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No. 1952| August 2014

Kiel Institute for the World Economy, Kiellinie 66, 24105 Kiel, Germany

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Who bears the costs of climate change? Evidence from Tunisia*

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Abstract

In order to estimate the economic costs of climate change for Tunisia, this paper uses a combination of biophysical and economic models. In addition, the paper draws on the literature to complement the quantitative analysis with policy recommendations on how to adapt to the changing climate. The results bear out the expectation that climate change has a negative but weak overall effect on the Tunisian economy. Decomposing the global and local effects shows that global climate change may benefit the agricultural sector since higher world market prices for agricultural commodities are likely to stimulate export expansion and import substitution. Locally felt climate change, however, is likely to hurt the agricultural sector as lower yields reduce factor productivities lead to lower incomes and higher food prices. The combined local and global effects are projected to be mostly negative and the costs will have to be carried mainly by urban and richer households. From a policy perspective, the results suggest that Tunisia should try to maximize the benefits from rising global agricultural prices and to minimize (or reverse) declining crop yields at home.

JEL: O5, O13, D13, C68
Keywords: climate change, agricultural growth, distribution, general equilibrium analysis, Tunisia, Middle East and North Africa

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*This study is part of the project "Economic impacts of climate change in Syria, Tunisia, and Yemen", financed by the World Bank. We are grateful for the ideas and contributions provided by the Ministry of Environment of Tunisia and for Mohamed Chemingui (UN-ESCWA) to provide the social accounting matrix for Tunisia. We thank Gerald Nelson (IFPRI) and Dorte Verner, Ana Elisa Bucher, Christophe Crepin, Svetlana Edmeades and Hoonae Kim (all World Bank) for their excellent support and comments. We also thank an anonymous referee for helpful comments and suggestions on earlier drafts of this paper.

1. Introduction

Climate change affects countries through a wide variety of channels and sectors, but the most obviously climate sensitive sector is agriculture (Mendelsohn and Dinar 2009). A recent World Bank report on climate change and development in Tunisia confirms that the country is and will continue to be impacted mainly through climate change's adverse effects on crop yields and livestock productivities resulting from increasing temperatures, reduced and variable precipitation, and salt water intrusion from rising sea levels (Verner 2013). These negative impacts on agriculture in turn have been shown to negatively affect livelihoods and human well-being, especially among the most vulnerable people in Tunisia (Kronik and Clément 2013).

Thus, the present study focuses primarily on Tunisia's agricultural sector. By doing so it distinguishes itself from previous studies and contributes to the climate change literature in two main ways. First, it does not only take the climate change induced local impacts of changing yields into account, but also the global impacts from changing yields in the rest of the world. The latter will affect agricultural world market prices for net importing and exporting countries with welfare implications at the household and macroeconomic level. Second, it takes into account the indirect effects that these local and global effects will have on non-agricultural sectors, especially the food-processing sector. When prices and yields of agricultural production change due to climate change, a series of cascading effects can be expected to take place. For example, if agricultural product prices rise, farmers will benefit by receiving higher incomes and thus improve their welfare. Yet, food processing industries are likely to suffer as they will face higher input prices. Consumers' real income will decline as they will have to spend a larger share of their budgets on food items. The changing prices and yields will also affect the relative profitability of the agricultural sector compared to other sectors, and depending on the adjustment flexibility of commodity and factor markets, autonomous adjustments to climate change may lead to very different welfare outcomes. Thus, the question of who bears the costs of climate change depends on a number of country specific characteristics.

To assess the socioeconomic costs for the case of Tunisia, this paper uses a recursive-dynamic computable general equilibrium (DCGE) model to quantify the climate change effects on agriculture, other economic sectors and household welfare in a global and local climate context. The general equilibrium framework allows for capturing explicitly all the major linkages between agriculture, the rest of the economy and households, which are the driving forces behind intersectoral allocation effects. The results will show that including interindustry linkages, exchange rate revaluations and factor price changes are critical for determining the final resource pull effects of climate change. Leaving any one of these effects out can lead to misleading conclusions on the impacts of climate change and inadequate policy recommendations with regard to mitigation and adaptation policies.

We follow an approach developed by Breisinger et al., which links results from the Decision Support System for Agrotechnology Transfer (DSSAT) and results from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) with country-specific general equilibrium models (Breisinger at al. 2013; Wiebelt et al. 2013). Thus, we focus the description of the modeling suite on the country-specific features and results for Tunisia and do not describe the DSSAT and IMPACT calculations of yield changes and world market price changes in detail. More specifically, the remainder of this paper is organized as follows. Section 2 introduces the DCGE model used. The discussion is organized in terms of modules, or model components. In section 3, the most important structural characteristics of the Tunisian economy are discussed first. Subsequently, general equilibrium analysis is applied to identify factors which account for structural and distributional changes to take place. Finally, in section 4, major results are summarized.

2. A Dynamic General Equilibrium Model of Tunisia

Because the focus is on agriculture, the multi-sectoral DCGE model has a special emphasis on agricultural activities and their linkages to other production sectors. In total, the model differentiates between twenty-one sectors - eleven agricultural sectors, nine industrial sectors and one service sector. A sectoral distinction is made within agriculture between import-substituting sectors (*wheat*, *other cereals*, *legumes*, *forage crops*, *vegetables*, and *other agriculture*), export-oriented sectors (fruits), and non-traded sectors (*olives*). The other agricultural sectors are *livestock*, *forestry*, and *fishing*. Several food-processing sectors *(meat*, *milk & milk products*, *flour milling & its products*, *olive oil*, *canned food products*, *sugar and its products*, *other food products*, *beverages*) are separated from *other industry* to capture their strong direct backward linkages to agricultural production. Finally, there is one *services* sector, which includes both private and public services. The model is based on a Social Accounting Matrix (SAM) for 2001 (Chemingui 2001), the base period of the study, that integrates national income, input-output, flow-of funds, balance-of-payments current accounts and household survey data into a comprehensive and consistent data set. The aggregated SAM and its components are presented in Appendix Tables A1 to A4. It is assumed to represent the initial equilibrium position of the Tunisian economy and provides numerical values to several parameters of the analytical model.

The analytical model belongs to a class of dynamic planning models developed by Dervis et al. (1982). The model used here to investigate the impacts of climate change impacts over 30 years follows a standard specification as documented in Diao and Thurlow (2012). One distinguishing characteristic of this type of model is its rooting in microeconomic theory: Producers minimize costs subject to certain technology constraints and prices, while consumers maximize utility subject to a budget constraint. Another trait is the detailed attention devoted to income and expenditure flows, including the extended functional distribution and the distribution of functional income to the owners of factors, i.e. different households, which allows for impact analysis; SAMs rather than input-output tables provide the structural backbone of these models.

While the equations of the model are summarized in Table 1, the following description focuses on the Tunisia-specific features and those parts of the Diao-Thurlow model that are most relevant for the subject of this paper, namely the impacts of changing world market prices and agricultural yields:

Table 1 – Equations of the Tunisia dynamic CGE model

I. Prices

(1) $PM_i = pwm_i(1 + tm_i)\bar{R}$
(2) $PE_i = pwe_i/(1 + te_i)\bar{R}$
(3) $PQ_i = f(PM_i, PD_i)$
(4) $PX_i = g(PE_i, PD_i)$
(5) $PV_i = PX_i - \sum_j a_{ij}\, PQ_i$
(6) $CPI = \sum_i \Omega_i\, PQ_i$
(7) $DPI = \sum_i \Psi_i\, PD_i$

II. Production, employment, and wage rates

(8) $QX_i = f(\bar{K}_i, L_{fi})$
(9) $W_f = PV_i(\delta QX_i/\delta L_{fi})$ f= labor, land
(10) $LD_f = \sum_i, L_{fi}$
(11) $LD_f - \overline{LS_f}$ = 0

III. Foreign trade

(12) $E_i = h(PE_i/PD_i)$
(13) $M_i = m(PM_i/PD_i)$
(14) $\sum_i pwm_i\, M_i - \sum_i pwe_i\, E_i - \bar{F} = 0$

IV. Income and flow of funds; endogenous variables calculated

(15) Y_h: income of households
(16) Y_G: government revenues
(17) S: total investment

V. Sectoral demand and product markets

(18) $I_i = \phi_i S$
(19) $Z_i = \sum_j b_{ij}\, I_j$
(20) $V_i = \sum_j a_{ij}\, QX_j$
(21) $C_i = \sum_h q_{ih}\,(1 - s_h)Y_h/PQ_i$ j=g, G
(22) $D_i = d_i(V_i + C_i + Z_i)$
(23) $d_i = 1/f_i(M_i/D_i,1)$
(24) $XD_i = D_i + E_i$
(25) $XD_i - QX_i$ = 0

VI. Dynamics

(26) $LS_{ft} = LS_{ft-1}(1 + \varphi_f)$
(27) $LS_{ft} = LS_{ft-1}(1 + \eta) + \sum_i \frac{PQ_{ft-1} I_{ft-1}}{\kappa} \varphi_f$
(28) $\alpha_{it} = \alpha_{it-1}(1 + \gamma_i)$

Subscripts

f	factor groups (labor, capital, and land)
h	household groups
i,j	sectors
t	time periods

Exogenous variables

$\bar{R}$	nominal exchange rate
$\bar{F}$	foreign savings balance
pwm	world import prices
pwe	world export prices

Exogenous parameters

α	factor productivity
Ω	consumer price index weights
Ψ	producer price index weights
ϕ	investment allocation shares
b	capital composition coefficients
a	input-output coefficients
q	expenditure shares
s	savings rates
tm	tariff rate
te	export subsidy rate

Endogenous variables

PM	import price
PE	export price
PQ	commodity price
PX	output price
PV	unit value added
CPI	consumer price index
DPI	producer price index
QX	output quantity
M	import quantity
E	export quantity
L	labor and land demand quantity
W	average factor return
L	factor demand quantity
Y	household income
YG	government revenue
S	total investment
I	investment by sector of destination
Z	investment by sector or origin
V	intermediate demand
C	consumption demand
D	domestic demand
d	domestic demand ratio

φ	land and labor supply growth rate	XD	total demand for domestic output
η	capital depreciation rate		
γ	Hicks neutral rate of technical change	f(−)	CES cost function
κ	base price per unit of capital stock	g(−)	CET revenue function

Source: Authors' compilation based on Diao and Thurlow (2012).

- Domestic consumers have constant-elasticity-of-substitution (CES) utility functions over imports and domestically produced goods. Assuming that they seek to minimize the costs for acquiring a given amount of an Armington composite good (Armington 1969), the demand for domestically produced goods and imperfect substitutes that are imported become derived demands. This leads to diverging import and domestic prices, one of the key drivers of the results of this paper.
- On the export side, producers are assumed to maximize revenues from selling to domestic and foreign markets subject to a constant-elasticity-of-transformation (CET) function, which defines the ease with which goods and services may be traded on the domestic and foreign markets.
- Capital is assumed to be fixed and sector-specific in the short term, i.e. within individual periods, but new capital from past investment is allocated to sectors according to profit rate differentials under a "putty-clay" specification. There are three labor groups: family labor and agricultural labor, which is only used in agricultural sectors, and non-agricultural labor, which is employed exclusively in industrial and services sectors. There are also three types of land, which are exclusively used in crops production: rainfed land, irrigated land and perennial land. Perennial land is exclusively used in fruits and olives production, while rainfed land is not used in vegetables production. All labor and land types are mobile across sectors. This means that workers in each group and land owners receive the same wage and income from land in every sector. Moreover, mobility of land within periods implies that farms and plantations are multi-product firms, which reallocate land across agricultural goods in an attempt to equalize real producer rentals.
- The level of foreign savings is assumed to be exogenous and fixed at the initial level. The level of investment is determined by the level of savings in the economy, the latter being the sum of private, public and foreign savings.
- The exchange rate is held constant as the model focusses entirely on the "real" economy. This means that all variables related to the real economy depend on relative prices and a numeraire determines the absolute price levels. We chose a constant exchange rate as the numeraire due to our interest in the incidence of climate change impacts on household welfare rather than the redistribution effects, which result from exchange rate revaluations.

The model's variables and parameters are calibrated to observed data from the national SAM that captures the initial equilibrium structure of the Tunisian economy in 2001. Parameters are then adjusted over time to reflect demographic and economic changes and the model is re-solved for a series of new equilibriums for the thirty-year period 2001-30. Between periods the model is updated to reflect exogenous rates of land and labor expansion. The rate of capital accumulation is determined endogenously, with the level of investment from the previous period converted into new capital stock using fixed prices. The new capital is added to previous capital stocks after applying a fixed long-term rate of depreciation. Finally, the model captures total factor productivity through the production function's shift parameter, with the rate of technical change determined exogenously, in our case inter alia by yield changes from DSSAT.

3. Economic Impacts of Climate Change in Tunisia

Climate change scenarios

The model outlined above is the basis for the analysis of climate change impacts described in this section. The analysis consists of examining the impact of increasing world market prices and yield changes, while we will focus the description of results mainly on sectoral value added and household welfare over the period 2001 to 2030. The impact is measured by comparing changes that result from two climate change scenarios (MIROC and CSIRO) with a perfect mitigation (NoCC) scenario.[1] Thus, we have a total of three sets of scenarios (Table 2).

Table 2—Overview of climate change scenarios

Scenario	Change in model	Input	World market price changes, 2001-2030	Yield changes (%age point change)
Global impacts of climate change				
Scenario 1	Perfect mitigation	IMPACT: NoCC	9-45 percent see Figure 1	n.a
Scenario 1A	Climate change	IMPACT: MIR_B1	21-36 percent	n.a.
Scenario 1B	Climate change	IMPACT: CSI_B1	8-27 percent	n.a.
Local impacts of climate change				
Scenario 2A	Crop yield changes	DSSAT: MIR_B1	n.a.	Wheat, legumes, forage crops, other agriculture: -0.18 other grains, olives, fruits: -0.57
Scenario 2B	Crop yield changes	DSSAT: CSI_B1	n.a.	Wheat, legumes, forage crops, other agriculture: -0.11 other grains, olives, fruits: -0.17
Joint impacts of climate change				
Scenario 3A	1A and 2A	IMPACT and DSSAT: MIR_B1	See Scenario 1A	See scenario 2A
Scenario 3B	1B and 2B	IMPACT and DSSAT: CSI_B1	See Scenario 1B	See Scenario 2B

Source: Authors' compilation.
Note: n.a. not applicable.

The first set captures the global impacts of climate change, while the second set assesses the local impacts of climate change. The third set combines the two to assess the joint effects. Within the first set

[1] Actually we investigated four climate change scenarios based on the global food price projections shown in Figure 1 below but report only results for two scenarios in this article.

of scenarios, we design three variants: scenario 1 changes the world market prices for wheat, other cereals, olives and olive oil, fruits, and vegetables consistent with IFPRI's IMPACT model results under perfect mitigation of climate change.[2] Under these conditions, world market prices for wheat, fruits and olive oil would increase by about 45 percent from 2001 to 2030, those for other grains by 41 percent, and prices for vegetables would rise by only 9 percent (Table 2). The results of this scenario provide a benchmark against which the other scenarios' results are assessed. Scenario 1A explores climate change-related price effects under MIROC A1B, with the assumption that no climate change impacts are felt locally in Tunisia. Scenario 1B is a scenario to test the sensitivity of results to alternative price projections under CSIRO A1B. Scenario 2 imposes the yield changes from the DSSAT model on a crop by crop level.[3] These include changes in yields for wheat, other grains (barley) and vegetables (potatoes) directly taken from the DSSAT model. In the absence of more specific information and consistent with the literature, we assume that yields of other agricultural crops such as fruits and olives are also negatively affected. Results for scenarios 1A−3B are reported as a change from the perfect mitigation scenario to isolate the climate change effects.

Sector and household characteristics

Tables 3 and 4 provide a summary of the most important structural features and crucial elasticities, which together determine the results of the simulations. Columns (1) and (2) of Table 3 describe the structure of production across sectors. The structure of gross output reveals the typical composition of production found in a semi-industrialized country, where agriculture still provides a large share of gross domestic output. Agriculture is an important part of the Tunisian economy, accounting for 12 to 16 percent of GDP, depending on the year. Agriculture and related food processing make up 27 percent of gross domestic production. The importance of intermediate inputs for each sector is indicated by the per-unit value added in column (2). High value-added ratios in the agricultural sectors indicate small backward linkages. Conversely, the food processing sectors exhibit the lowest value-added ratios suggesting strong backward linkages, particularly to agriculture (see Table A4). This implies that any rise in agricultural prices as a result of global and local climate change increases intermediate input costs in these sectors thereby hampering international and national competiveness of the food-processing sectors.

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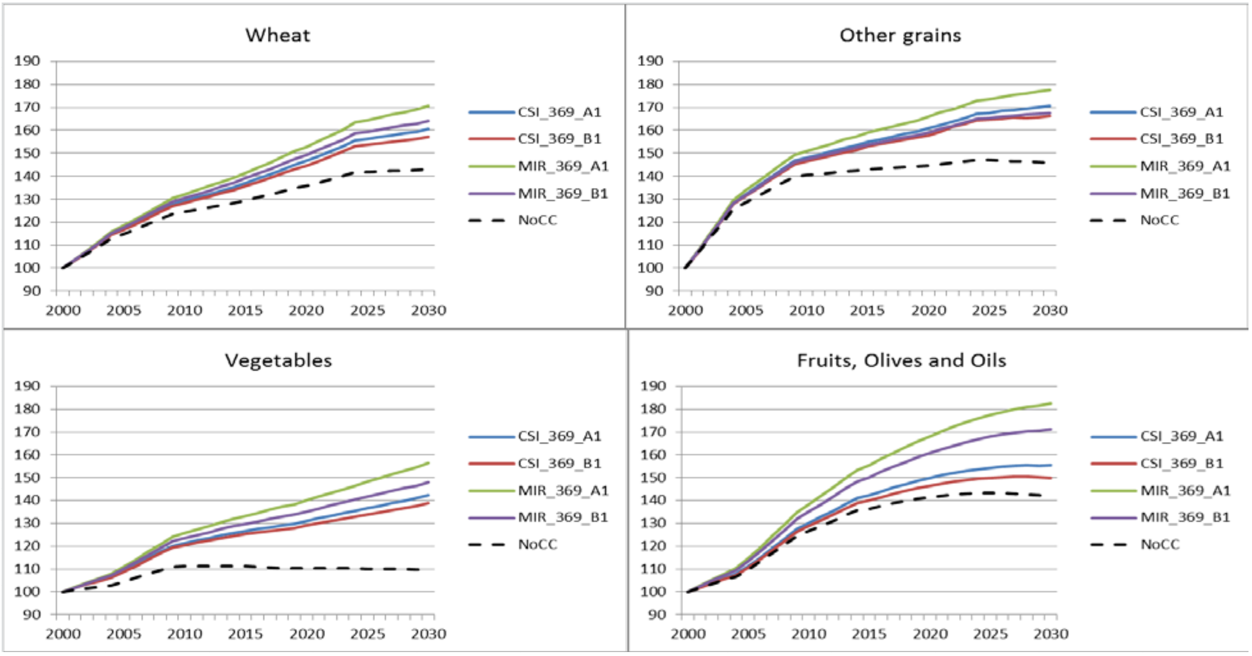
[2] In a nutshell, IMPACT projects world market price changes for several crop and livestock commodities, which result from changes in global supply and demand that could be traced back, inter alia, to higher temperature and lower precipitation as a result of climate change. For future climate change, we use the Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC). More specifically, our price projections and yield changes are based on the Model for Interdisciplinary Research on Climate (MIROC; MIR_369_A1 and MIR_369_B1) and Commonwealth Scientific and Industrial Research Organisation (CSIRO; CSI_369_A1 and CSI_369_B1). More technical details can be found in Nelson et al. (2009) and Rosegrant et al. (2008).

[3] The DSSAT crop-modeling suite assesses the potential effects of climate change on crop yields at a very local geographical level. More technical detail is given by (Jones et al. 2003).

Figure 1 – Global food price scenarios, price indices, 2000=100 (2000-2030)



Source: IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).
Note: NoCC stands for no climate change (or perfect mitigation).

Columns (3) to (7) provide information about each sector's use of labor, capital and land. Family labor, agricultural labor and land are not used in industrial and services sectors, while non-agricultural labor is not used in agriculture. Thus, there is no competition on the national level for labor between agriculture and non-agriculture. But these sectors do compete for capital. Agriculture and services are labor-intensive, and food processing as a whole is the most capital intensive, with other industries are somewhere in between.

The next three columns provide information about each sector's trade orientation. Column (8) indicates that 5 out of the 13 tradables-producing sectors export more than 10 percent of their output, with olive oil, canned food products and other industrial goods being the most export-oriented sectors in the economy. Olives are not directly exported, yet 36 percent of olive oil is exported. Generally, export ratios are low, and reflect a country that has followed an inward-looking development strategy. On the import side, the typical picture emerges when one considers both the share of imports in domestic absorption (which indicates the degree of "import orientation") and the share of imported intermediate inputs in total intermediate inputs (which indicates the degree of "import dependence"). Food crop sectors and other industry are the most import-oriented sectors and most agricultural and food processing sub-sectors are highly import-dependent. Olives and meat are the only non-traded sectors, yet 23 percent of total intermediates used in olives production are imported.

The last 2 columns show the elasticities that determine the sectoral results of climate change simulations by the model. Because production technology for sectoral value added is modelled by two-level CES production functions, the shares observed in the benchmark equilibrium data set together with the factor substitution elasticities provide us with a set of partial labor demand and output elasticities. Given this technology specification and identical factor substitution elasticities of 2.0 for any pair of primary factors in all production sectors, price elasticities are highest in labor-intensive sectors with a large share of labor value added in total value added (see column (11)). Since (i) the demand for intermediate goods is not price sensitive, (ii) investment demand is specified by fixed capital composition shares, and (iii) government consumption demand is determined exogenously, the partial equilibrium price elasticity of demand for the composite good in each sector is almost completely determined by the price elasticity of consumer demand. Consumer demand is derived from a Linear Expenditure System (LES) with exogenously estimated income elasticities of demand. The resulting partial own-price elasticities are shown in column (12). The foreign trade elasticities used in the simulations capture the extent of product differentiation due to differences in quality and degree of product homogeneity. We assume identical import substitution elasticities of 3.0 and identical export transformation elasticities of 2.0 for all goods to reflect the fact that import orientation in Tunisia is higher than export orientation. Together with the trade shares shown in columns (8) and (9), these trade elasticities determine the sectors' trade adjustment flexibility to terms-of-trade-shocks. With identical trade elasticities across sectors, the extent of export expansion and import-substitution in individual sectors is determined by trade shares.

Table 3 – Structure of the Tunisian economy in the base year solution

			Factor shares					Trade shares			Elasticities	
	Output	VAshr	agrlab	nonalab	famlab	capital	land	EXP-OUTshr	IMP-DEMshr	IMPV-DEMVshr	ε_S	η_D
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Wheat	751.8	71.3	17.5		30.7	26.3	25.6	3.7	47.5	39.7	1.9	0.2
Other cereals	148.3	63.7	19.7		12.6	34.3	33.4		87.8	31.0	1.0	0.2
Legumes	159.6	79.3	10.4		33.8	33.3	22.4		8.3	29.3	1.6	0.2
Forage crops	30.1	64.9	16.7		28.2	15.6	39.5	3.6	67.7	34.8	1.6	
Olives	1,938.6	89.3	40.0		32.2	16.4	11.4			23.4	5.2	
Other fruits	2,043.5	71.0	8.9		32.7	27.5	30.9	13.3	1.5	10.1	1.4	1.1
Vegetables	1,543.3	68.9	13.0		32.4	31.4	23.1		2.5	15.7	1.7	0.5
Other agriculture	29.6	72.0	10.6		45.7	23.6	20.1	16.9	32.8	20.7	2.6	0.5
Livestock	3,238.1	63.6	13.9		28.8	57.3			1.5	24.4	1.5	0.5
Forestry	150.7	88.3	16.0		36.8	47.2			7.4	12.9	2.2	0.2
Fishing	799.0	63.2	11.5			88.5		4.9	5.6	11.3	0.3	0.5
Meat	2,637.5	5.0		34.5		65.5				6.7	1.1	0.5
Milk and its products	1,078.7	25.8		32.8		67.2			9.5	21.1	1.0	0.5
Flour milling & its products	2,036.8	14.8		67.1		32.9		3.9	2.7	27.0	4.1	0.5
Oils	5,290.9	17.0		10.9		89.1		36.2	35.7	16.7	0.2	0.5
Canned food products	621.5	16.8		21.8		78.2		33.6	10.7	14.3	0.6	0.5
Sugar and its products	584.5	28.1		20.4		79.6		2.8	32.1	23.3	0.5	0.5
Other food products	2,284.3	12.1		45.0		55.0		5.8	12.1	32.3	1.6	0.5
Beverages	1,471.6	32.8		26.6		73.4		4.8	9.2	21.5	0.7	0.5
Other man. and non-man. industries	78,676.3	30.5		42.2		57.8		35.3	46.2	36.9	1.5	1.2
Services	57,020.4	81.0		50.3		49.7		9.9	5.5	32.9	2.0	1.3
Agriculture	10,832.6	64.9	14.4		28.6	42.1	14.9	3.5	16.4			
Food processing	16,005.8	14.5		36.8		63.2		7.7	7.0			
Other industry	78,676.3	29.3		42.2		57.8		35.3	46.2			
Services	57,020.4	81.6		50.3		49.7		9.9	5.5			
Sum/average	162,535.1	48.6	1.9	40.7	3.8	51.6		21.2	28.4			

Source: Tunisia DCGE model.

Note: Sectors directly affected by yield changes

Note: Sectors directly affected by world market price changes

Household welfare is affected by climate change on the income earnings side via changes in factor remuneration and on the expenditure side via changes in consumer prices. Table 4 summarizes income and expenditure patterns for rural farm and non-farm households as well as for urban households.

Table 4 - Structure of household income and expenditures in the base year solution

	Household income (percentage share of total)				Total (millions TND)	Household expenditure (percentage share of total)			
	Labor	Capital	Land	Remittances		Agriculture	Non-agriculture	Tax	Savings
NAT	49.4	33.5	2.1	15.0	23,384.8	9.5	74.9	4.8	10.8
URBTOT	45.4	37.0	2.4	15.2	16,647.6	8.4	75.9	5.2	10.5
RURF	74.3	12.5	0.8	12.4	2,169.2	13.7	70.0	4.0	12.3
RURNF	52.0	30.5	1.9	15.7	4,568.0	11.6	73.4	3.7	11.3
RURTOT	59.2	24.7	1.6	14.6	6,737.2	12.3	72.3	3.8	11.7

Source: Tunisia DCGE model.

Farm households, which make up 30 percent of total population (according to our classification), earn about 9 percent of total household income, while the population and income shares are 30 percent and 19 percent for rural non-farm households and 40 percent and 70 percent for urban households. The sources of household incomes are strongly related to factor and human capital endowments. Farm households receive most of their income from the provision of labor (about 75 percent), both as family (28 percent) and agricultural labor (17 percent), but also from non-agricultural labor (30 percent) used in the industrial and services sector, while urban and rural non-farm households rely exclusively on non-agricultural labor and capital as income source. On the expenditure side, the major difference between households is that rural households spend a larger share of their earned income on agricultural goods than urban households, and this share is larger for farm households than for rural non-farm households.

Climate change, agricultural adjustment, and household welfare

We can now use our fully specified numerical model to examine the effects of climate change. Because we are primarily interested in the impact on agriculture and household welfare, emphasis will be given to a discussion on how and why individual agricultural sectors are affected differently, and how this affects functional and household income distribution. We will first discuss the direct impacts of global climate change via increasing world market prices, then the direct impacts of local climate change via reduced agricultural yields, and finally the indirect impacts.

i. Direct impacts of global climate change via increasing world market prices

Rising world market prices increase the difference between the domestic price of imports and domestically produced substitutes. This will induce domestic users to change their composition of the composite good, thereby increasing demand on the domestically produced substitute and causing upward pressure on the domestic price of agricultural goods. The resulting change in domestic prices depends on the cross-price elasticity of demand for the domestic good, which itself depends on the price elasticity of demand for the composite good and the elasticity of substitution in use between the domestically produced and foreign goods. Increasing world market prices as a result of global climate change will, ceteris paribus, lead to a large increase in demand for the domestically produced substitutes

- if it is easy to substitute them for imports (as indicated by high substitution elasticities);
- if the sectoral import share is large (implying relatively large demand increases for the domestic product in order to compensate for relatively small reductions in imports);
- if the demand for the composite good is relatively inelastic with respect to the composite price (reflecting the importance of these goods as intermediates in domestic production).

Moreover, the extent of the increase in domestic agricultural prices also depends on production characteristics as indicated by the elasticity of domestic supply. Low supply elasticities imply large increases of the domestic price in the case of small shifts of domestic demand. Finally, export supply is also important when there is a change in agricultural world market prices, especially when the export share is large. The higher the elasticity of transformation between supply to the foreign and the domestic market, the larger will be the domestic price change resulting from increasing world market prices. The increase in the world market price will lead to a rise in exports as domestic output is withdrawn from domestic use towards foreign markets. The easier this transformation process, the larger will be the price increase.

Returning to Table 3, from the demand characteristics of agricultural markets one would expect large price increases for wheat, other cereals, olives and olive oil in response to the world market price changes shown in Figure 1. These sectors exhibit high import intensities and low composite demand elasticities. Together with high substitution elasticities of 3.0, these characteristics imply large shifts of the domestic demand towards domestically produced goods. By contrast, low import intensities in the fruits and vegetables sectors imply much lower shifts in domestic demand. Finally, high export intensities and low supply elasticities together with high transformation elasticities of 2.0 in olive oil supply (and other sectors' supply) mean that there is additional upward pressure on the domestic price of olive oil from the supply side as producers shift their supply from the domestic to the foreign market.

ii. Direct impacts of local climate change via changing yields

Lower yields as a result of local climate change (lower precipitation and higher temperatures in Tunisia) reduce domestic agricultural outputs and cause upward pressure on domestic prices, which induces producers and consumers to shift their production and consumption towards foreign markets, thereby reversing the impacts of global climate change described above. As in the case of world market price changes, the extent of the restructuring of supply and demand depends on the cross-price elasticities. However, as indicated in Table 3, while global climate change affects only a small proportion of total output (3.7 percent of wheat and 13.3 percent of fruits), local climate change affects total output of all types of crops. Although yield reductions through local climate change are projected to be much lower for wheat, legumes, forage crops, and other agriculture than for other grains, olives and fruits, and are generally lower in the CSIRO than in the MIROC climate change scenarios (Table 2), local climate change has a significant negative direct impact on agricultural output and factor income earning possibilities in the agricultural sector, as will be shown below.

These are the direct effects determining the initial domestic output price response in the affected agricultural markets. In order to estimate the final resource shifts and the impact of climate change in Tunisia, we also take into account the indirect or economy-wide effects:

iii. Indirect impacts of global and local global climate change

Effects on intermediate input costs: Other things being equal, those sectors with strong backward linkages to those sectors, which are most affected by global and local climate change, are penalized the most, whereas strong forward linkages stimulate production. As can be seen from the per-unit value added shares (Table 3, column 2), secondary inputs are not very important in any of the agricultural sectors. Moreover, input coefficients (Table A4) indicate that inter-industry linkages are weak among Tunisia's agricultural sectors. However, forward linkages to the olive oil sector are strong for olives – the only non-traded agricultural sector – as indicated by the share of intermediate demand in gross domestic production in connection with the input coefficient. This means that any expansion of olive oil production would stimulate the production of olives.

Real exchange rate effects: An increase in world market prices will induce a shift of demand towards domestically produced tradables and non-tradables thereby leading to a balance-of-trade surplus. In addition, higher world market prices provide an incentive to producers to shift their supply from domestic to export markets thereby increasing the trade surplus. The trade surplus is somewhat reduced by higher domestic prices which result from lower agricultural yields and the following restructuring of supply and demand towards domestic markets and import markets, respectively. Overall, the price of tradables must fall relative to the price of non-tradables to eliminate the balance-of-trade surplus, i.e. an appreciation of the real exchange rate is required. In addition, sensitivity analysis shows that the real exchange rate response increases with decreasing trade elasticities. This is because the rise in domestic prices needed to reduce exports and to increase imports in order to eliminate the trade surplus is greater, the lower the export transformation and import substitution elasticities. Consequently, in the global climate change scenarios, the real exchange rate appreciation is 50 and 30 percent higher in the MIROC and CSIRO scenarios than in the perfect mitigation scenario by 2030.

Factor income effect: There is an effect on factor remuneration that will have a differential impact across sectors, depending on the difference in relative factor intensities (Table 5). However, as shown in Table 3, labor markets are segmented with non-agricultural workers being exclusively employed in industry and services, while land and family and agricultural workers are only used in agriculture. Thus, direct spillovers via labor and land markets of global and local climate change are restricted to agricultural sub-sectors. Moreover, capital is assumed to be sector-specific in the short run but mobile across all sectors in the long run (putty-clay assumption). This means that over time capital stocks are reallocated both between agricultural sub-sectors and between agriculture and industry and services. While decreasing agricultural yields due to local climate change lower the remuneration of all factors under both climate change scenarios, higher world market prices for agricultural goods due to global climate change increase the average agricultural wage and land rental rate, with family workers' and agricultural workers' wage rates increasing by 0.35 to 1.2 percentage points more than under a perfect mitigation scenario (Table 5). The average land rental rate also increases with the increase being strongest for perennial land that is exclusively used in olives and fruits production. By contrast, the profit rate and the wage rate for non-agricultural workers both decrease in both climate change scenarios due to both global and local climate change. This is because changes in world market prices and in yields have a strong impact on economic structure. In general, higher agricultural prices (lower agricultural yields) increase (decrease) domestic wages, profits and land rentals. Affected sectors and non-tradables producing sectors benefit (loose) from global (local) climate change. Since these sectors are very intensive in the use of agricultural labor and perennial land, the wage rate for agricultural workers and the land rental for perennial land rises (falls) the most. Capital, which is intensively used in industry is attracted into agriculture, thereby lowering both the average profit rate (because capital has become relatively less scarce) and the wage rate of non-agricultural workers (because limited mobility excludes urban-rural migration).

Table 5 - Average annual %age point change in factor remuneration compared to perfect mitigation scenario (2000-2030)

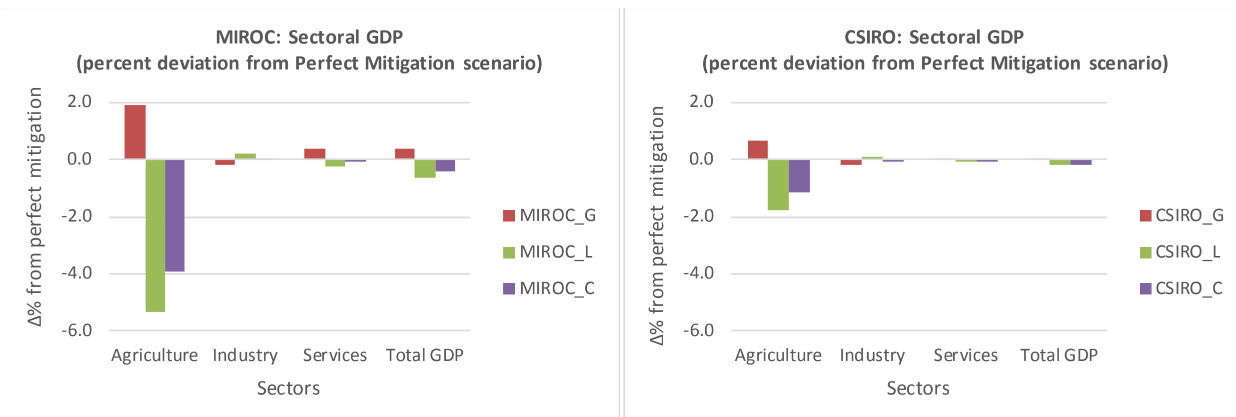
		Global climate change		Local climate change		Combined climate change	
	Perfect mitigation	MIROC	CSIRO	MIROC	CSIRO	MIROC	CSIRO
Agricultural labor	2.35	1.20	0.51	-0.40	-0.13	0.65	0.37
Non-agricultural labor	1.78	-0.10	-0.06	-0.04	-0.01	-0.14	-0.07
Family labor	1.89	0.84	0.35	-0.28	-0.09	0.43	0.24
Capital	1.19	-0.06	-0.03	-0.04	-0.01	-0.11	-0.04
Dry land	2.28	0.24	0.25	-0.21	-0.09	0.04	0.16
Irrigated land	2.2	0.38	0.22	-0.09	-0.04	0.29	0.19
Perennial land	3.52	0.93	0.35	-0.34	-0.11	0.46	0.22

Source: Tunisia DCGE model.

There are income effects associated with changes in the foreign terms of trade in the case of global climate change and with yield changes in the case of local climate change. Global food price changes as shown in Figure 1 rise domestic absorption by between 1 and 5 percent until year 2030 in the CSIRO and MIROC scenarios, respectively, while lower yields lead to a lower fall in absorption of between 0.7 and 2.3 percent.

These direct and indirect effects of world market price changes and yield changes are reflected in Figures 2 to 5, which report on changes of sectoral GDP, agricultural sub-sectoral GDP and household welfare of global and local climate change under the two climate change scenarios compared to a benchmark scenario of perfect mitigation. These results take into account autonomous adjustments by Tunisian producers and consumers and therefore provide information on the (final) impact of climate change at the sectoral and household level.[4] In general, the results bear out the expectation that climate change (i) has a strong negative effect on agriculture, (ii) has a negative but weak overall effect on the Tunisian economy, and (iii) that this effect is much weaker for the CSIRO scenario than for the MIROC scenario.[5] This is so, because the impact of local climate change via lower agricultural yields dominates the impact of global climate change via higher world market prices for agricultural goods, but higher world market prices and lower yields affect only 1.4 percent and 4 percent of total Tunisian output, respectively (Table 3). This is best illustrated at the macro level (Figure 2). The combined impact of climate change leads to a reduction of GDP of 0.2 to 0.4 percent compared to the perfect mitigation scenario, which can be traced back almost exclusively to agricultural gains and losses ranging from 0.7 percent to 1.9 percent and -1.2 percent to -5.3 percent in the CSIRO and MIROC scenarios, respectively. These results correspond with the findings reached for other countries in Latin America and the MENA region (Andersen et al. forthcoming; Breisinger at al. 2013; Wiebelt et al. 2013).

Figure 2 - Impacts of climate change on sectoral and total GDP, 2000-2030



Source: Authors' elaboration based on DCGE simulation results.

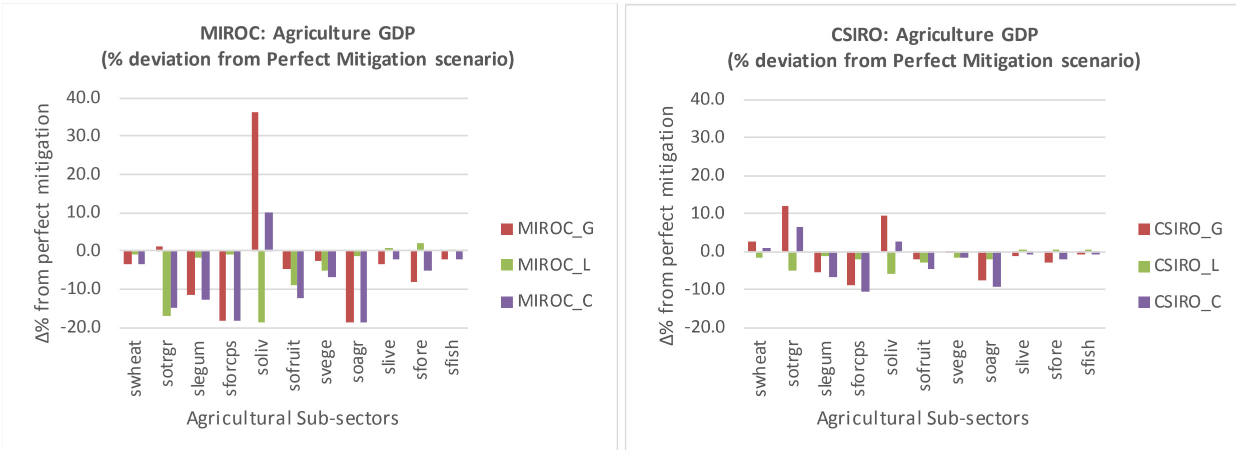
A more differentiated picture emerges when we turn to an examination of the resource pulls at the agricultural sub-sector level (Figure 3). As can be seen, olives production is the only agricultural sub-sector that is projected to benefit from climate change and the benefits are solely attributable to higher world market prices, i.e. the impacts of global climate change, which overcompensate the losses resulting from yield reductions, i.e. local climate change. Yet, olives is a pure non-tradable (see Table 3) and therefore not directly affected by world market price changes. Moreover, according to the Tunisian SAM olives are not directly consumed by private households. Rather all output from the olives

[4] The model also provides results on the macroeconomic impacts of climate change on, e.g. investment versus consumption, private versus public consumption. However, the composition of real national accounts demand aggregates is hardly affected by climate change and thus not reported here.

[5] The effect is higher than in the MIROC scenario if we base our DCGE analysis on the price projections of the MIR_369-A1 climate scenario and somewhere between the MIROC and the CSIRO results if we use the CSI_369_A1 climate scenario.

production enters the processing sector. Thus, the expansion of the agricultural olives sub-sectors has to be traced back to indirect effects, described above, most notably to rising intermediate demand from the oils processing manufacturing sub-sector.

Figure 3 - Impacts of climate change on agricultural sub-sectors, 2000-2030



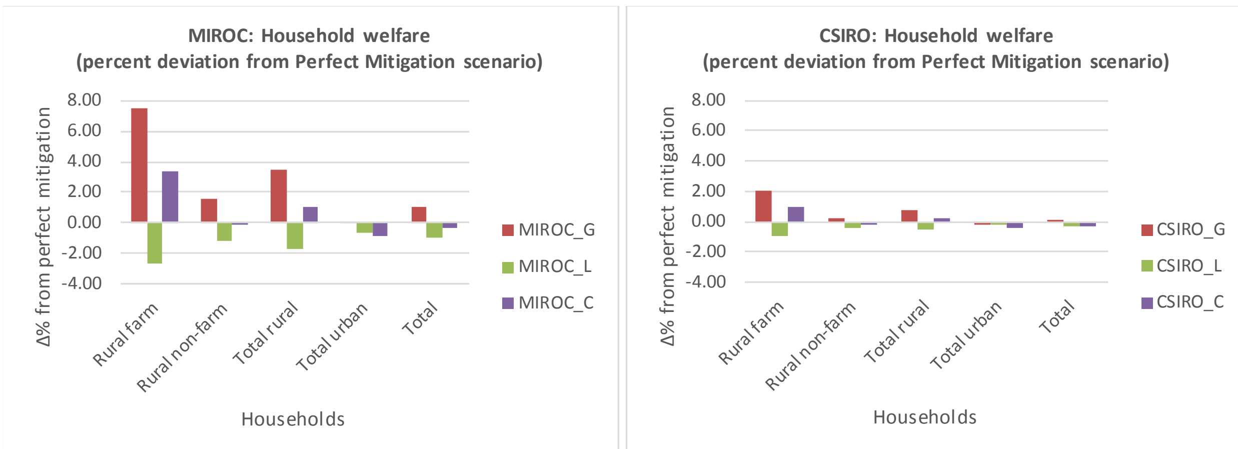
Source: Authors' elaboration based on DCGE simulation results.

Being both export and import oriented (see Table 3) the oils processing manufacturing sector benefits twice: Import substitution by consumers in response to a higher import price drives up the price for the domestically produced substitute. At the same time, export transformation by domestic producers in response to a higher export price reduces domestic supply, which enforces upward pressure on the domestic price. Thus, both oils processing and olives production benefit from global climate change, the former from higher world market prices, the latter from backward linkages of oils processing.

All other agricultural sub-sectors experience real income losses as a result of climate change (Figure 3). The reason is that the expansion of olives production exerts upward pressure on wages and land rental rates for perennial land (see Table 5) thereby increasing production costs. A higher land rental for perennial land affects the production of other fruits, which is the only sector that competes with olives for the use of this type of land (see Table 3). However, land rentals for dry land and irrigated land also increase because agricultural producers try to substitute more expensive labor by using more land, thereby adding to higher production costs. The changes in real income are most pronounced in agricultural sub-sectors, which depend on agricultural labor and family labor that are intensively used in olive production, i.e. forage crops and other agriculture. Yet, these are tiny sectors contributing less than 0.1 percent to overall output (see Table 3). Overall, the real income losses in agriculture are mainly due to lower yields in the production of olives, other grains, other fruits and vegetables, which cannot be compensated by income gains that result from higher world market prices for olives and olive oil.

While climate change reduces agricultural and overall GDP under both climate scenarios, the factor market effects described above lead to a redistribution of income and changes in consumer prices, which affect individual household's welfare differently.[6] As shown in Figure 4, rural farm households benefit from climate change, while urban households' welfare is negatively affected. Rural non-farm households are almost unaffected by climate change. Moreover, the improvement of rural welfare is exclusively due to global climate change impacts, while local climate change impacts reduce welfare of all households, both rural and urban. This can be traced back to differences in factor endowments with rural households being well endowed with agricultural and family labor (that becomes relative scarce) and the wages that will increase with higher world market prices for agricultural goods, whereas urban households receive most of their income from lower-paid non-agricultural labor and capital (that becomes relative abundant; see Table 5).

Figure 4 – Impacts of climate change on household welfare, by household types, 2000-2030

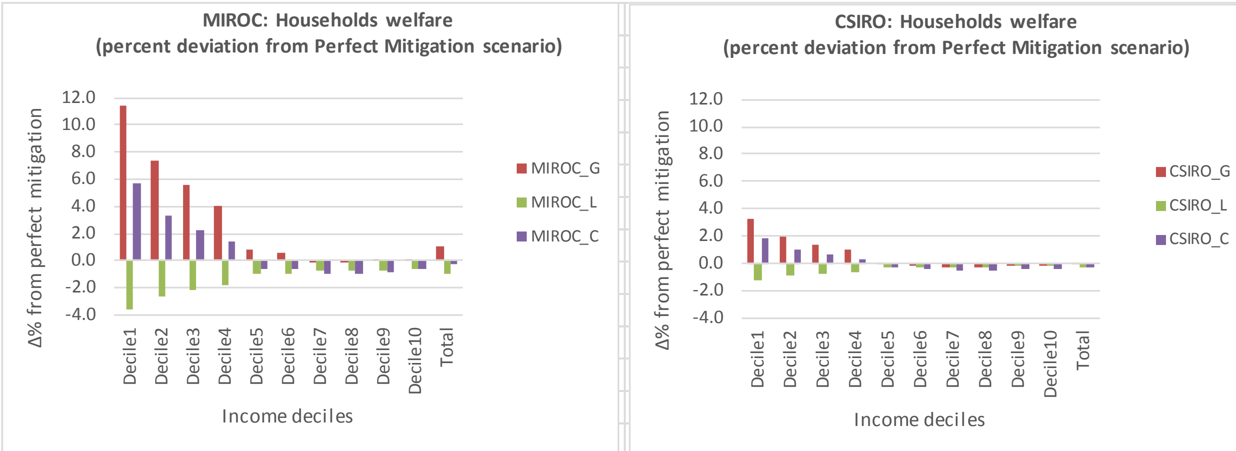


Source: Authors' elaboration based on DCGE simulation results.

Moreover, climate change impacts on household welfare seem to be pro-poor because rural households, which are located at the lower end of the income spectrum, receive most of their income from farm activities and from supplying agricultural labor (Figure 5). As net producers of agricultural goods, the poorer segments of the Tunisian society benefit from higher agricultural prices that result from global climate change, but are more severely affected from lower yields. By contrast, better off segments of the Tunisian society are net consumers of agricultural goods and are therefore negatively affected by higher prices, both as a result of global and local climate change. However, welfare losses are almost negligible since factor market spillovers to the industrial and services sectors are small. As a result earned income in these sectors is not affected dramatically. In addition, agricultural goods make up only a small share of the consumption basket of these households, and therefore price changes do not dramatically affect real consumption. Nevertheless, the cost of climate change has to be borne by industrial and services sectors and those employed in these sectors, while the agricultural sector and those who earn their living from this sector actually benefit from climate change impacts.

[6] We measure household welfare by the so called Hicks'ian equivalent variation, which takes into account price changes.

Figure 5 – Impacts of climate change on household welfare, by income deciles, 2000-2030



Source: Authors' elaboration based on DCGE simulation results.

4. Summary and Conclusions

This paper has addressed specific questions within the much broader discussion on climate change impacts in developing countries. The impact of global and local climate change on growth, resource allocation and household welfare in Tunisia was analyzed numerically using a dynamic computable general equilibrium model of an open economy featuring product differentiation between domestically and foreign produced goods. The analysis was carried out at a twenty-one sector level of disaggregation, including 11 agricultural and 8 food processing sectors. Households were differentiated according to income levels and factor endowments.

1. In general, the results bear out the expectation that climate change has a negative but weak overall effect on the Tunisian economy, and this effect is much weaker for the CSIRO than for the MIROC scenario. These results conform to recent findings for other countries in the MENA region and for countries in Latin America.
2. Global and local climate change, besides direct effects, induces general equilibrium repercussions, which have large indirect effects on the directly affected and other sectors. Generally, global climate change benefits agriculture since higher world market prices for agricultural commodities stimulate export expansion and import substitution. Local climate change hurts agriculture because lower yields reduce factor productivities in the affected sectors. Although the effects are weaker with product differentiation this general pattern corresponds with other partial equilibrium studies and reduced form analyses.
3. The benefit of the CGE analysis becomes apparent at the more disaggregated level of analysis since individual, indirect effects have a differential impact across sectors. Most important are effects on intermediate input costs, the real exchange rate and factor prices.
4. Within agriculture, olives production – though being a pure non-tradable and therefore unaffected by world market price changes – is the only sub-sector that is projected to expand under climate

change. This is due to linkages to the oils processing sector and the lack of a domestically produced substitute. Other agriculture, which is slightly export-oriented and easy to substitute by imports, suffers from the decline in exports and cheaper imports induced by the appreciation of the real exchange rate and the dominating factor-price effect. The latter also holds true for other agricultural commodities, such as other cereals, legumes, and forage crops, which are all easy to substitute by imports and, therefore, their production is discriminated against by the real exchange-rate effect.

These results point to the importance of economic structure in determining the final income, resource allocation and sectoral incidence effects of climate change.

The benefit of CGE analysis also becomes apparent at the disaggregated level of household income and welfare analysis, since here too, indirect effects have a differential impact across households.

1. While rural households in Tunisia – both farm and non-farm households – benefit from global climate change and higher world market prices, all households – rural and urban – experience welfare losses as a result of the indirect factor price effects of local climate change.
2. Although rural households are more strongly affected by local climate change on the income earnings and income spending side, the resulting real income losses from local climate change are overcompensated by real income gains from global climate change.
3. The costs of climate change have eventually to be carried by urban and richer households, though overall welfare losses are rather low in Tunisia, while rural and poorer households are projected to actually benefit from climate change.

From a policy perspective, the results of the CGE analysis of climate change impacts suggest that Tunisia should try to maximize the benefits from global climate change and to minimize the losses from local climate change. At given trade structures, as reflected in Table 3, the former would involve a combination of policies to a) support import substitution in the wheat and other cereals sectors, and b) policies to support export diversification and export market penetration, e.g. for other fruits and other agriculture. If such a policy-induced adaptation strategy would focus on wheat and other agriculture, it could also contribute to minimizing losses from local climate change since yield losses are projected to be much lower in these sectors than in other cereals and fruit production.

Other policies to minimize the negative impacts of local climate change in Tunisia should first of all try to avoid the yield and output losses resulting from temperatures and rainfall variations. Those include investments in climate-proof crops but also extension services to improve on-farm management techniques, such as shifting the planting date, switching crop varieties, and improving irrigation efficiency, especially in the face of already-constrained water resources. The results from the CGE analysis suggests that the bulk of adaptation to climate change would, however, have to come from the non-agricultural sector and urban households, which bear most of the costs of climate change in Tunisia.

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Table A1 – Macro SAM, Tunisia, 2001 (Mio. TDN)

Revenues /Expenditures	Activities	Commodities	Factors			Institutions			Capital account	Rest of the world	Total
			Labor	Capital	Land	Enter-prises	House-holds	Govern-ment			
Activities		52,400									52,400
Commodities	26,334						19,735	4,489	7,072	11,155	68,786
Labor	11,543										11,543
Capital	12,821										12,821
Land	498										498
Enterprises				5,086							5,086
Households			11,543	7,734	498	96				3,513	23,385
Government	1,204	1,654				424	1,118			525	4,925
Capital account						3,213	2,531	353	-525	975	6,547
Rest of the world		14,732				1,353		83			16,168
Total	52,400	68,786	11,543	12,821	498	5,086	23,385	4,925	6,547	16,168	

Source: Calculated from Chemingui (2001).

Table A2 – Sectoral production costs, Tunisia, 2001 (Mio. TDN)

	Sector	Intermediate input costs	Factor costs							Net indirect tax	Total
			Family workers	Agricultural workers	Non-agricultural workers	Capital	Rain-fed land	Irrigated land	Perrenial land		
1	Wheat	119	52		91	77	54	21		-55	358
2	Other cereals	25	9		6	15	13	2		-21	48
3	Legumes	24	10		31	31	18	3		-2	116
4	Forage crops	25	8		13	7	13	6		-1	70
5	Olives	23	76		62	31			22	5	218
6	Other fruits	272	59		218	183			205	4	941
7	Vegetables	267	77		192	186		137		3	862
8	Other agriculture	10	3		12	6	2	3		0	36
9	Livestock	598	145		301	600				-6	1,638
10	Forestry	11	13		29	38				1	91
11	Fishing	153	30			232				5	420
12	Meat	1,241		22		42				6	1,312
13	Milk and its products	433		49		101				-37	547
14	Flour milling & its products	1,084		127		62				2	1,275
15	Oils	439		10		80				3	531
16	Canned food products	283		12		45				10	350
17	Sugar and its products	190		15		59				-2	262
18	Other food products	879		55		67				364	1,364
19	Beverages	328		43		117				116	604
20	Other man. and non-man. industries	16,829		3,114		4,262				934	25,139
21	Services	3,103		6,662		6,580				-125	16,220
	Total	26,334	481	10,109	954	12,821	99	172	227	1,204	52,400

Source: Calculated from Chemingui (2001).

Table A3 – Commodity supply and demand, Tunisia, 2001 (Mio. TDN)

	Commodity	Import supply	Domestic supply	Total supply and demand	Inter-mediate demand	Household demand			Govern-ment	Invest-ment	Exports
						Rural farm	Rural non-farm	Urban			
1	Wheat	311	358	670	513	14	9	4	0	116	13
2	Other cereals	343	48	390	260	7	6	4	0	113	0
3	Legumes	11	116	126	121	9	14	28	0	-48	1
4	Forage crops	141	70	211	151	0	0	0	0	58	3
5	Olives	0	218	218	212	0	0	0	0	6	0
6	Other fruits	13	941	954	57	73	159	525	0	15	125
7	Vegetables	22	862	884	181	124	188	370	0	14	6
8	Other agriculture	14	36	50	24	2	3	5	0	10	6
9	Livestock	25	1,638	1,663	1,299	38	79	198	0	31	19
10	Forestry	7	91	98	43	12	15	26	0	2	0
11	Fishing	24	420	443	102	17	55	239	0	9	21
12	Meat	0	1,312	1,312	222	117	243	612	0	117	1
13	Milk and its products	58	547	605	131	54	107	264	0	44	7
14	Flour milling & its products	34	1,275	1,309	350	163	225	423	0	100	49
15	Oils	188	531	719	321	34	57	122	0	-7	192
16	Canned food products	28	350	378	82	10	25	120	0	24	118
17	Sugar and its products	120	262	383	134	47	73	163	0	-41	7
18	Other food products	177	1,364	1,540	555	59	145	754	0	-52	80
19	Beverages	58	604	662	375	20	45	172	0	21	29
20	Other man. and non-man. industries	13,962	25,139	39,101	15,820	487	1,249	4,823	0	7,850	8,873
21	Services	851	16,220	17,071	5,383	530	1,185	5,186	4,489	-1,308	1,607
	Total	16,386	52,400	68,786	26,334	1,816	3,882	14,038	4,489	7,072	11,155

Source: Calculated from Chemingui (2001).

Table A4 – Input coefficients, Tunisia, 2001

	Commodity/Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Wheat	0.18											0.00		0.43			0.02				0.01
2	Other cereals		0.20							0.07			0.00		0.00				0.21	0.06		0.00
3	Legumes	0.01	0.00	0.33	0.01					0.02	0.01				0.01		0.01	0.11	0.08	0.00	0.00	
4	Forage crops				0.16					0.10			0.07									
5	Olives					0.29				0.02						0.43	0.01		0.00			0.00
6	Other fruits						0.00			0.00				0.00	0.00		0.04	0.00	0.01	0.09		0.00
7	Vegetables							0.06									0.21		0.07			0.01
8	Other agriculture								0.16	0.01				0.00							0.00	0.00
9	Livestock	0.01	0.01	0.02	0.00	0.03	0.02	0.01	0.18	0.01			0.84	0.15	0.01						0.01	0.02
10	Forestry									0.03	0.05	0.01									0.00	0.00
11	Fishing											0.03					0.22				0.00	0.01
12	Meat																				0.00	0.06
13	Milk and its products													0.16	0.02			0.02	0.00		0.00	0.01
14	Flour milling & its products									0.02				0.00	0.27			0.01	0.01		0.00	0.01
15	Oils										0.01			0.00	0.01	0.09	0.02	0.02	0.14		0.00	0.04
16	Canned food products											0.01		0.00	0.00		0.04			0.00		0.02
17	Sugar and its products									0.00				0.03	0.01		0.00	0.31	0.01	0.07		0.01
18	Other food products									0.55		0.00	0.00	0.02	0.03		0.04	0.04	0.04	0.01		0.04
19	Beverages													0.08	0.01					0.31	0.00	0.07
20	Other man. and non-man. industries	0.66	0.23	0.56	0.47	0.48	0.12	0.26	0.28	0.06	0.17	0.14	0.01	0.35	0.08	0.27	0.21	0.18	0.11	0.22	0.77	0.63
21	Services	0.15	0.56	0.08	0.35	0.20	0.87	0.67	0.37	0.10	0.76	0.80	0.08	0.20	0.11	0.22	0.21	0.28	0.32	0.25	0.22	0.06

Source: Calculated from Chemingui (2001).