter, \( \delta_c^c \) is CET function share parameter and \( \rho_c^c \) stands for CET exponent function.

### 2.2.2. Price Block

The model price system is rich, primarily because of the assumed quality differences amongst commodities of different origins and destinations (exports, imports, and domestic outputs used
domestically). The price block consists of equations in which endogenous model prices are linked to other prices (endogenous or exogenous) and to non-price model variables (Lofgren, et al., 2002). Here is price of commodity supplied defined from total activity price.

\[ PA_a = \sum_{c \in C} PXAC_{a,c} . \theta_{a,c} \Rightarrow \begin{bmatrix} \text{activity} \\ \text{price} \end{bmatrix} = \begin{bmatrix} \text{producer prices} \\ \text{times} \\ \text{yields} \end{bmatrix} \]

Where \( a \in A \) stands as a set of activities, \( PA_a \) is activity price (gross revenue per activity unit) with \( PXAC_{a,c} \) specified as Producer price of commodity \( c \) for activity \( a \), and \( \theta_{a,c} \) considered to be Yield of output \( c \) per unit of activity \( a \). Gross revenue per activity unit activity price, is the return from selling output or outputs of the activity, defined as yields per activity unit multiplied by activity-specific commodity prices, summed over all commodities. This allows the fact that activities may produce multiple commodities. Given the gross price of an activity, percentage change of food supply prices in major crops infer about the allocation and affordability of domestically produced food. Thus, price change indicates the food access dimensions.

**Absorption**

It is total domestic spending on commodity valued at domestic demander price. Expressed as sum of domestic output spending and imports at demand price. These prices include cost of trade inputs but exclude commodity sales tax i.e. prices are net of sale tax.

\[ PQ_c . (1 - tq_c) . QQ_c = PDD_c . QD_c + PM_c . QM_c \ldots ce(CDU\cup CM) \].

**Marketed Output Value**

Marketed output value, for each domestically produced commodity at producer prices stated as sum of values of domestic sales and exports excluding output value of home-consumption. In this case, Domestic sales and exports are valued at the prices received by the suppliers.

\[ PX_c . QX_c = PDS_c . QD_c + PE_c . QE_c \ldots ceCX \].

Where, \( PX_c \) is aggregate producer price for commodity, \( QX_c \) is aggregate market quantity of domestic output of commodity, \( QE_c \)quantity of export and a set of \( c \in C \).

**Consumer price index CPI**

\[ CPI = \sum_{c \in C} PQ_c . cwtS_c \].

CPI is calculated multiplying price of aggregated commodity \( c \) and weight of commodity \( cwt \).
Unlike default CGE of IFPRI, CPI is flexible, to made adjustment in consumption expenditure for micro-simulation analysis.

**Producer price index for non-traded market output (DPI)**

Producer price index for domestically produced marketed output determined by domestic supply price multiplied weight of commodity C in DPI. DPI set to be numeraire. That is doubling value of producer price index would double all prices but leave real quantities unchanged specified as:

\[
\overline{DPI} = \sum_{c\in C} PPDS_c \cdot dwtS_c
\]

Where, \(dwtS_c\) weight of commodity \(c\) in the producer price index and \(\overline{DPI}\) is fix Producer price index for domestically marketed output.

**2.2.3. Institution Block**

Model distinguish various institutions within the economy, including enterprises, government, and households. Income payments from each factor of production will be allocated to households and other institutions using fixed shares derived from national SAM. Using Linear Expenditure System household consumption was optimized from Stone-Geary utility function. Institution block has equations that define distribution of income to factors of production and owners of the factors of production, intra-institutional transfers, and household consumption expenditure (domestically produced, imported commodities), investment demand, savings and government expenditures. Primary source of income for households and enterprises are factor returns generated during production were specified.

\[
YF_f = \sum_{a\in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa}
\]

Where, \(YF_f\) is factor \(f\) income, \(WF_f\) is average price for factor \(f\), \(WFDIST_{fa}\) Wage distortion factor for \(f\) in activity \(a\), and \(QF_{fa}\) is quantity demand of factor \(f\) from activity \(a\).

**Household Consumption Expenditures**

Households within each income category are assumed to have identical preferences, and are modeled as representative consumers. Inside model, decision of agents changes as a result of change economy driven by food consumption expenditure used as proxy food access dimension.
of food security. Household consumption expenditure derived from Stone-Geary utility function maximization subject to household budget constraint presented as:

\[ \text{EH}_h = \left( 1 - \sum_{i \in \text{INS}} \text{shii}_{i \ h} \right) \cdot (1 - \text{MPS}_h) \cdot (1 - \text{TINS}_h) \cdot Y_{\text{h}} \]

Where \( i \in \text{H} (\subset \text{INS}) \) is set of household, \( \text{EH}_h \) household consumption expenditure, \( \text{shii}_{i \ h} \) is share of net income of household transferred to institution \( i \), \( \text{MPS}_h \) is marginal propensity to save to households, \( \text{TINS}_h \) is direct tax rate of households, and \( Y_{\text{h}} \) is household income (Lofgren et al., 2002). Household consumption spending on marketed commodity determined using equation:

\[ \text{PQ}_c \cdot \text{QH}_{c \ h} = \text{PQ}_c \cdot y_{c \ h}^m + \beta_{c \ h} \cdot \left( \text{EH}_h - \sum_{c \in C} \text{PQ}_c \cdot y_{c \ h}^m - \sum_{a \in A} \sum_{c \in C} \text{PXAC}_{a \ h} \cdot y_{a \ h}^c \right) \]

Where, \( \text{QH}_{c \ h} \) is quantity of marketed commodity “C” to consumption for household \( h \), \( y_{c \ h}^m \) is marginal share of consumption spending on marketed commodity \( c \) for household \( h \) and \( y_{a \ h}^c \) is subsistence consumption of home commodity \( c \) from activity \( a \) for household \( h \).

**Investment Demand**

Investment demand exogenously derived by multiplicity of base-year quantity by factor adjustment.

\[ QINV_c = \text{IADJ} \cdot \text{qinv}_c \quad c \in C \]

Where, \( QINV_c \) fixed investment demand quantity for commodity, \( \text{IADJ} \) is investment adjustment factor (exogenous variable) and \( \text{qinv}_c \) is base-year quantity fixed investment demand.

**Government Expenditure**

Government expenditure before and after shock with description and equation presented as.

\[ \text{EG} = \sum_{c \in C} \text{PQ}_c \cdot \text{QG}_c + \sum_{i \in \text{INS}} \text{trnsfr}_{i \ \text{gov}} \cdot \text{DPI} \]

Where, \( \text{EG} \) government expenditures, \( \sum_{c \in C} \text{PQ}_c \cdot \text{QG}_c \) government consumption spending, and \( \sum_{i \in \text{INS}} \text{trnsfr}_{i \ \text{gov}} \cdot \text{DPI} \) Government transfers.

**2.2.4. System Constraint Block**

The last block contains equations that balance market for factors of production, market for commodities (demanded equals supply), and government revenue equals expenditure. The model closure governed each market discuses in this block. Commodity markets prices adjust to equate
supply and demand through equilibrate domestic and foreign prices. In factor market equilibrium capital market (including livestock), assumed to be fixed by sector and region or assumed fully employed activity specific. Capital stock is fixed and immobile across sectors (earn sector-specific returns). Households and enterprises earn factor incomes in proportion to implied share of each factor stock. Enterprises are sole recipient of capital income, that transfer to households after having paid corporate taxes (based on fixed tax rates), saved (based on flexible savings rates), and remitted profits to rest of the world. Land viewed fixed by region, but mobile across crops and fully employed. In labor markets total supply of labor is fixed, fully employed, mobile and real wages adjust endogenously so demand for labor equal to supply. Fully employed labor assumption is reliable with widespread evidence that, though relatively few people have formal sector jobs, the large majority of working age people engage in activities that contribute to GDP.

Similarly closures for macro balances are specified: trade balance, assumed to have fixed foreign savings (foreign capital inflow), consequently trade balance (current account) is fixed. Then, real exchange rate adjusts to achieve export supply and import demand that yield fixed trade balance. In absorption balance, assumed aggregate investment, government demand, and consumption are fixed shares of total absorption and all tax rate taken as constant. Any macro adjustment burden shared equally across macro aggregates. In addition, government spending tax rates are fixed share of absorption. Government deficit is endogenous, adjusts government balance. Investment driven closure is adopted as saving rate adjust to investment in Ethiopia’s case, assuming saving rate ensures saving and investment equilibrium, with exogenously fixed investment. Finally, Producer price index is numeraiers; i.e., all price determined relative to fixed producer price index. Consumer price index is flexible, it ready to flexible for update consumption expenditures used in micro simulation model. Since price has normalized to one in the model, the changes in CPI indicate consumer prices changes that bring about new equilibrium.

2.4. Food security and Microsimulation Analysis

2.4.1. Food Security in CGE Modeling

This study adopts derivation of food security components done by(Wua W. etal., 2010) in which, per capita food production consider as indicator of food security to signify food availability
dimension in supply side. In addition, food access proxies by food consumption expenditure and per capita real GDP from the market demand part. These food security components described in equations below: per capita food production standpoint will denote food availability and stability dimension. Change ratio of total food production CR_p calculated based on simulated crop yields change comparing food production in climate change pattern with baseline without climate impact. By this, study develops the following equation for per capita food production of crops.

\[ CR_p = \frac{\sum_{i=1}^{n} Y_{i}^t * A_{i}^t}{\sum_{i=1}^{n} Y_{i}^l * A_{i}^l} \]  

Where CR_p is change ratio of total production, Y stands for crop yield for crop type i; A represent crop area for crop type i and n total number of crops. Computing total food production by itself can’t state food availability, relative changes in per capita food availability (CR_a) for the same period of climate change and without it, with the following Equation.

\[ CR_a = \frac{\sum_{i=1}^{n} Y_{i}^t \cdot A_{i}^t}{\sum_{i=1}^{n} Y_{i}^l \cdot A_{i}^l} \]  

Where CR_a change ratio of per capita food availability, Y is crop yield for crop type i; A represent crop area for crop type i, POP is total population and n total number of crops. This will use in analysis part through comparing per capita food availability for climate change and without climate change.

The consumption expenditure ratio of counterfactual scenario over baseline scenario is assumed:

\[ CE_R = \frac{EH_{h,0}}{EH_{h,1}} \]  

Where:

CE_R Consumption expenditure ratio EH_{h,0} is consumption expenditure without climate change and EH_{h,1} consumption expenditure with climate change. Consumption expenditure ratio represents climate change induced food access, which is household affordability.

### 2.4.2. Micro simulation Module

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The main role of micro-simulation module provide detailed computation at the household level, through comprehensive description of economic system, and estimate individualistic behavioral responses to policy change. For instance, through the use of micro econometric equations, one can model behaviors’ such as labour supply or consumption pattern (J. Lay 2010). In this article, sequential micro-simulation model with hypothesis that climate change could induced adjustment on individual behavior, concerning their level of expenditure used. First, study solve CGE model, then changes in consumption expenditure passes household model. Current consumption profiles and anticipated behavioral responses of households to consumption expenditure changes after climate change is primer condition to develop suitable tool for impact analysis at individual.

It could be difficult to extract household status of food security. To do so, it might be useful to construct an index that picks the most important indicators that present food security profile of the household. Various methods used to estimate level of food security among sample households. Principal Component Analysis and Foster-Greer-Thorbecke widely used. Explicitly, food insecurity incidence, depth and severity, would have been determine using FGT. The study split food security into three categories: food secure, food insecure without hunger, food insecure with hunger. The procedure acquired on Foster et al. (1984) computation of incidence, depth and severity of food insecurity. The FGT measure equation is:

$$\text{FGT}(\alpha) = \left(\frac{1}{n}\right) \sum_{i=1}^{q} \left[ \left( \frac{c - y_i}{c} \right) \right]^\alpha$$

Where: n is the number of sample households; $y_i$ is the measure of household size deflecting consumption expenditure of $i^{th}$ household; c represents the cut off between food security and food insecurity households; q is the number of food-insecure households; and $\alpha$ is the weight attached to the severity of food insecurity. In FGT index, $y_i \geq c$ implies the specified household is food secure. Three most commonly working indices computed within FGT index are: head count ratio, food insecurity gap and squared food insecurity gap (Alaba O. & Reuben O., 2014). Head count ratio describes the percentage of sampled households whose per capita consumption is below the predetermined subsistence level i.e., FGT ($\alpha=0$) = $\frac{q}{n}$. The food insecurity gap, FGT ($\alpha=1$), measure how far the food insecurity of households, squared food insecurity gap ($\alpha=2$),
measures severity of food insecurity gap. Thus, this paper will capture the possible implication of simulated climate change on household food security using data from Household Income Consumption Expenditure Survey of (CSA, 2004/05) comprises sample of 21,594 household. So that what happens after climate change strictly address individual household impact effect of climate change through transmission of economic wide change, CPI and consumption expenditure headed for household. Accordingly, simulation results for before and after climate shock will fed into household model using (DASP) software produces food security indices. Conceptually, figure below represents.

![Figure 3.2: The Top-down Approach](source: Colombo G., 2010)

### 3.5 Scenario Consideration

This section describes estimate baseline and counterfactual scenarios in CGE. The baseline projection modeled Ethiopia’s economy from base year 2005/06 updated to year 2014/15 cropping season is benchmark trajectory of Ethiopian economy. In baseline, TFP growth estimated at historical percent for all sectors of the economy. And baseline growth path assumes economy continues to change during 2005/06–2014/15 season in line with its recent economic performance. For each year, researchers would update changes in population, labor supply, and factor productivity. Accordingly, United Nation medium population growth projection would base labor force and population growth projection (UN, 2015), while total factor productivity (TFP) trends for without climate change could agree in conformity with World Bank long-run GDP growth projections for Ethiopia (World Bank, 2010). Sector priorities consider government...
policy documents in establishing the baseline. Consequently, the annual average GDP growth rate of 6% (World Bank, 2010, (Robinson S. et al., 2011) are assumed.

Climate changes induce scenario build based on total factor productivity estimate of crop model as input parameter for CGE modeling. Then author would bases estimated coefficient, allowing assumption of perfect product and resource market Recardian estimation of net revenue change breaks consistent towards total factor productivity. Specifically, the shift parameter on crop production function foreseen, is simulating accomplished on change in total factor productivity enclosed shock. Though, farmers don’t anticipate climate change, partly autonomous adjustment on crop production might make in response to climate change.

Two climate scenarios, relies prediction of CGM2 and PCM models over 2050 has been base for crop model. And climate prediction is an average, which couldn’t explicitly introduce variability to observed climatologically data, rather changes in mean climate. Thus, counterfactual scenario of agricultural damages, lead national crop productivity shocks were calculated based on published climate change impact estimates of (Deressa T. & R. Hassan, 2009). Nonexistence sector specific productivity estimate, give intuition to assume uniform crop productivity shocks over entirely crop sectors. Three simulation scenarios for cropping year 2014/15 were considered. These climate change scenarios are dependable on CGCM2 and PCM model average predictions to Ethiopia over 2050.

1. The baseline scenario: in the BASE scenario, it is assumed that there is no climate change productivity effect.
2. Simulation 1, Climate change induced crop productivity damages of 9.71% under CGCM2\(^1\) projection is simulated.
3. Simulation 2, Climate change induced crop productivity damages of 15.4% under PCM\(^2\) projection is simulated.

\(^1\)CGCM2 (Coupled global Climate Model) based on IPCC Special Report on Emission Scenario(SRES) assumption, projects temperature to increase from 21.25-24.51\(\circ\)C in 2050, whereas precipitation to decrease from 76.77-64.75 and
\(^2\)PCM (Parallel Climate model) projects temperature to increase from 21.25-23.50\(\circ\)C, and precipitation to increase from 76.77 to 80.83 in 2050 (Deressa T. & R. Hassan, 2009).
3. SIMULATION RESULTS AND DISCUSSION

3.1. Economy-Wide Modeling Results

Computable general equilibrium model used crop yield results to estimate the economy-wide impacts of climate change. Reported percentage change in key macroeconomic variables for climate induced economy compared with baseline scenario has discussed. Real GDP measured using vale added approach accounts large deviation in all scenarios. It decline by 4.50 and 7.21% for the first and second simulation respectively. This is because the economy is agrarian based at which almost 40% of the GDP sourced from it.

**Table 3.1: Macroeconomic Simulation results**

<table>
<thead>
<tr>
<th>Macro Variables</th>
<th>CGM2 Scenario</th>
<th>PCM Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private consumption</td>
<td>-5.04</td>
<td>-8.05</td>
</tr>
<tr>
<td>Government Consumption</td>
<td>0.24</td>
<td>0.39</td>
</tr>
<tr>
<td>Real GDP</td>
<td>-4.50</td>
<td>-7.21</td>
</tr>
<tr>
<td>GDP at factor cost</td>
<td>-4.64</td>
<td>-7.43</td>
</tr>
<tr>
<td>Exports</td>
<td>-6.10</td>
<td>-9.64</td>
</tr>
<tr>
<td>Imports</td>
<td>-2.18</td>
<td>-3.44</td>
</tr>
<tr>
<td>Investment</td>
<td>-0.75</td>
<td>-1.30</td>
</tr>
<tr>
<td>Total Absorption</td>
<td>-3.66</td>
<td>-5.87</td>
</tr>
</tbody>
</table>

**Source:** CGE simulation

As can be seen in the above result, government consumption is the only macroeconomic variable increased in spite of crop productivity slowdown. It increased by 0.24% and 0.39% for CGCM2 and PCM scenarios, respectively. This could be justified by substantial government spending shoots up to support the household whose income decline following climate changes. Those might happen to reduce relative food insecurity among households as a sort of subsidy.

Given that the foreign saving is fixed by model closure, stronger impact of climate change on export triggers appreciation of exchange rate so that current account is maintained. Result shows export volume decreases by higher rate than import volume as exchange rate would adjusts by higher rate than the import volume. Consequently, exchange rate (measured as local currency unit per foreign currency unit) were seen 2.19% and 3.79% lower than it would be in without climate change for the CGCM2 and PCM scenario, respectively.
Figure 3.1: Percentage Change on Macro Economic Variables

3.1.1 Static impact of climate change on food security

Food security is a broad concept that cuts across many dimensions, at its most basic level at least two parts of this complex concept: access and available to food used. These dimensions of food security might have meaningful household variation across included household group. Accordingly, food security for climate induced economy designated using two pillars.

Static effects of climate change on food availability

Food availability refers food supply or productive capacity. It is measured using annual per capita food production. Climate change distresses food availability, because it affects basic elements of food production. Changing temperatures and precipitation patterns create conditions for direct effects on yields. Accordingly, per capita food production compared for two scenarios of climate change shows static impact of climate change on food availability. Exhaustively, computed per capita food production ratios of climate scenarios CGCM2 and PCM with base is less than one. It denotes 8.28% and 13.21% drop in supply side proxy for the CGCM2 and PCM scenarios, respectively. This result is consistent with other studies such as (Kebede W., 2012).
Table 3.2: Per Capita Food Production Ratio \((CR_p)\)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>CCGM2</th>
<th>PCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Capita Food Production ((CR_p))</td>
<td>-8.28</td>
<td>-13.21</td>
</tr>
</tbody>
</table>

*Source: CGE Simulation*

Static for effects of climate change on food access

Although climate change has paramount direct effect for food accessibility dimensions, other factors can similarly contribute share for the fluctuation in demand side food security pillars, which indirectly lounged unquestionable damage happening on crop yield. Food becomes scarce, and unaffordable, i.e. unapproachable, for a growing food production also. Food access proxies by household expenditure was examined for two climate change scenarios and results compared with baseline. Computable general equilibrium simulation result shows 5.57% decline for food consumption expenditure under CGCM2 scenario and 9.04% drop in PCM scenario respectively.

Table 3.3: per capita Food Consumption Expenditure Ratio \((FEP_{hp})\)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>CGCM2</th>
<th>PCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Capita Food Production ((FEP_{hp}))</td>
<td>-5.57</td>
<td>-9.04</td>
</tr>
</tbody>
</table>

*Source: CGE simulation*

The result shown in table above is consistent with other studies (Kebede W., 2012) for Ethiopia; and (Sassi M. & Cardaci A., 2012) for Sudan, that claimed food consumption expenditure reduced in respective scenarios. Therefore, this study ended with consistent output, that smaller amount of consumption expenditure seats less food access nation for climate change induced economy than no climate change pleasing the two basic scenarios.

Impact on household consumption expenditure

Household food security status expresses how far household food consumption expenditure for climate scenario comparing with baseline. Computable general equilibrium result shows decline consumption for all included household group due to lower changes in absorption and income of households. In both scenarios, consumption of rural non-poor harmed more following climate
change. Result indicates 5.7% and 9.1% reduction in rural non poor household consumption for CMC2 and PCM scenario respectively. These food expenditure reductions in rural non poor household would be reasoned to highest reduction in rural non poor domestic non-government institution incomes for the two scenarios. In addition huge magnification in agricultural output price following climate change could also another reason for consumption expenditure to be fall. These justification embraces for all households consumption drop. However, urban none poor household consumption was affected least relative to other household categories; it shows 3 and 4.8 percent consumption expenditure reduction for CGCM2 and PCM scenario respectively.

![Household consumption expenditure percentage change](image)

**Figure 3.2:** Household Consumption Expenditure %age Change  
*Source: CGE own computation*

Another impact on climate change persuaded households is shift in composition of consumption. For all household groups, the results revealed that there has been difference among households consumption trend. The move in consumption is mainly governed by the strength of income and substitution effects. However, it is very difficult to distinguish the mechanism of those effects. Instead the final results combinations of all the forces are observed.

In this study, price for agricultural commodities considerable increment has been observed. As a result, household substitute non-agricultural goods to agricultural. This, however, doesn’t fit in
all cases for Ethiopia especially in rural areas, where agricultural commodities endures basic necessities. Hence, consumption of agricultural commodities either increases or decreases by smaller percentage for low income households.

**Figure 3.3:** agricultural & nonagricultural GDP percentage change

*Source: CGE own computation*

### 3.2. Micro-Simulation Results

#### 3.2.1. Food Security Analysis

Entire household expenditure deflated by household size used for micro simulation analysis. The study made necessary adjustments on deflating household consumption expenditures of 2004/05 HICE survey using the CGE results for each climate simulation. After this impact of climate change simulation defines the bottom 40% as poor in terms of descending household consumption expenditure deflating by household size following EDRI modified SAM of Ethiopia. Therefore, food insecurity cutting line is 4321.07. As seen in the economy wide illustration, four household groups have discussed. Here, micro simulation modeled households into urban, rural besides national. Then consumption expenditure introduced as proxies for food insecurity using DASP estimates indices using FGT.

The following few paragraph illustrates FGT output before and after climate shock. Static effect of climate change at household level for the entire Ethiopia disaggregated as national rural and urban household group for two diverse simulations presented in three successive Tables. The FGT indices allow comparing three measures of food insecurity: head count ratio, food insecurity gap and squared food insecurity gap. The food insecurity head-count increases for all households in the first simulation, and those headed by rural heads incidence increases a lot. The
depth of insecurity and its severity increase as well in both simulations. Tallying with worse food insecurity indices for all households in simulation2 (PCM. This advocates that government spending increment discussed in CGE part may play major role in alleviating food insecurity.

**Food Insecurity Head Count Index (P₀)**

Here is detail discussion for all three measurement, Table 4.3 presents head count index results, which signifies proportion of food insecure households from total population, it comes with 9.5%, 9.6% and 9.3% of poor at the national, rural and urban households, respectively for the base line. Study shows food insecurity incidence rises for all household groups in all comprised scenarios. InCGCM2 scenarios rural, national and urban head counts incidences rises by 12%, 11.3% and 11%, respectively. PCM Scenarios about three household cluster increases the head count incidence, with significant increment for rural household. That is, rural food insecurity incidence increased by 13% for PCM involving relative hard case scenario. This might be due to the decline in share food item that goes to the households as a consequence of lower food production. An increase in agricultural output price combine with the fall in income reduces the consumption expenditure. It leads 12.3% of urban population under food insecurity line for PCM scenario. On this scenario the national average food insecurity incidence is 12.6%. Generally, result displayed below shows relatively major portion of rural households are food insecure in the base line and for the two included scenarios.

**Table 3.3: Effects of CGE Simulations on Food Insecurity head count index (P₀) (% changes**

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>CGCM2 Scenario</th>
<th>PCM Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>0.095</td>
<td>0.113</td>
<td>0.126</td>
</tr>
<tr>
<td>Rural</td>
<td>0.096</td>
<td>0.120</td>
<td>0.130</td>
</tr>
<tr>
<td>Urban</td>
<td>0.093</td>
<td>0.111</td>
<td>0.123</td>
</tr>
</tbody>
</table>

**Source:** Micro simulation result

**Food Insecurity Gap Index (P₁)**

The headcount index does not take account the depth of food insecurity among poor, index does not change if individuals below food insecurity line become secure. Measuring food insecurity gap could overcome shortfall of head count index. It shows gap amongst food insecure
individual, it indicates extent which individuals below cut point. Table below presents food insecurity gap as percentage of cut point. This index represents the mean aggregate consumption discrepancy across households relative to food insecurity line. Implies, it denotes average distance separating the poor from the cut line. Result ensures uniform change in the sense that, index increases fashionable to scenarios from the base and slightly bigger rise has distinguished in rural household than the rest two. As seen in table below climate change leads food insecurity gap widening for the national food insecure, rural food insecure and urban food insecure very nearly equal percentage change of 2.3% in CGCM2 simulation. Although PCM simulation food insecurity gap percentage is larger than CGCM2 scenario, it shows equivalent enlargement for three household groups. Result displays that, inequality is widening under all scenarios and it could more evident among rural poor. In PCM scenario nearly an equal weight of 2.6 percentage change has been registered, implies households’ consumption must rise by 2.6% to move out food security manifold.

**Table 3.4: Effects of simulations on food insecurity index (P1) (% changes)**

<table>
<thead>
<tr>
<th>Household</th>
<th>Base</th>
<th>CGCM2 Scenario</th>
<th>PCM Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>0.0190</td>
<td>0.0231</td>
<td>0.02624</td>
</tr>
<tr>
<td>Rural</td>
<td>0.0186</td>
<td>0.0230</td>
<td>0.02625</td>
</tr>
<tr>
<td>Urban</td>
<td>0.0188</td>
<td>0.02323</td>
<td>0.02622</td>
</tr>
</tbody>
</table>

*Source: Micro-simulation result*

This result confirms relatively equal percentage change food insecurity have been there. On the other hand, very insignificant differences among households have seen. National average accounts higher food insecure household gap with reference point. However, scenario shows higher gap for urban household under CGCM2 and it is rural household under PCM. In effect food insecurity gap increases for all household though it shows slight difference in between.

**Food Insecurity Severity Index (P2)**

The food insecurity squared gap index takes into account not only the insecurity gap but also inequalities among insecure. This would have variances in food security status along households.
Hence, this insecurity measure imposes higher weight on households that are found far below the poverty line. The output shows that severity increases for all scenarios and household group. Exciting severity index (P2) shows 0.89%, 0.86% and 0.83% extremely urban poorer, national and urban household respectively in PCM which is bit harder than CGCM2 situation. Insecurity hurt most urban poorer in either of the included scenarios. This is because the negative impact of climate change on income and price increment following that would distress portion of population who bought food item. Urban household food insecurity gap among insecure still increases because food production has been fall in all scenarios and relatively urban household are sensitive for price and income change than rural and national average.

**Table 3.5: Effects of simulations on poverty head count index (P2) (% changes)**

<table>
<thead>
<tr>
<th>Households</th>
<th>Base</th>
<th>CGCM2 Scenario</th>
<th>PCM Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>0.0061</td>
<td>0.0076</td>
<td>0.0086</td>
</tr>
<tr>
<td>Rural</td>
<td>0.0058</td>
<td>0.0073</td>
<td>0.0083</td>
</tr>
<tr>
<td>Urban</td>
<td>0.0064</td>
<td>0.0079</td>
<td>0.0089</td>
</tr>
</tbody>
</table>

*Source: Micro-simulation result*

Over all rate of decrease in household consumption expenditure under climate shock in CGCM2 scenario, remains lower for all household groups than under the PCM scenario, as simulation2 supposed higher productivity damage that comes with unaffordability of household consumption

### 4. CONCLUSION AND POLICY IMPLICATIONS

#### 4.1. Conclusion

Mounting food security remains central objective of any policy though climate change leads for potential food security problem. Linking CGE and Micro simulation gives more disaggregated macro environmental shock analysis. This article investigated wide-ranging impacts of climate
change which disturbs entire economy grounded on model scenario. Within this particular CGE model, simulation experiments on crop losses due to global climate change considered.

Result displays food security shortfall and macroeconomic reduction. It has displayed most key macroeconomic variables impacted negatively by climate change. Government consumption is exceptional variable which grown. Nevertheless, real GDP, private consumption, investment, absorption, import and exports have been declined both in CGCM2 and PCM simulation scenarios. These negative impacts of climate change have been observed for food security pillars. Household consumption expenditure proxies for food security access revealed decline trend for CGE model. These could be justifiable since the most common determinants of food access income falls and price rise for all scenarios.

Micro-simulation results shows rise in food insecurity incidence for both of the included scenarios in head count index. Relatively, majority of rural household are below food insecurity line than the rest included household group. The food insecurity gap accounts depth of food insecurity among insecure. Household consumption must rise by 2.6% to move out from food security problem.

Food insecurity is sever for urban food insecure household. That increases by 0.89 in the second scenario and rises by 0.79% for the first simulation scenarios. These indeed conforms urban household food insecurity were dip following climate change.

**Policy implications**

Policy makers have to make strong decisions about environmental policies that will have a far-reaching impact. It is important that there should be well informed policy maker about the possible effects of the implementation of various policy packages or sets of measures. The author recommends that more disaggregated micro level data needs to be established to model feedback effect of policy change using TD/BU micro-simulation.

Further scientific-economic research is recommended to develop combination of all the proxies for food security. That could be possible to construct an index and then apply principal component analysis in the micro-simulation model that could give more disaggregated result.
Government spending increment following climate change that might subsidize the food insecure household must be readjusting by investment based economy. Authors also recommend policy intervention that shrinks consumption expenditure inequality is needed. Finally, Author recommends macro micro simulation analysis is the best way for policy shock analysis than using them separately.

Therefore, there must be prudent policies and depth macroeconomic analysis for particular microeconomic deviation that could balance the government policy and global climate change problems.
REFERENCES


