Purdue University
Purdue e-Pubs

Open Access Dissertations | Theses and Dissertations

Spring 2014

Agriculture, climate change, and adaptation in Morocco: A computable general equilibrium analysis

Ismail Ouraich
Purdue University

Follow this and additional works at: https://docs.lib.purdue.edu/open_access_dissertations

Part of the Agricultural Economics Commons

Recommended Citation
Ouraich, Ismail, "Agriculture, climate change, and adaptation in Morocco: A computable general equilibrium analysis" (2014). *Open Access Dissertations*. 529.
https://docs.lib.purdue.edu/open_access_dissertations/529

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

Graduate School Form 30
Updated 1/15/2015

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By Ismail OURAICH

Entitled

AGRICULTURE, CLIMATE CHANGE, AND ADAPTATION IN MOROCCO: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

Wallace E. TYNER
Chair

Gerald E. SHIVELY

Otto C. DOERING III

Keith CHERKAUER

To the best of my knowledge and as understood by the student in the Thesis/Dissertation Agreement, Publication Delay, and Certification Disclaimer (Graduate School Form 32), this thesis/dissertation adheres to the provisions of Purdue University's "Policy of Integrity in Research" and the use of copyright material.

Approved by Major Professor(s): Wallace E. TYNER

Approved by: Gerald E. SHIVELY 4/28/2014

Head of the Departmental Graduate Program Date

AGRICULTURE, CLIMATE CHANGE, AND ADAPTATION IN MOROCCO: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Ismail Ouraich

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

May 2015

Purdue University

West Lafayette, Indiana

"In the name of Allah, the Merciful, the Compassionate. Recite in the name of your Lord who created. Created man from a clinging substance. Recite, and your Lord is the most Generous -.Who taught by the pen - Taught man that which he knew not."

Qur'an - Chapter 96, Verses 1-5

"The Prophet Muhammad (peace be upon him) said: "If anyone travels on a road in search of knowledge, God will cause him to travel on one of the roads of Paradise. The angels will lower their wings in their great pleasure with one who seeks knowledge. The inhabitants of the heavens and the Earth and (even) the fish in the deep waters will ask forgiveness for the learned man. The superiority of the learned over the devout is like that of the moon, on the night when it is full, over the rest of the stars. The learned are the heirs of the Prophets, and the Prophets leave (no monetary inheritance), they leave only knowledge, and he who takes it takes an abundant portion."

Sunan of Abu-Dawood, Hadith 1631

ACKNOWLEDGEMENTS

Many people come to mind and who deserve my utmost gratitude and acknowledgement on these pages. Throughout my journey toward earning my doctorate degree, I have benefited greatly from the support - whether spiritual or emotional or intellectual - of many different individuals.

But first and foremost, all gratitude and praise to Allah (swt) without whom presence and guidance I would have never accomplished anything.

Second, I extend my gratitude and acknowledgment to my committee members, Prof. Gerald E. Shively, Prof. Otto C. Doering and Prof. Keith A. Cherkauer for their support and insights, but also for their intellectual probity and challenge to always think critically. In this regard, I want especially to thank Prof. Wallace E. Tyner as the chair of my dissertation committee and who is a co-author on the two essays that make up this dissertation. I want to express my gratitude for his mentorship, for the freedom to pursue research topics and ideas, and the great scholarly discussions and otherwise. His supervision, advice and encouragement have had a positive impact on me and a source of motivation to always excel and do my best. These lessons I hope to carry with me for the remainder of my career.

Third, I would love to acknowledge my colleagues and friends in the Department of Agricultural Economics at Purdue University. Throughout this journey, I have been touched by their kindness and support. I also have benefitted greatly from fruitful discussions regarding course work, research ideas and life in general. I hope to treasure these relationships and make them endure the vagaries of time and distance differences.

Finally, I dedicate this dissertation to my dad, Muhammad Ouraich, and mom, Berrad Rkia, and my brothers Omar Ouraich and Zakaria Ouraich, whom unconditional love, faith, support, and encouragement to achieve this highest of degrees would not have been possible.

TABLE OF CONTENTS

Page

LIST OF TABLES ix

LIST OF FIGURES xii

ABSTRACT xvi

CHAPTER 1. INTRODUCTION 1

1.1 Overview and Research Questions 1

1.2 Structure of the Thesis 7

CHAPTER 2. TAXONOMY OF THE MOROCCAN ECONOMY 9

2.1 Overview of Demographic and Socioeconomic Indicators 9

2.2 The Moroccan Agricultural Sector: A Historical Perspective 18

2.2.1 Moroccan Agriculture in the Colonial Period 18

2.2.2 Moroccan Agriculture in the Post-independence Era 21

2.3 Climate in Morocco 31

2.3.1 General Background 31

2.3.2 Recent Trends in Moroccan Climate 34

2.3.3 Projected Climate in Morocco 37

2.4 Climate in Morocco 40

2.5 Summary 41

CHAPTER 3. CLIMATE CHANGE IMPACT ASSESSMENT AND ADAPTATION: A REVIEW OF METHODOLOGIES AND CONCEPTS 43

3.1 Introduction 43

3.2 Estimating Climate-induced Impacts: A Review of Methods and Modeling Approaches 44

3.2.1 The Biophysical Approach 44

Page

3.2.1.1 Process-based Models 45
3.2.1.2 Empirical Statistical Models 50
3.2.2 The Socio-economic Approach 52
3.2.2.1 Bio-Economic Farm Models (BEFM) 54
3.2.2.2 Partial Equilibrium (PE) Models 55
3.2.2.3 Computable General Equilibrium (CGE) Models 57
3.2.3 The Integrated Assessment Models (IAMs) Approach 61
3.3 Adaptation in Impact Assessment of Climate Change 64
3.4 Summary 68
CHAPTER 4. CLIMATE CHANGE, AGRICULTURE AND THE ADAPTATION POTANTIAL OF THE 'PLAN MAROC VERT' IN MOROCCO: A CGE ANALYSIS 70
4.1 Introduction 70
4.2 The Morocco Country-based CGE Model 71
4.3 Description of Regionalization Assumptions and Data 74
4.4 Yield Projections and Scenarios Analysis for Morocco 79
4.4.1 Climate-induced Yield Projections 79
4.4.2 Scenario Analysis and the PMV Strategy 99
4.4.2.1 Scenario Analysis for the Morocco CGE model 99
4.4.2.2 A Discussion of the Plan Maroc Vert (PMV) Strategy 103
4.5 Simulation Results and Discussion 113
4.5.1 Welfare and Macroeconomic Impacts of the PMV Strategy 113
4.5.2 Macroeconomic Impacts of Climate Change without the PMV (CC-Only) and with the PMV (CC-PMV) 118
4.5.3 Climate Change Impacts on Household Income, Consumption and Welfare Without (CC-Only) and With (CC-PMV) the PMV Strategy 124
4.5.4 Sectoral Impacts 132
4.6 Summary and Conclusions 142
CHAPTER 5. TRADE LIBERALIZATION AND ADAPTATION TO CLIMATE CHANGE IN MOROCCO 147

Page

5.1 Introduction 147
5.2 Modeling Framework: GTAP Model 149
5.3 Yield Impacts and Scenario Analysis 152
5.3.1 The IFPRI Food Security CASE Maps Database 153
5.3.2 The IMAGE Yield Database 160
5.3.3 Harmonization Assumptions and Procedure for IFPRI and IMAGE Data.. 164
5.3.4 Descriptive Analysis of the New Yield Database 168
5.4 Simulation Results and Discussion 170
5.4.1 Welfare and Macroeconomic Impact of Climate Change 170
5.4.2 Trade Liberalization under Climate Change: Welfare and Economy-wide Impacts 174
5.5 Impacts of Trade Liberalization under Climate Change: A Comparison between Morocco and Turkey 185
5.5.1 A Descriptive Analysis of the Macroeconomic Structure in Morocco and Turkey 185
5.5.2 Analysis of Aggregate Welfare and Macroeconomic Impacts 190
5.5.3 Decomposition of Welfare and Macroeconomic Impacts 195
5.5.4 Sectoral Impacts: Trade, Prices, and Production 196
5.5.4.1 Trade: Imports and Exports 196
5.5.4.2 Domestic Demand and Production 202
5.6 Conclusions 204
CHAPTER 6. GENERAL CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH 207
6.1 General Conclusion 207
6.2 Limitations and Future Research 211
LIST OF REFERENCES 212
APPENDICES
Appendix A Figures 228
Appendix B Tables 248

Page

VITA 318

LIST OF TABLES

Table ..... Page
Table 2.1 Evolution of Real Aggregate and Per Capita Agricultural Value-added Growth Rates during Phase I (in annual percent change) 24
Table 2.2 Evolution of Real Aggregate and Per Capita Agricultural Value-added Growth Rates during Phase II (in annual percent change) 24
Table 2.3 Evolution of Number of Farmers and Arable Agricultural Area by Farm Size for the General Agricultural Censuses of 1974 and 1996 26
Table 2.4 Comparative Analysis of the Volatility of Performance between Phase I and Phase II 27
Table 2.5 Evolution of Real Aggregate and Per Capita Agricultural Value-added Growth Rates during Phase III (in annual percent change) 28
Table 2.6 Comparative Analysis of the Volatility of Performance between Phase II and Phase III 29
Table 2.7 Evolution of Growth Rates for GDP and Sector Value-added in Real Terms . 30
Table 2.8 Moroccan Agro-Ecological Zones (AEZ) and Key Characteristics 32
Table 2.9 Moroccan Agro-Ecological Zones (AEZ) and Key Characteristics (continued) 33
Table 2.10 Evolution of Observed Temperatures and Precipitation Trends for the Period 1960-2006 35
Table 2.11 Evolution of Observed Frequency of Hot/Cold Days and Hot/Cold Nights for the Period 1960-2006 36
Table 4.1 Regional Households Share in Total Expenditure 77
Table 4.2 Percentile Distribution of Climate Change Impacts on Precipitation and Temperature by 2050 81

Table ..... Page
Table 4.3 Regional Distribution of Projected Investments under the PMV Strategy by Pillar by 2020 (in Million MAD and in % Share) 107
Table 4.4 Sectoral Distribution of Projected Investments under The PMV Strategy by Pillar by 2020 (in Million MAD and in % Share) 108
Table 4.5 Description of Scenario Analysis 110
Table 4.6 Projected Impacts on Crop Yields under the Plan Maroc Vert (PMV) for Strategic Crops by Region by 2020 111
Table 4.7 Evolution of the PMV Investment Costs for the Period 2009-2013 (in billion MAD and in % Share)..... 112
Table 4.8 Macroeconomic Impacts of the PMV Strategy by 2020 (in millions MAD and % change)..... 114
Table 4.9 PMV Impacts on Household Income, Real Consumption Expenditure and Welfare by Household Type and Region (in millions MAD and % Change) 116
Table 4.10 Impacts of the PMV Strategy on Sectoral Value-Added by 2020 (in millions MAD and % Change)..... 117
Table 4.11 Macroeconomic Impacts of Climate Change — Without and With the PMV Strategy by 2050 (in % Change from BASE)..... 121
Table 4.12 Agricultural Gross Domestic product (GDP) by Crop Sector (in 2003 million MAD)..... 124
Table 4.13 Average Impacts of Climate Change on Sectoral Value-Added—Without and With the PMV Strategy by 2050 (in % change from BASE) 132
Table 5.1 Regional and Sectoral Aggregation in the GTAP Model 151
Table 5.2 Definition of Simulation Scenarios..... 153
Table 5.3 GDP and Population Growth Scenarios in IFPRI Database 154
Table 5.4 Description of IMAGE Database Dimensions..... 160
Table 5.5 Summary of Crop Matching Between GTAP, IFRPI and IMAGE Crops..... 166
Table 5.6 Average Yield Impact in IFPRI and IMAGE (in % change)..... 168
Table 5.7 Decomposition of Welfare Impacts of Climate Change by Effect for the World by 2050 (in 2004 $US million) 171

Table ..... Page

Table 5.8 Decomposition of Average Welfare Impacts by Effects and by Region under Climate Change Only by 2050 (in 2004 $US million) 173

Table 5.9 Decomposition of Average Welfare Impacts for the World Region by Effects by 2050 (in 2004 $US million) 177

Table 5.10 Decomposition of Impacts on Domestic and Imports Sales by Commodity in OECD Europe under Climate Change Only and the 'CCAGLIBEU' Trade Liberalization Scenario by 2050 (in % change) 179

Table 5.11 Net Welfare Impacts of Trade Liberalization in Morocco by Climate and Trade Scenario (in 2004 $US million) 193

Table 5.12 Allocative Efficiency Effect by Commodity for Morocco for the Multilateral Trade Liberalization Scenario 'MULTI' under Climate Scenarios A1B and B1 (2004 $US million) 194

Table 5.13 Average Import Tariff and Tax on Firms' Imports by Commodity (% ad valorem rate) 198

LIST OF FIGURES

Figure ..... Page
Figure 2.1 Evolution of Population in Morocco (1960-2050) 10
Figure 2.2 Evolution of Population Growth Rates in Morocco (1960-2050) 11
Figure 2.3 Evolution of Birth, Death and Fertility Rates in Morocco (1960-2012) 11
Figure 2.4 Evolution of Urban and Rural Income Per Capita in Morocco (1965-2011) .. 12
Figure 2.5 Evolution of Population by Age Group in Morocco (1960-2012) 14
Figure 2.6 Evolution of Unemployment Rates by Age Group in Morocco 15
Figure 2.7 Evolution of Average Employment by Sector in Morocco (2000-2011) 16
Figure 2.8 Evolution of Value-added Shares in GDP and Real Growth Rates by Sector in Morocco (1966-2012) 17
Figure 2.9 Evolution of Observed and Simulated Projected Average Annual Temperatures and Precipitations by SRES Scenario for Morocco 39
Figure 3.1 Summary of Methodological Framework in Linking Crop and Climate Models 46
Figure 4.1 Administrative and Economic Regions in Morocco 74
Figure 4.2 Projected Yield Impacts at the National Level for SRES A2 and B2 by 2050 84
Figure 4.3 Projected Yield Impacts by 2050 at the National Level for SRES A2 And B2 with and without CO2 Fertilization Effects 86
Figure 4.4 Distribution of Average Projected Yield Impacts by 2050 across Crops under the SRES A2 by Region 89
Figure 4.5 Distribution of Average Projected Yield Impacts by 2050 across Crops under the SRES B2 by Region 90
Figure 4.6 Kernel Distribution of Projected Yield Impacts for Durum Wheat by 2050 by SRES scenario in Major Producing Regions 92

Figure ..... Page

Figure 4.7 Kernel Distribution of Projected Yield Impacts for Common Wheat by 2050 by SRES scenario in Major Producing Regions 93
Figure 4.8 Kernel Distribution of Projected Yield Impacts for Barley by 2050 by SRES scenario in Major Producing Regions 94
Figure 4.9 Kernel Distribution of Projected Yield Impacts for Tomatoes by 2050 by SRES scenario in Major Producing Regions 96
Figure 4.10 Kernel Distribution of Projected Yield Impacts for Citrus by 2050 by SRES scenario in Major Producing Regions 97
Figure 4.11 Kernel Distribution of Projected Yield Impacts for Olives by 2050 by SRES scenario in Major Producing Regions 98
Figure 4.12 Technical Change in Factor Input Productivity: Neutral Technological Progress (Left), Capital Saving Technological Progress (Middle) and Labor Saving Technological Progress (Right) 102
Figure 4.13 Distribution of Net Impacts of the PMV Strategy on GDP Components by 2050 (% Change from BASE) 123
Figure 4.14 Distribution of Net Impacts of the PMV Strategy on Rural and Urban Households Incomes by 2050 (% Change from BASE) 127
Figure 4.15 Distribution of Net Impacts of the PMV Strategy on Rural and Urban Households Real Expenditure by 2050 (% Change from BASE) 129
Figure 4.16 Distribution of Net Welfare Impacts of the PMV Strategy on Rural and Urban Households by 2050 (in million MAD) 131
Figure 4.17 Percentile Distribution of Climate Change Impacts on Sectoral Value-Added — With and Without the PMV Strategy by 2050 (% Change from BASE) 134
Figure 4.18 Percentile Distribution of Net Impacts of the PMV Strategy on Sectoral by 2050 (% Change from BASE) 135
Figure 4.19 Percentile Distribution of Net Impacts of the PMV Strategy on Domestic Prices and Production for Agricultural Crop Sectors by 2050 (% Change from BASE) 140

Figure ..... Page

Figure 4.20 Percentile Distribution of Net Impacts of the PMV Strategy on Domestic Prices and Production for Food Processing Sectors by 2050 (% Change from BASE) 141
Figure 4.21 Historical Evolution of Corn Grain Yield (in BU/Acres) between 1996-2014 145
Figure 5.1 Structure of Regional Household and Components of Final Demand in the GTAP Model 149
Figure 5.2 Structure of Production in the GTAP Model 150
Figure 5.3 Evolution of Distribution across Scenarios of Yield for Irrigated and Rainfed Wheat in the Top Five Producing Countries in IFPRI Database 156
Figure 5.4 Evolution of Distribution across Scenarios of Intrinsic Productivity Growth Rates (IPRs) for Irrigated and Rainfed Wheat in the Top Five Producing Countries in IFPRI Database 157
Figure 5.5 Evolution of the Distribution across Scenarios of Yield Data for Maize in the Top Four Producing Regions in the IMAGE Database 162
Figure 5.6 Evolution of the Distribution across Scenarios of Management Factors (MF) Data for Maize in the Top Four Producing Regions in the IMAGE Database 163
Figure 5.7 Average Distribution of Projected Yield Impacts by Region across Crop Sectors by 2050 169
Figure 5.8 Distribution of Welfare Impacts under Climate Change Only, and Climate Change and Trade Liberalization for the World Region by 2050 (in 2004 $US million) 176
Figure 5.9 Kernel Distribution of Welfare Impacts of Trade Liberalization under Climate Change by Scenario by 2050 (in 2004 $US million) 182
Figure 5.10 Share of Domestic Markets in Aggregate Output by Sector (in %) 186
Figure 5.11 Share of Export Markets in Aggregate Output by Sector (in %) 187
Figure 5.12 Percent Share Distribution of Domestic Output by Sector and by Demand Category in Turkey 188

Figure ..... Page
Figure 5.13 Percent Share Distribution of Domestic Output by Sector and by Demand Category in Morocco 188
Figure 5.14 Percent Share Distribution of Import Sales by Sector and by Demand Category in Turkey 189
Figure 5.15 Percent Share Distribution of Import Sales by Sector and by Demand Category in Morocco 190
Figure 5.16 Average Welfare Impacts for Morocco and Turkey by Scenario by 2050 (in 2004 $US million)..... 191
Figure 5.17 Average Gross Domestic Product (GDP) Impacts for Morocco and Turkey by Scenario by 2050 (in 2004 $US million) 192
Figure 5.18 Average Percent Change in Exports and Imports Price and Quantity Indices by 2050..... 200

ABSTRACT

Ouraich, Ismail Ph.D., Purdue University, May 2015. Agriculture, Climate Change, and Adaptation in Morocco: A Computable General Equilibrium Analysis. Major Professor: Wallace E. Tyner.

The empirical analysis in this dissertation comprises two essays investigating the impacts of climate change on agriculture in Morocco, with an emphasis on climate uncertainty and robust adaptation.

The first essay in Chapter 4 provides estimates of economic impacts of climate change, and estimates on the extent to which the current Moroccan agricultural development and investment strategy, the Plan Maroc Vert (PMV), could help in agricultural adaptation to climate change and uncertainty.

We simulated three cases. First, we examined the impacts of PMV on the economy in the absence of climate change and found that it could provide about a 2.4% increase in GDP if the targets could be achieved. Subsequently, we did a separate simulation of the impacts of climate change on the Moroccan economy with no PMV (CC-Only) and found that there would be negative GDP impacts ranging between -0.5% and -3% depending on the climate scenario under the without CO_2 case. Including CO_2 fertilization effects induces a slight change in the distribution of impacts, which range from -1.4% to +0.3%. Finally, we evaluated the extent to which PMV could help mitigate the adverse impacts of climate change, and we found that the gain was quite small ranging between +0.02% and +0.04%.

The ability of the PMV strategy to mitigate the negative effects of climate change is limited at best, if non-existent. This is due to the scope of the PMV simulations limited to the strategic agricultural crop sectors in Morocco, which jointly represent no more than 35% of aggregate agricultural GDP; whereas the rest of the sectors account for 65%. Additionally, the likelihood of meeting the PMV productivity targets is low in light of our benchmark analysis comparing productivity prior to and after the adoption of GMO technologies.

The second essay examines the interaction of globalization through trade liberalization and climate change. Our hypothesis was that the more trade is liberalized, the higher the potential to compensate for losses due to climate change.

Our findings suggest that at the global level, our hypothesis is verified. World welfare gains are highest under a multilateral trade liberalization scenario, which induces a total offset of climate change welfare losses. However, under partial trade liberalization, the welfare gains become very small in comparison with the climate change impacts.

At the regional level, the results are more nuanced and our hypothesis does not hold for all regions. For instance, and focusing on Morocco as a case study, the net welfare impacts associated with trade liberalization are negative on average. But under the multilateral trade liberalization scenario, Morocco experiences net welfare gains under the SRES A1B and B1, which respectively reached US$ +23 million and US$ +16 million. Although trade liberalization induces net allocative efficiency gains under most scenarios, the large negative terms of trade effects offset most of the gains.

CHAPTER 1. INTRODUCTION

1.1 Overview and Research Questions

The trend of agricultural productivity growth in the last decades has been tremendous in many ways, which helped to alleviate poverty and food insecurity in many areas (although there are still substantial differentials across regions). This was primarily due to improved production systems and investments in crop and livestock breeding programs. Nonetheless, climate change threatens to exacerbate the existing challenges faced by agriculture. The global population is estimated to reach 9 billion by 2050, with the bulk of the increase occurring mostly in Africa and South Asia. Also, taking into account the accelerated demand for food and changes in dietary habits, the level of undernourished population post-economic crisis is at an all-time high compared to the level that existed when the hunger-reduction target was agreed at the World Food Summit in 1996 (FAO, 2010). Thus, the FAO estimated that feeding world population will require a 70 percent increase in total agricultural production by 2050 (FAO, 2010; WDR, 2010). Yet, the problem gets compounded as we take into consideration the threat of climate change to the stability and productivity of the agricultural sector. Numerous studies (Cline, 2007; Fisher et al., 2002; IPCC, 2007) have shown that the specter of climate change is looming even bigger for regions already experiencing low and erratic productivity levels (e.g. Africa and South Asia). For instance, it has been estimated that a

warming of 2˚C could result in a 4 to 5 percent permanent reduction in annual income per capita in Africa and South Asia (WDR, 2010).

In its Fifth Assessment Report (AR5), the Intergovernmental Panel on Climate Change (IPCC) stated that the African continent is poised to be among the most vulnerable regions to climate change and climate variability, a situation that is aggravated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions, and limited access to capital, infrastructure and technology (IPCC, 2014). Recent findings suggest that the evidence for warming across the continent has increased based on decadal analyses of temperatures trends in the last 50-100 years. Current projections indicate that mean annual temperature under the climate scenarios A1B and A2 could rise by >2°C by the end of the 21st Century relative to the late 20th Century. But, under the newly developed climate scenarios in the IPCC's Fifth Assessment Report (AR5) - namely the Representative Concentration Pathways (RCPs),[1] the exceedence of the 2° C threshold could occur as early as mid-century and reach between 3 and 6° C by the end of the century.

With respect to precipitation, the findings suggest with medium to high confidence that precipitation are projected to fall over North African and south-western parts of South Africa by the end of the 21st Century under the A1B and A2 scenarios. For

[1] Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome. (Moss et al., 2010). For further details, refer to the IPCC Working Group I final report: http://www.climatechange2013.org/.

sub-Saharan Africa, projected rainfall change remains uncertain. Indeed, depending on region-specific topographical characteristics, rainfall and extreme rainfall are likely to increase in some areas (e.g. Ethiopian Highlands). But overall, climate change is projected to exacerbate existing water stresses over the African continent in terms of water availability.

Chief among the concerns for the African continent is the modernization of the agricultural systems (at the level of both commercial and subsistence agriculture) deemed for many countries in the continent as necessary for economic growth. For example, the contribution of agricultural GDP varies from one country to the other, but is still substantial where the average in the continent is 21% (ranging from 10% to 70%) (Mendelsohn et al., 2000b).

Reforming the agricultural sector in Africa is a necessity to tackle problems pertaining to food security, water scarcity, access and management, health and malnutrition, etc. Indeed, many countries in the continent already experience challenging climatic conditions that impact negatively the prospects for agriculture. For example, in the wake of the Financial Crisis of 2007-08, the FAO food price index rose by 27% in 2007, and this increase persisted and even accelerated during the first half of 2008. The food price surge caused substantial supply disruptions, especially in Africa, which was particularly affected and where food riots erupted violently (FAO, 2009). Climate change is projected to increase the strain on supply chains as yield reductions are projected to reach as high as 50% by 2020 (IPCC, 2007).

In terms of socio-economic impacts in the continent, acute yield reductions as mentioned above could have severe consequences in terms of economic growth and

poverty alleviation, given the fact that many African countries rely substantially (to varying degrees) on the agricultural sector as a source of national income through exports of cash crops and also as a major provider for job opportunities, especially in rural areas. Perhaps the one challenge that tops the list is depicted by the linkages between climate change and the hydrologic dimension (e.g. water scarcity, changing rainfall patterns, etc.). In rainfed-driven regions like Africa, there is great uncertainty around predicting drought and flood cycles, and their magnitude which has a important impact on water availability (quantity, quality, and timing) for water supply and sanitation, agricultural production, energy (hydropower), and environmental sustainability (World Bank, 2009). In a recent study, Ward (2011) analyzed the effect of irrigation expansion on agricultural yields in Sub-Saharan Africa and evaluated its effectiveness in mitigating yield loss from climate change. Their findings suggest that despite positive impacts on yields, irrigation expansion does not offset the negative impacts of climate change on cereal yields in Sub-Saharan Africa.

Competition among different water usages will be exacerbated under climate change, thereby altering the future patterns of both water availability and usage leading to increased water stress, which was the conclusion reached by numerous studies. For example Arnell (2004), accounting for population growth and the impact of climate change, estimated that by 2020s between 0.4 to 1.7 billion people will suffer from increased water stress, and by 2050s the figure reached between 1 to 2.7 billion.

Nonetheless, these represent global estimates that do not showcase the regional differentials that exist among different regions in terms of the distribution of impacts. For instance, in the Middle East and North Africa (MENA) (of which Morocco is part), water

represents the major vulnerability in the region, where per capita water availability is projected to halve by 2050 even without the effects of climate change. This is primarily driven by an increasing trend in population, high rates of urbanization, increasing competition for water resources between the agricultural sector and the rest of the economy, etc., and in combination with inefficient patterns of water delivery and consumption due to inadequate infrastructure (especially in the agricultural sector).[2] The increased water stress combined with greater variability in precipitation and increased frequency of extreme events (e.g. drought, floods, etc.) will put greater pressures on the agricultural sector, which accounts for some 85% of water usage in the region (World Bank, 2010).

Moreover, increased urbanization and expansion of economic activity in urban areas will put more pressure on water demand, which will exacerbate the vulnerability of the agricultural sector as it competes for water. Therefore, the challenge facing the region calls for adequate policy responses at the country and regional levels in order to formulate feasible adaptation strategies to help protect the prospects of economic growth, protect peoples' livelihoods and strengthen their resilience in the face of climate uncertainty. Hence, adaptation strategies ought to be built into national development strategies. Thus, and in order to help policymakers in making informed decisions, there is great need for sound economic impact assessments.

---

[2] For instance, investments options in new water storage in the region are limited given that almost 90% of fresh water resources are already mobilized in reservoirs. Water usage (mainly for irrigation) in the agricultural sector is highly inefficient given the predominance of gravity irrigation at the expense of more water irrigation schemes (e.g. drip irrigation). Nevertheless, there exist a potential for reducing these inefficiency through water recycling, upgrading of water delivery systems, etc.

In recent years, there has been a great improvement in the science of climate change through advances in our understanding of the biophysical processes of climate, which enhanced our modeling capacity providing us with relatively more robust climate projections at the global level. Nonetheless, more analysis is needed on the economics of climate change. There are many factors that explain this slower development of economic impact analysis, but chief among them is the dependency of economic impact assessments upon reliable climate projections that could be fed into economic models to measure impacts at the socio-economic level, and evaluate policy mitigation and/or adaptation strategies. The early literature of economic impact assessment of climate change has provided some useful insights on the issue, but remained limited in scope and depth as most of it focused on highly aggregated unit of analysis (e.g. at the continental or sub-continental levels). Nonetheless, the current trend of the empirical literature on the issue of economic impact assessment of climate change display a shift towards engaging in 'case-by-case' analyses at the country and/or sub-country level. This is driven by the fact that consensus is growing among policymakers on the need to act upon the challenges of climate change. But also due to increased availability of climate projections at finer geographical scales that helps refine the analyses, and improves our ability to capture the intricate linkages that exist between climate change and the economy.

One of the major issues in the current literature of economic impact analysis as it pertains to climate change linkages is the gap in accounting for the uncertainty dimension and the ability to evaluate the robustness of mitigation and/or adaptation policies. Indeed, the challenge of coping with climate risks, in the form of intra- and inter-season variability, has always been a prime concern for farmers globally. Thus, many scholars

advocate focusing primarily on addressing the climate variability as a stepping stone towards dealing with longer-term trends (Hertel and Lobell, 2012; Washington et al., 2006; Cooper et al., 2008). In recognition of this literature gap in the empirical analysis of climate change impacts, especially in the context of developing countries, the present research will focus its attention on Morocco. The main objectives of the analysis are:

- to estimate the economic impacts of different climate change scenarios on the agricultural sector, and their wide-economy welfare implications; and
- to investigate the robustness of adaptation policies analyzed in the face of the uncertainty characterizing climate change impacts on agriculture.

1.2 Structure of the Thesis

This thesis is organized in six chapters. Chapter 1 provides a general introduction into the theme being treated and the overall objectives of the research effort. Chapter 2 describes the evolution of key socioeconomic indicators in Morocco, and particularly focusing on the agricultural sector. The objective is to understand the current state of affairs in light of a historical analysis of key policy reforms that enabled it, which will enable us to contextualize the findings of our analysis. In Chapter 3, we provide a scoping literature review on state of the art impact assessment methodologies in the context of climate change and analyze the recent evolution of the adaptation concept. This will allow us to situate our analysis within a growing body of literature and help us draw findings on the strengths and limits of our work.

In order to achieve the stated goals, we selected two frameworks to analyze the adaptation potential of selected policies and their robustness in the face of climate-driven

uncertainty in the case of Morocco. First, we will use a regionalized country-based CGE model to investigate the adaptation potential of the “Plan Maroc Vert” (PMV). The PMV is an investment strategy launched in 2008 as an effort to modernize the agricultural sector and enhance its resilience in the face of climate change (Chapter 4). Second, we use the multi-sector, multi-region GTAP CGE model to investigate the extent to which trade liberalization as a policy prescription can prove to be a robust adaptation measure in the face of climate change (Chapter 5).

In Chapter 6, we will summarize our findings and contrast the results from both frameworks in order to derive policy lessons and shed light on further research.

CHAPTER 2. TAXONOMY OF THE MOROCCAN ECONOMY

2.1 Overview of Demographic and Socioeconomic Indicators

Located in the north-west of the African continent, and only kilometers away from Europe, Morocco enjoys a very interesting geostrategic location with its 3,500 kilometers of seashores, spanning the Atlantic Ocean and the Mediterranean. And equally important is its diversity in terms of landscapes and ecosystems: the Mountain chains of the North, and the Northeast to the Southwest, the Plateaus of the East, the Plains in the West and the Centre, and the Desert in the South. The country has a typical temperate Mediterranean climate, but with dry conditions in much of the country. Indeed, half the country's area is desert, whereas the rest is split among cultivable agricultural area (9 million Ha), forests (6 million Ha), grassland (3 million Ha), and rangeland (21 million Ha). The country suffers from a cruel paradox in the form of advantageous precipitation patterns in the northern regions, but with very poor soil quality, and vice-versa in the southern regions (Akesbi, 2006).

Cereals represent about 60% of the cultivable agricultural area. Legumes, industrial crops, forage, and vegetable crops, each have 2-5% of agricultural area. Fruit plantations, mainly dominated by olive, almond, and citrus, are produced on approximately 7% of total agricultural area.

In terms of demographics, projections based on the latest census of 2004 indicate that by 2013, total population will reach 33 million (19.5 million in urban areas and 13.5 million in rural area), which corresponds to an average growth rate for the period of 1.1% (HCP, 2007). Urban and rural populations are increasing, albeit the latter at a much slower rate than the former. This is due to decreasing fertility rates driven by a rapid decline in birth rates (Figures 2.1, 2.2 and 2.3).

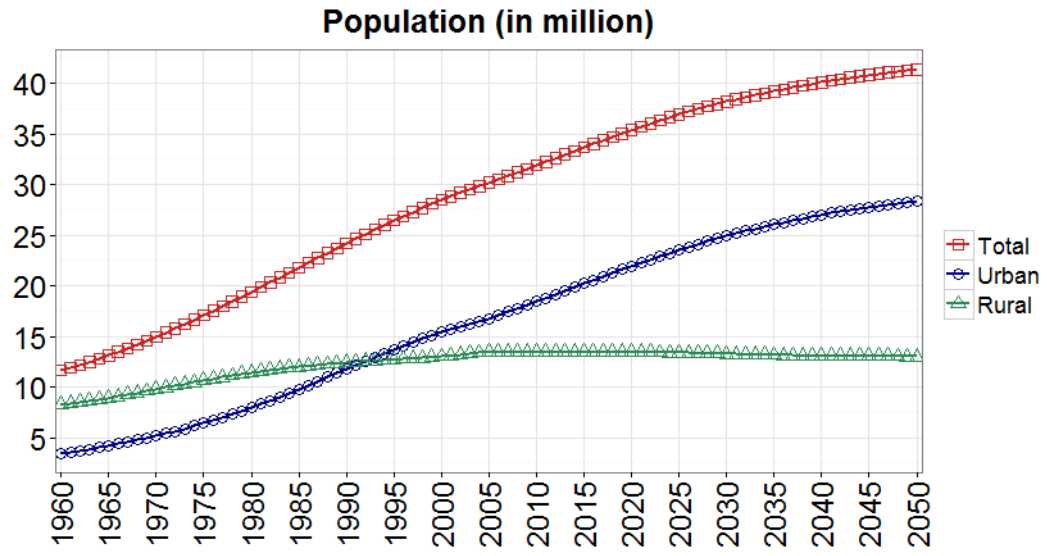

Figure 2.1 Evolution of Population in Morocco (1960-2050)

Source: Author's adaptation (Data Source: Haut Commissariat au Plan (HCP), http://www.hcp.ma/Demographie-population_r142.html - Last accessed 1/30/2015)

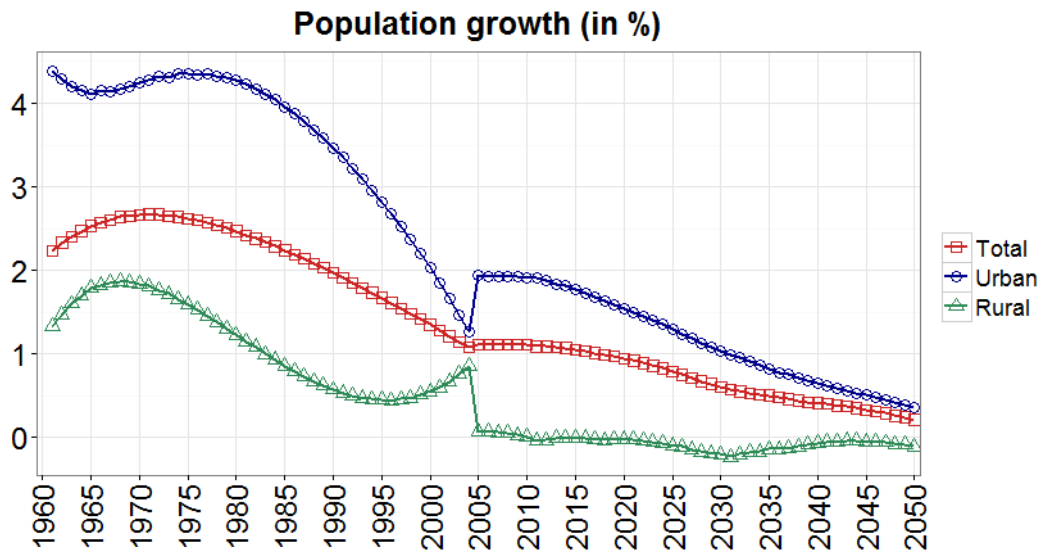

Figure 2.2 Evolution of Population Growth Rates in Morocco (1960-2050)

Source: Author's adaptation (Data Source: Haut Commissariat au Plan (HCP), http://www.hcp.ma/Demographie-population_r142.html - Last accessed 1/30/2015)

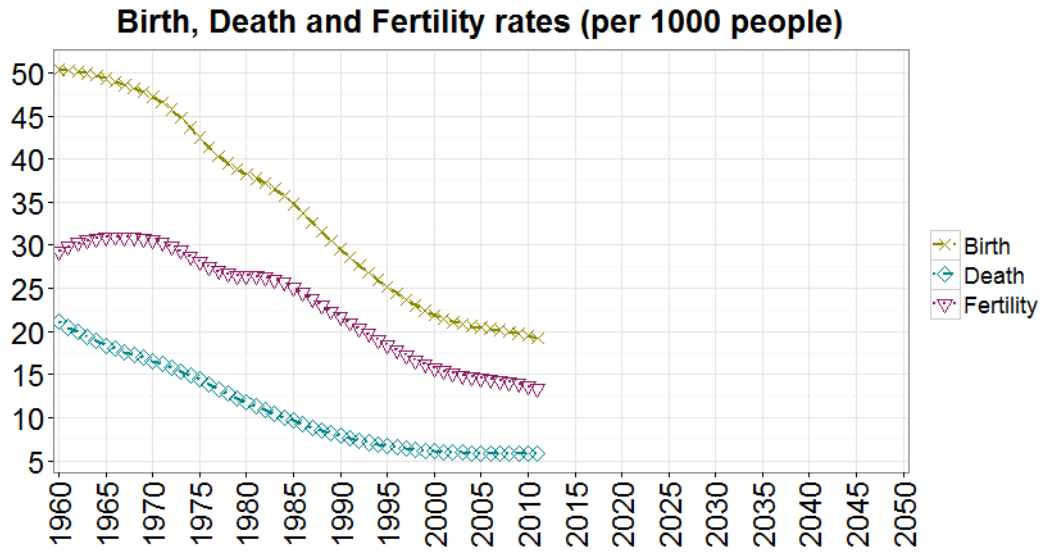

Figure 2.3 Evolution of Birth, Death and Fertility Rates in Morocco (1960-2012)

Source: Author's adaptation (Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

During the early post-independence decades, rural population was larger than urban population. By the early '90s urban population became larger due to increasing rural migration to urban centers (Figure 2.1). Improved economic prospects in urban areas and deteriorating living conditions for rural households, mostly among small-scale farmers, are the main factors explaining continued migration from rural to urban areas. Following the failures of agricultural policy reforms initiated in the pre-independence era and continued after independence, the wedge between income levels in rural and urban areas grew substantially (Figure 2.4).

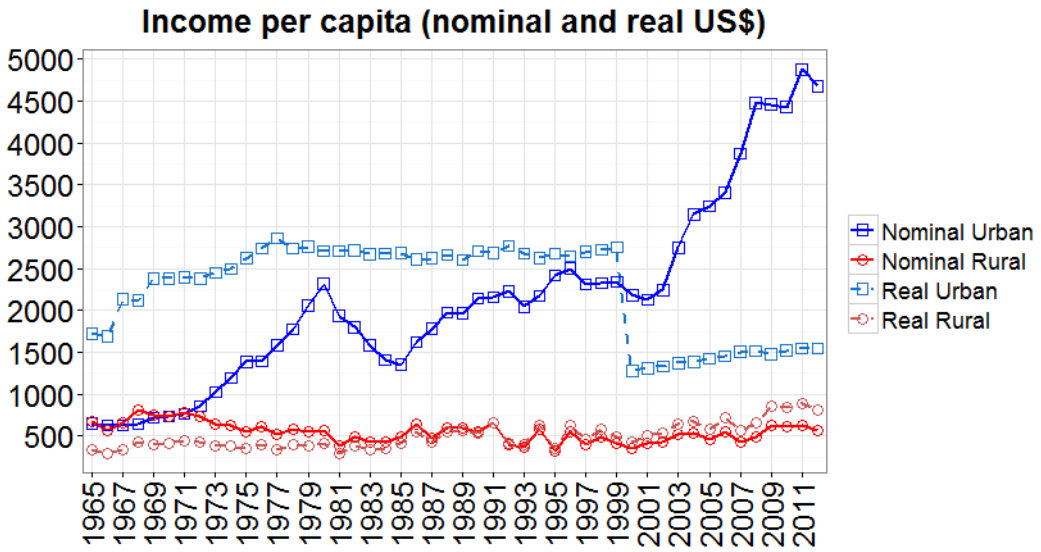

Figure 2.4 Evolution of Urban and Rural Income Per Capita in Morocco (1965-2011)

Source: Author's adaptation (Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

Indeed, the evolution of per capita income confirms the latter where urban per capita income experienced a sudden surge throughout the ‘70s, which was primarily driven by substantial public investments in industry and manufactures primarily centered in urban areas. Despite the debt crisis of the early ‘80s, and the macroeconomic impacts of the adoption of the Structural Adjustment Plan (SAP) which substantially impacted income levels, urban per capita income renewed its upward trend by the mid-‘80s and continued throughout the ‘90s albeit at a subdued pace, but in stark contrast with the stagnation observed in the evolution rural per capita income.

In terms of the age structure of the population, Morocco has a burgeoning youth population. This is explained by the fact that Morocco still enjoys relatively high fertility rates, although declining. Fertility rates experienced an increase in the early ‘60s and were at their highest level in the mid-60s as suggested by the large differential between crude birth and death rates. The impact of high fertility rates during much of the ‘60s and ‘80s translated into an ever increasing share of the active population, which by 2011 represented more than 65% of total population. This share is projected to increase in the coming decades (Figure 2.5).

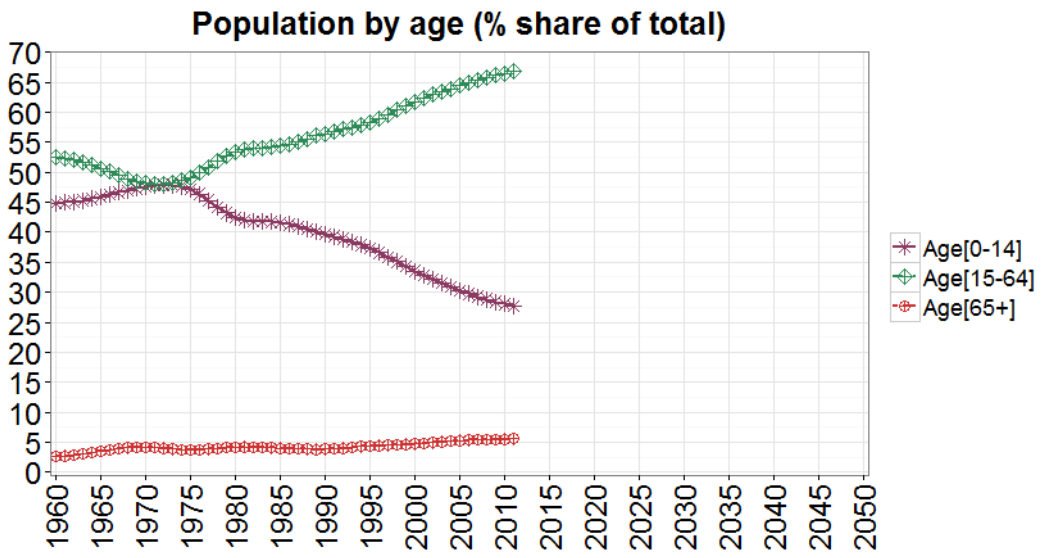

Figure 2.5 Evolution of Population by Age Group in Morocco (1960-2012)

Source: Author's adaptation (Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

The burgeoning of a young active population in Morocco creates increasing pressure on the economy in terms of achieving higher growth rates to induce a sustainable stream of job creation in order to absorb the influx of additional labor force. Historically, the public sector was the largest employer in Morocco given its preponderance in the economy through publicly-owned firms. These firms produced much of the economic growth observed in early decades of post-independence though public investments and a strong commitment to import-substitution investment strategies. Nonetheless, and due to the debt crisis in the ‘80s and the following adoption of the Structural Adjustment Plan (SAP), unemployment increased considerably and peaked at 23% by late ‘90s (35% for youth unemployment). This is in part due to the failings of

policy reforms enacted since independence to achieve a sustainable and stable growth path. Also, the overall economy remained linked with the highly volatile agricultural sector, which remains the major purveyor of jobs.

In the last decade, Morocco managed to achieve stable and accelerated GDP growth (Figure A2.1, Appendix A). Yet, it remains obvious that the latter was not enough to match the evolutionary dynamics of population transition owing to volatile growth rates. Despite the important strides realized in cutting down unemployment from the mid-90s historical highs, in the 2000s youth unemployment is again on the rise despite the growth performance registered during the last decade (Figure 2.6).

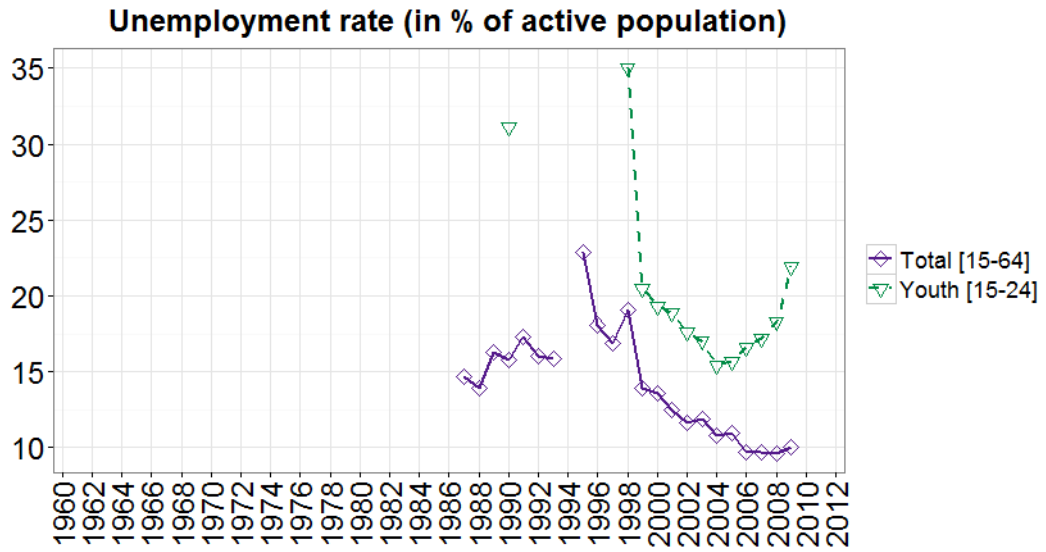

Figure 2.6 Evolution of Unemployment Rates by Age Group in Morocco

Source: Author's adaptation (Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

One of the major challenges facing the Moroccan economy is one of volatility in economic performance. Despite enormous efforts to decouple the economy from the

agricultural sector, the latter still affects economic performance through many channels. On the one hand, and as argued previously, agriculture (including forestry and fisheries) is a major purveyor of jobs nationally where it employs 40% of total active population and 75% of rural active population (Figure 2.7).

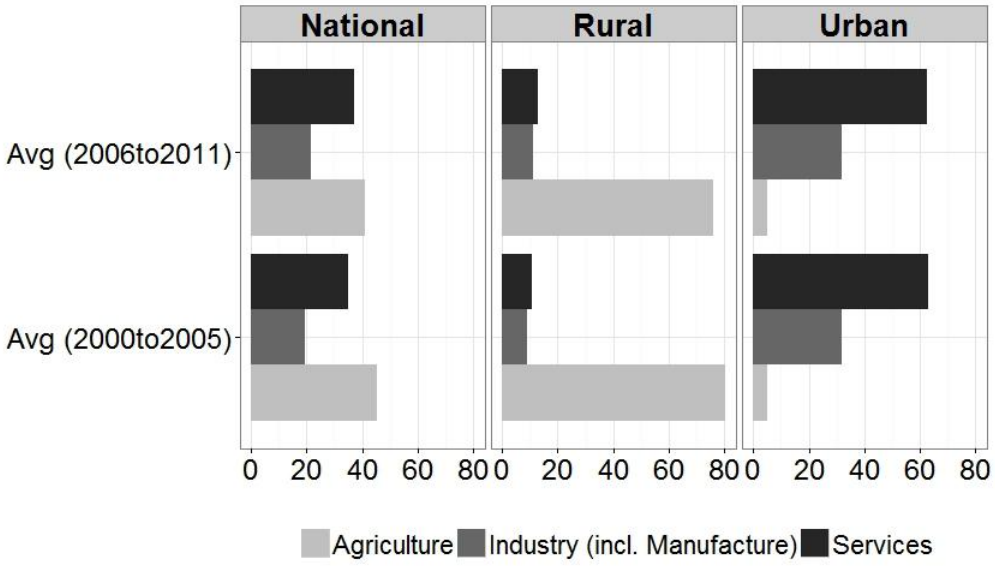

Figure 2.7 Evolution of Average Employment by Sector in Morocco (2000-2011)
Source: Author's adaptation (Data Source: Haut Commissariat au Plan (HCP), http://www.hcp.ma/Emploi_r67.html - Last accessed 1/30/2015)

On the other hand, despite a surge in government spending and investment in the sector throughout the ‘70s and ‘80s, the latter still suffers from volatile productivity owing to its dependency on rainfall patterns, which in turn affects performance to varying degrees in the non-agricultural sectors through backward linkages. This is clearly depicted by the correlation between the agricultural sector and non-agricultural sector growth pattern which displays little evolution in the direction of the decoupling of agriculture and non-agriculture sectors (Figure 2.8). Thus, the structurally volatile

performance in the agricultural sector results in a dampening of the performance of the rest of the economy.

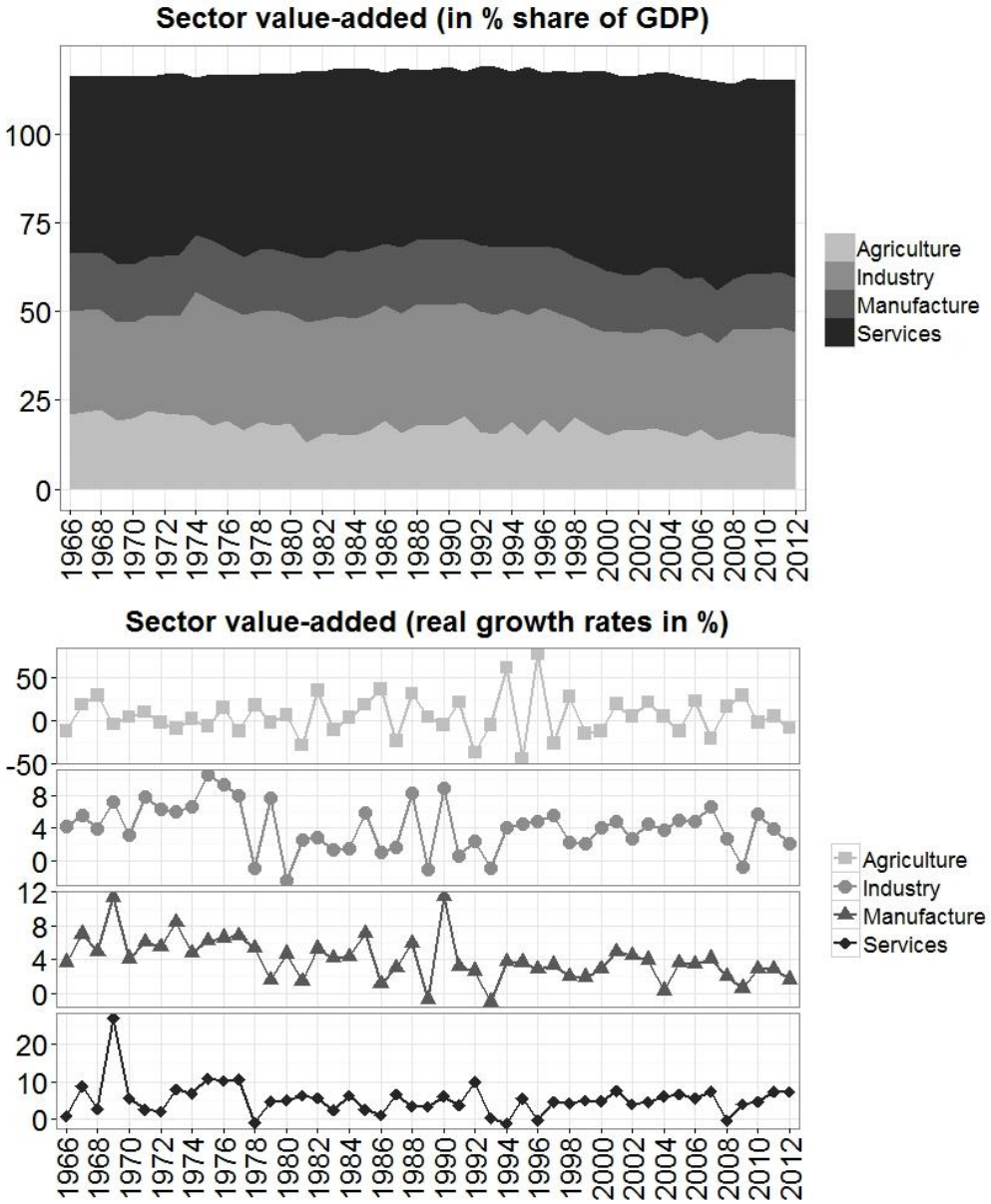

Figure 2.8 Evolution of Value-added Shares in GDP and Real Growth Rates by Sector in Morocco (1966-2012)

Source: Author's adaptation (Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

2.2 The Moroccan Agricultural Sector: A Historical Perspective

The agricultural sector in Morocco is still highly dependent on climatic conditions as depicted by the strong correlation observed between precipitations levels and average cereal yield for the four main cereal crops (i.e. common wheat, durum wheat, barley and maize) (Figures A2.2, Appendix A). This is due in part to the general structure of production activities in the sector, which has a high proportion of rainfed crops that are highly sensitive to climatic conditions and represent 55% of total value-added of crop production and occupy 65% of agricultural area.

Export crops, mainly citrus and vegetables, represent 15% of value added and respectively occupy 0.85% and 3% of total agricultural area. In terms of land cover, citrus and vegetables occupy a very small share, but their share in agricultural-added is substantially higher given the fact that those niches are usually more labor, chemical, and especially water intensive compared with cereals. Most of these crops are irrigated.

2.2.1 Moroccan Agriculture in the Colonial Period

The production structure, with its main focus on cereal production and especially wheat production is a direct result of colonial policies, which weighed heavily on subsequent attempts at reforms in the agricultural sector post-independence (Swearingen, 1985; Swearingen, 1987). During the first half of the colonial period (1912-1956), the Protectorate authorities initiated a “wheat policy” with the aim to assist France in achieving its wheat self-sufficiency. The policy was based on officially encouraging agricultural settlements of French farmers through a substantial subsidy program to shore up production and subsequently wheat exports to France and the world. As a result of the

Protectorate government-sponsored settlement program, 1,600 settlers occupied 250,000 hectares in the most fertile agro-ecological regions (e.g. Fes-Meknes, Chaouia, Marrakech, and Gharb regions). Additionally, 550,000 hectares were settled privately by 1,500 Europeans, mostly French nationals (Swearingen, 1985). Nonetheless, under the combined effect of high production costs, volatile productivity[3] and a costly subsidy program, Moroccan wheat production was hardly competitive in world trade. Thus, most of the production was directed toward the local and national French markets, which was in direct competition with nationally produced French wheat.

By 1929, France achieved wheat self-sufficiency, and moved to establish imports quotas on Moroccan wheat to curb competition with local production. Therefore, the official French settlement enterprise came to a complete halt by 1931 due to the deterioration of the financial viability of settler-farmers. As a response, the Protectorate authorities between 1929 and 1933 initiated a major overhaul of the agricultural sector in Morocco. The aim was to modernize production through investment in irrigated agriculture based on the "Californian model". The latter sought to invest in high value-added, export oriented crop varieties (e.g. vegetables and fruits). For this purpose, the

[3] As is still the case nowadays, cereal production suffered from weather fluctuations given the fact that most of the production was rainfed and relied on dry farming methods. Thus, during most of the colonial and post-colonial period, cereal yield was perennially low and highly volatile, which meant high production costs per unit of wheat and low net returns to farmers. Recent studies suggest an even worsening outlook with respect to the volatility of yield during the post-colonial period, and especially from the 80s onward.

O.C.E (Office cherifien de Contrôle et d'Exportation)[4] agency is created. It was modeled after the "California Fruit Growers Exchange" (Swearingen, 1987; Bouderbala, 1996).[5]

By the end of '30s, the "Californian" strategy morphed into a larger policy reform program as a response to the realization of the inadequacy of the "wheat policy". The aim of the new investment strategy was to achieve the strategic objective of irrigating 1 million hectares of crop production (Swearingen, 1985). To achieve the latter, public investments in large scale irrigation infrastructure was initiated, but was limited to a dozen perimeters in the most favorable agro-ecological regions in the coastal plains, which were geared toward production of high value-added, export-oriented crops (mainly vegetables and fruits). The beneficiaries usually were European settler farmers and rich Moroccan families who benefited from large land assets at the expense of small-scale farmers in rural areas, who received little support from authorities.

The dual-track policy reforms engaged in by the Protectorate authorities greatly affected the structural characteristics of the agricultural sector in Morocco, which continued to shape agricultural reforms that Moroccan authorities initiated in the post independence era. Reconciling the existing wedge between the modern and traditional agricultural sector was a major task of successive Moroccan governments. One of the major obstacles faced by reforms was the structure of agricultural land ownership which was highly unequal, and characterized by a concentrated structure where Europeans and a minority of Moroccans benefited from large tracts of land. In fact, most of the

---

[4] Dahir du 6 moharrem 1351 (12 mai 1932) relatif au contrôle des fruits et primeurs d'origine marocaine à l'exportation (BO N°1020 du 13-5-1932).
[5] http://en.wikipedia.org/wiki/California_Fruit_Growers_Exchange (accessed on: 06/12/2013)

agricultural land that benefited from the Protectorate authorities' modernization efforts (e.g. subsidies for mechanization of production, irrigation, etc), which amounted to 1.3 million hectares, was owned by 5,900 Europeans and 1,700 Moroccans according to official statistics (Swearingen, 1987; Bouderbala, 1996; Akesbi, 1997; Akesbi, Benatya and El Aoufi, 2008).

2.2.2 Moroccan Agriculture in the Post-independence Era

Upon investigating the long term trend in the sector's performance, we can identify three phases representing distinct growth patterns in term of volatility in the performance of the agricultural sector (Figure A2.3, Appendix A).

Phase I (1965-1980) was characterized by a rather weak performance of agricultural production, and even a slight decline of the per capita levels given the accelerated rate of population growth. The performance recorded during this period was contingent upon the performance of policies targeting the agricultural sector adopted in the early post-Independence years (1956-1965). These were to a great extent influenced by colonial-era policy reforms initiated by the Protectorate authorities. The first set of policies was oriented towards a reform of the status of property rights of agricultural land ownership through the nationalization of official and private colonial lands, and their redistribution by the Government (Swearingen, 1985; Swearingen, 1985; Akesbi, Benatya, and El Aoufi, 2008). Nonetheless, the scope of nationalization was limited to preserve vital commercial ties with France and to mitigate the risk of a potential economic crisis in the export-oriented modern agricultural sector with the departure of

European settlers who accumulated valuable know-how (Bouderbala et al. 1974; Swearingen, 1987).

The Moroccan authorities earnestly started to engage in an agrarian reform by late 1963, in which full nationalization of official colonial agricultural lands was a primary objective. The latter has been followed in 1973 by the recuperation of private colonial lands. In total, the nationalization policy of agricultural lands allowed the State to recuperate 1 million hectares of colonial lands (Bouderbala, 1997). Nonetheless, the effectiveness of the reforms did not address structural problems in the agricultural sector as depicted by the limited and skewed redistribution of newly nationalized agricultural lands that benefited small farmers only marginally (less than 50%) (Bouderbala, 1997; Akesbi, 1997).

By 1965, and due to a worsening economic outlook, the Moroccan authorities requested the World Bank's assistance, which specifically targeted the agricultural sector as a lever of economic development. The main objectives of the World Bank reform package centered on "modernization" and "profitability" in the sector (Akesbi, Benatya and El Aoufi, 2008). Nonetheless, most of the investment and reform agenda mainly targeted the export-oriented agricultural sector given the potential for short-term high returns. It is in this context that the old colonial objective of the 1 million hectares of irrigated agricultural production by 2000 was revived (Swearingen, 1987; Akesbi, 2005; Doukkali, 2005). Therefore, and with assistance from the World Bank, the government initiated a massive investment strategy in irrigation infrastructure. It mainly centered around building large-scale dams to mobilize the irrigation potential in Morocco. This policy was coined the "Politique des Barrages". To support the realization of the 1

million hectares objective, the government in 1969 introduced a new set of policy reforms coined the “Code des investissements agricoles”. It is presented as a contract between farmers and the government, defining rights and duties in irrigated perimeters to modernize and intensify production. In exchange for substantial fiscal incentives (e.g. subsidies, tax exemptions, etc) for acquisitions of machinery, fertilizers, seeds, etc., and favorable irrigation water tariffs, farmers in the irrigated perimeters agreed to land tenure and cropping patterns. Additionally, the agricultural investment code of 1969 included key rules aiming at structural reforms such as limitation of land fragmentation, regrouping of lands, registration of property rights, collective farming, etc. Nonetheless, the latter remained again largely unenforced given the socio-political context of the period (Akesbi, 2000).

Basically, in the two decades of post-independence era, the economic strategy adopted by Morocco was ambitious since it involved the combination of an “import-substitution” led growth strategy coupled with promotion of high value-added agricultural exports, and in which the modern agricultural sector was the main engine (Akesbi, 2006). Nonetheless, the government has intervened heavily and selectively to regulate markets and control prices for so-called “strategic” commodities (e.g. grains, milk, and industrial crops), which translated technically into controlling the flow of imports and exports. The policy objective that motivated the heavy intervention of the government was one of achieving food self-sufficiency. Hence, the combined effect of these policies has led to an implicit taxation of the sector, especially when accompanied with the overvalued exchange rate at the time (Doukkali, 2006) (Table 2.1).

Table 2.1 Evolution of Real Aggregate and Per Capita Agricultural Value-added Growth Rates during Phase I (in annual percent change)

	Total average 1966-2012	5-year averages		
		1966-70	1971-75	1976-80
Aggregate	5.3	7.3	-1.2	5.1
Per capita	3.3	4.5	-3.7	2.4

Source: Author's adaptation

(Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

Phase II (1981-1999), displays a substantial increase in value of agricultural production. At the aggregate level, output increased by 7% per year, and per capita output by 5% per year in real terms. These results are in sharp contrast with the growth performance observed during Phase I. In fact, the growth figures for Phase II are higher than the average growth rate registered for the period 1966-2012. Average real growth in aggregate and per capita levels reached 7% and 5% respectively for Phase II, compared with an average of 5% and 3% respectively for the period 1966-2012 (Table 2.2).

Table 2.2 Evolution of Real Aggregate and Per Capita Agricultural Value-added Growth Rates during Phase II (in annual percent change)

	Total average 1966-2012	5-years averages			
		1981-85	1986-90	1991-95	1996-99
Aggregate	5.3	3.6	8.8	-0.5	16.2
Per capita	3.3	1.2	6.6	-2.3	14.4

Source: Author's adaptation

(Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

The boost in agricultural productivity during this period came as result of relatively favorable climatic conditions, but also due to the combined effect of the King's plan in 1985 to double the area cultivated in wheat, and the sustained liberalization effort in the agricultural sector and the exoneration of agricultural revenues from income tax. The result was an expansion of agricultural area and a reduction of small scale farms, which came about due to increased investment and consolidation in the sector. This was depicted in the results of the General Agricultural Census in 1996, which demonstrated an increase in the arable agricultural area by 21% and a decrease of farm exploitations by 22% compared with the results of the General Agricultural Census of 1974. Between 1974 and 1996, the number of landless farmers and farmers with lands less than 1 hectare decreased by 86% and 28% respectively. The most noticeable increase is displayed by the number of farmers with lands between 5 and 10 hectares, which reached 13%. Nonetheless, small scale agriculture still dominates the distribution of arable lands as suggested by the share of number of farmers with less than 5 hectares, which still represents 71% the total population of farmers (Table 2.3).

Table 2.3 Evolution of Number of Farmers and Arable Agricultural Area by Farm Size for the General Agricultural Censuses of 1974 and 1996

Farm size (ha)	No. of farmers (1000)		Share (%)		Change (%)		SAU (1000 ha)		Share (%)		Change (%)	
	RA 1974	RGA 1996	RA 1974	RGA 1996	No. of farmers	Share	RA 1974	RGA 1996	RA 1974	RGA 1996	SAU	Share
no land	450.2	64.7	23.4%	4.3%	-85.6%	-81.5%	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
[0-1]	439.7	315.3	22.8%	21.1%	-28.3%	-7.6%	188.7	170.4	2.6%	2.0%	-9.7%	-25.2%
[1-3]	431.6	446.7	22.4%	29.9%	3.5%	33.3%	759.9	904.7	10.5%	10.4%	19.1%	-1.4%
[3-5]	217.8	237.7	11.3%	15.9%	9.1%	40.6%	823.3	1,011.1	11.4%	11.6%	22.8%	1.7%
[5-10]	219.8	247.8	11.4%	16.6%	12.7%	45.2%	1,507.2	1,894.7	20.8%	21.7%	25.7%	4.1%
[10-20]	114.1	125.2	5.9%	8.4%	9.7%	41.3%	1,525.2	1,880.5	21.1%	21.5%	23.3%	2.1%
[20-50]	43.8	47.9	2.3%	3.2%	9.4%	40.9%	1,215.3	1,526.3	16.8%	17.5%	25.6%	4.0%
[50-100]	7.7	7.8	0.4%	0.5%	1.3%	30.5%	512.3	585.1	7.1%	6.7%	14.2%	-5.4%
[100+]	2.5	3.2	0.1%	0.2%	28.0%	64.9%	699.5	759.4	9.7%	8.7%	8.6%	-10.1%
Total	1,927.2	1,496.3	100.0%	100.0%	-22.4%		7,231.4	8,732.2	100.0%	100.0%	20.8%	

Source: Author's adaptation (Data Source: MADRPM/DPAER 1998)

The 1985 King's plan to expand area cultivated in cereals also resulted in increased volatility of cereal production as production expanded onto more marginal lands. As a consequence, volatility of agricultural value-added increased given the weight of cereals production in the Moroccan agricultural sector. The observed change in standard deviation and variance attest to the previous conclusion. Indeed, between Phase I and Phase II, agriculture value-added growth's standard deviation and variance increased by 167% and 615% respectively; and hence the increase in GDP growth's standard deviation and variance by 69% and 187% respectively. These changes are slightly higher for the per capita levels (Table 2.4).

Table 2.4 Comparative Analysis of the Volatility of Performance between Phase I and Phase II

		Standard deviation		Variance	
		GDP	Agriculture, VA	GDP	Agriculture, VA
Phase I	Aggregate	3.4	12.5	11.3	155.1
	Per capita	3.3	12.1	10.6	147.3
Phase II	Aggregate	5.7	33.3	32.4	1109.1
	Per capita	5.6	32.7	31.1	1070.2
%Change (II - I)	Aggregate	69%	167%	187%	615%
	Per capita	71%	170%	193%	627%

Source: Author's computation

(Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

Phase III (2000-2012) displays a reinforcement of the increasing trend in terms of the evolution of the absolute value of production, both at the aggregate and per capita levels. For example, between 2000 and 2004, aggregate and per capita agricultural value-

added grew by 7.7% and 6.4% in real terms respectively. Nonetheless, productivity in the sector still hinges on climate conditions as depicted by the performance registered between 2010 and 2012, which exhibits negative growth rates at the aggregate and per capita levels. On average for Phase III, real growth rates in aggregate and per capita were lower than for the previous period (Table 2.5).

Table 2.5 Evolution of Real Aggregate and Per Capita Agricultural Value-added Growth Rates during Phase III (in annual percent change)

	Total average 1966-2012	5-year averages		
		2000-04	2005-09	2010-12
Aggregate	5.3	7.7	7.3	-1.7
Per capita	3.3	6.4	6.1	-2.8

Source: Author's adaptation

(Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

In terms of the policy, this period is characterized by continued effort of liberalization in the agricultural sector. Overall, the level of production compared to pre-1991 levels was clearly higher and more robust. When comparing measures of volatility between Phase II and Phase III, we notice a important decrease as suggested by the percent change in the standard deviation and variance of agricultural value-added growth trends (Table 2.6).

Table 2.6 Comparative Analysis of the Volatility of Performance between Phase II and Phase III

		Standard deviation		Variance	
		GDP	Agriculture, VA	GDP	Agriculture, VA
Phase II	Aggregate	5.7	33.3	32.4	1109.1
	Per capita	5.6	32.7	31.1	1070.2
Phase III	Aggregate	1.9	15.8	3.5	248.8
	Per capita	1.9	15.6	3.5	243.3
%Change (III - II)	Aggregate	-67%	-53%	-89%	-78%
	Per capita	-67%	-52%	-89%	-77%

Source: Author's computation

(Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

Nonetheless, agricultural growth is still subjected to important fluctuations driven by the successive drought episodes and increased volatility of rainfall that characterized the period, which were particularly severe for cereals.

In terms of linkages with the rest of the economy, GDP growth averaged by 4.5% per annum between 1965 and 1991. This was primarily driven by robust growth in the non-agricultural sectors where value-added in industry, manufacture and services grew annually by 4.2%, 4.9% and 5.6% respectively. Nonetheless, the growth in GDP and the non-agricultural sectors decelerated from 1990 onward, despite the relative improvement in the agricultural sector performance (Table 2.7).

Table 2.7 Evolution of Growth Rates for GDP and Sector Value-added in Real Terms

Period	GDP (% growth)	Sector value-added (% growth)			
		Agriculture	Industry	Manufacture	Services
1961-65	3.6	n.a.	n.a.	n.a.	n.a.
1966-70	6.3	7.3	4.8	6.2	8.9
1971-75	5.0	-1.2	7.4	6.2	5.9
1976-80	5.5	5.1	4.3	5.0	5.9
1981-85	3.4	3.6	2.8	4.5	4.5
1986-90	4.5	8.8	3.7	4.2	4.0
1991-95	1.1	-0.5	2.1	2.5	3.6
1996-00	4.0	10.6	3.7	2.7	3.5
2001-05	5.0	7.7	4.1	3.5	5.6
2006-12	4.9	9.4	3.8	2.6	4.1

Source: Author's adaptation

(Data Source: World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2013 - Last accessed 1/30/2015)

Overall, it appears that the agricultural sector in Morocco has been, and is still at the core of the Government's economic strategy given its strategic importance with respect to issues pertaining to employment, food security, poverty alleviation, etc. Despite the progress that has been achieved, there remain important challenges in the faceoff fully taking advantage of the potential of the agricultural sector. There is a strong consensus among policymakers that the growing hydrologic constraints in the country, owing among other things to climate change and its impacts on precipitation patterns, will be one of the major challenges in subsequent decades due to increased scarcity of water resources and demand driven by demographic pressure.

2.3 Climate in Morocco

2.3.1 General Background

Given its geographic location at the extremity of Northern Africa, between latitudes of 21°N and 36°N, Morocco's climate is characterized by two main climatic zones: the Mediterranean climatic zone in the northern coastal regions and the Sahara climatic zone which lies in the hinterland of the country to the south and southeast. These two zones are naturally separated by the Atlas mountain range that runs through the center of the country. The Mediterranean facade to the North (512 km from Saidia in the East to Cap Spartel in the West) and the Atlantic facade to the West (2934 km from Cap Spartel in the North to Lagouira in the South) play a major role in attenuating temperature variation across seasons.

The coastal plain regions in the north benefit from substantial rainfall, accompanied with snow in the mountainous regions. Summer temperatures are mild and vary between 22-25°C during July-August-September. Winter temperatures during January-February-March usually range between 10-12°C. Moving from the coastal plain regions in the west eastward, the climate becomes more continental with cooler temperatures at high altitudes, which on average are lower. The Moroccan interior depicts larger variability in terms of temperature across seasons, ranging on average from between 25-30°C in the summer season (July-August-September) and dropping considerably during the winter (January-February-March) to less than 15°C. In terms of precipitation, the wet season lasts between November and March with an average monthly precipitation of 50 to 100 mm. The latter affects mostly the northern coastal plains. In the south, average annual precipitation does not usually exceed 150 mm.

Using the classification method of agro-ecological zones (AEZ), Morocco can be divided into nine AEZs. Table 2.8 summarizers key characteristics for each AEZ based on the geographical identification in Figure A2.4 (Appendix A).

Table 2.8 Moroccan Agro-Ecological Zones (AEZ) and Key Characteristics

AEZ No.	Geography	Climate	Agriculture
I and II	- 10.5% of country area - Largely mountainous owing to the Rif and Haut Atlas mountains range	- Humid, with average annual precipitation range of 500-1050mm	- Agricultural land accounts for 19.8% of total regional area and 17% of total agricultural land - Irrigated land represents 14.9% total irrigated land - 25.3% of agricultural farms
III	- 4.9% of country area - Largely mountainous owing to the Moyen and Anti Atlas range	- Dry, with average annual precipitation <400mm	- Agricultural land accounts for 5.5% of total regional area and 2.1% of total agricultural land. - Irrigated land represents 2.2% of total irrigated land - 4.9% of agricultural farms
IV	- 5.4% of country area - Coastal plains and hills	- Relatively humid, with average annual precipitation >400mm	- Agricultural land accounts for 60.2% of total regional area and 27.5% of total agricultural land. - Irrigated land represents 17.7% of total irrigated land - 21.4% of agricultural farms nationwide
V	- 3.7% of country area - Arid plains and plateaus	- Dry, with average annual precipitation <400mm	- Agricultural land accounts for 50.7% of total regional area and 16.6% of total agricultural land. - Irrigated land represents 2.6% of total irrigated land - 11.3% of agricultural farms nationwide

Table 2.9 Moroccan Agro-Ecological Zones (AEZ) and Key Characteristics (continued)

VI	- 6.2% of country area - Arid plains and plateaus	- Relatively dry, with average annual precipitation <600mm	- Agricultural land accounts for 53.2% of total regional area and 28.5% of total agricultural land. - Irrigated land represents 47% of total irrigated land - 26.6% of agricultural farms nationwide
VII	- 9.2% of country area - Sub-arid and Arid plains and steppes	- Dry, with average annual precipitation range of 150-300mm	- Agricultural land accounts for 9% of total regional area and 5.8% of total agricultural land. - Irrigated land represents 4.1% of total irrigated land - 4% of agricultural farms nationwide
VIII	- 13% of country area - Pre-Sahara with concentrated oases systems	- Arid, with average annual precipitation range of 10-150mm	- Agricultural land accounts for 1.5% of total regional area and 1.1% of total agricultural land. - Irrigated land represents 6.3% of total irrigated land - 4.6% of agricultural farms nationwide
IX	- 47.2% of country area - Pre-Sahara and Sahara with dispersed oases systems	- Arid, with average annual precipitation range of 10-150mm	- Agricultural land accounts for 0.4% of total regional area and 0.4% of total agricultural land. - Irrigated land represents 5.2% of total irrigated land - 1.8% of agricultural farms nationwide

Source: Author's adaptation based on CGDA (2009)

(Data Source: http://www.agriculture.gov.ma/pages/publications/atlas-de-lagriculture-marocaine - Last accessed 1/31/2015)

2.3.2 Recent Trends in Moroccan Climate

Recent findings suggest that Morocco experiences increasing temperatures, with an observed increase in mean annual temperature of 0.9^{o}C since 1960, which corresponds to an average rate of temperature increase of 0.2^{o}C per decade. The trend in temperature increases varies with seasonal fluctuations, with statistical significance observed for the April-May-June and September-October-November seasons. The most rapid rate of temperature increase is observed for the April-May-June dry and hot season with 0.34^{o}C per decade. Increasing average annual temperature is accompanied by an increase in the frequency of hot days, which was found statistically significant across seasons, except for the September-October-November season. In addition, the frequency of hot nights has increased for all seasons. At the same time, the frequency of 'cold' days and nights has decreased for all seasons. In terms of precipitation, no significant trend is observed for the mean annual rainfall since 1960. Tables 2.9 and 2.10 summarize key findings on the evolution of temperature, precipitation, and frequency of hot/cold days/nights.

Table 2.10 Evolution of Observed Temperatures and Precipitation Trends for the Period 1960-2006

	Temperature		Precipitation		
	Observed Mean 1970-99 (°C)	Observed Trend 1960-2006 (change in °C per decade)	Observed Mean 1970-99 (mm per month)	Observed Trend 1960-2006 (change in mm per decade)	Observed Trend 1960-2006 (change in % per decade)
Annual	17.6	0.20*	23.6	-1.1	-4.5
JFM	11.8	0.05	36.3	-2.4	-6.7
AMJ	19.1	0.34*	18.5	-1.7*	-9.4*
JAS	25.3	0.14	6.2	0.3	4.3
OND	14.4	0.26*	33.2	-0.3	-1.1

* : Indicates statistical significance

Source: Author's adaptation based on McSweeney et al. (2010) (Data source: UNPD country profile - Morocco (2010) - Last accessed 4/29/2015)

Table 2.11 Evolution of Observed Frequency of Hot/Cold Days and Hot/Cold Nights for the Period 1960-2006

	Frequency of Hot Days (TX90p)		Frequency of Hot Nights (TN90p)		Frequency of Cold Days (TX10p)		Frequency of Cold Nights (TN10p)	
	Observed Mean 1970-99 % Frequency	Observed Trend 1960-2006 Change in frequency per decade	Observed Mean 1970-99 % Frequency	Observed Trend 1960-2006 Change in frequency per decade	Observed Mean 1970-99 % Frequency	Observed Trend 1960-2006 Change in frequency per decade	Observed Mean 1970-99 % Frequency	Observed Trend 1960-2006 Change in frequency per decade
Annual	11	1.37*	12	2.52*	9.4	-1.35*	8.7	-1.85*
JFM (DJF)	11.3	(1.62*)	11.5	(1.51*)	9.2	(-1.51*)	8.9	(-1.39*)
AMJ (MAM)	10.4	(1.41*)	11.8	(2.44*)	9.6	(-1.38*)	9.4	(-1.20*)
JAS (JJA)	12	(2.88*)	14	(4.71*)	8.9	(-1.68*)	7.5	(-2.18*)
OND (SON)	10.3	-0.54	11.8	(2.55*)	9.7	(-1.32*)	9	(-2.17*)

* : Indicates statistical significance

Source: Author's adaptation based on McSweeney et al. (2010) (Data source: UNPD country profile - Morocco (2010) - Last accessed 4/29/2015)

The historical record depicts a situation in Morocco characterized by increasing temperatures and diminishing precipitation, which can transform into severe drought episodes. Indeed, studies using tree-ring analysis in Morocco showed that from the fourteenth to the twentieth century, the country suffered from 147 droughts averaging 22 dry years per century (Morton and Sear, 2001; Chbouki, 1992; and Stockton, 1988). Swearingen and Bencherifa (1996) further finds that from late ninth century to early 1900s, Morocco experienced 49 major drought-related famines.

In recent decades, frequency of intense drought episodes has increased, especially from the 1980s onward. For instance, Stour and Agoumi (2008) find that prior to 1972, drought frequency and geographic reach was minimal. But between 1972 and 2004, the latter increased in frequency and intensity as demonstrated by the severe episodes of 1980-85, 1990-95 (especially 1994-95) and 1998-2000 (Shetty, 2006). The increasing frequency and intensity of climatic droughts affects greatly water supplies in Morocco, hence the occurrence of hydrological droughts. Ouassou et al. (2007) found that the most severe hydrological droughts occurred for the periods 1980-81 to 1985-86; 1991-92 to 1994-95 and 2000-01 to 2002-03. As a consequence, acute shortages in water flows occurred where surface water runoff estimated at 19 billions of m^3 decreased to 10 billions of m^3 for the period 1980-85, 4.9 billions of m^3 in 1992-93 and 5.3 billions of m^3 in 1994-95.

2.3.3 Projected Climate in Morocco

Recent results from analysis of climate projections suggest that Morocco's climate is becoming drier and hotter (IPCC, 2007). Average annual temperatures are projected to

increase by 1.1 to 3.5^{o}C by 2060s and 1.4 to 5.6^{o}C by the 2090s. The results of climate models depict substantial variability. Nonetheless, the projected trend in temperatures is increasing. For average annual precipitations, simulation results display a consistent pattern of decreasing rainfall. Deviations from the reference period range from small increases of up to 10% to a maximum decrease of 52%, with an average median change of -15 to -29% (Figure 2.9).

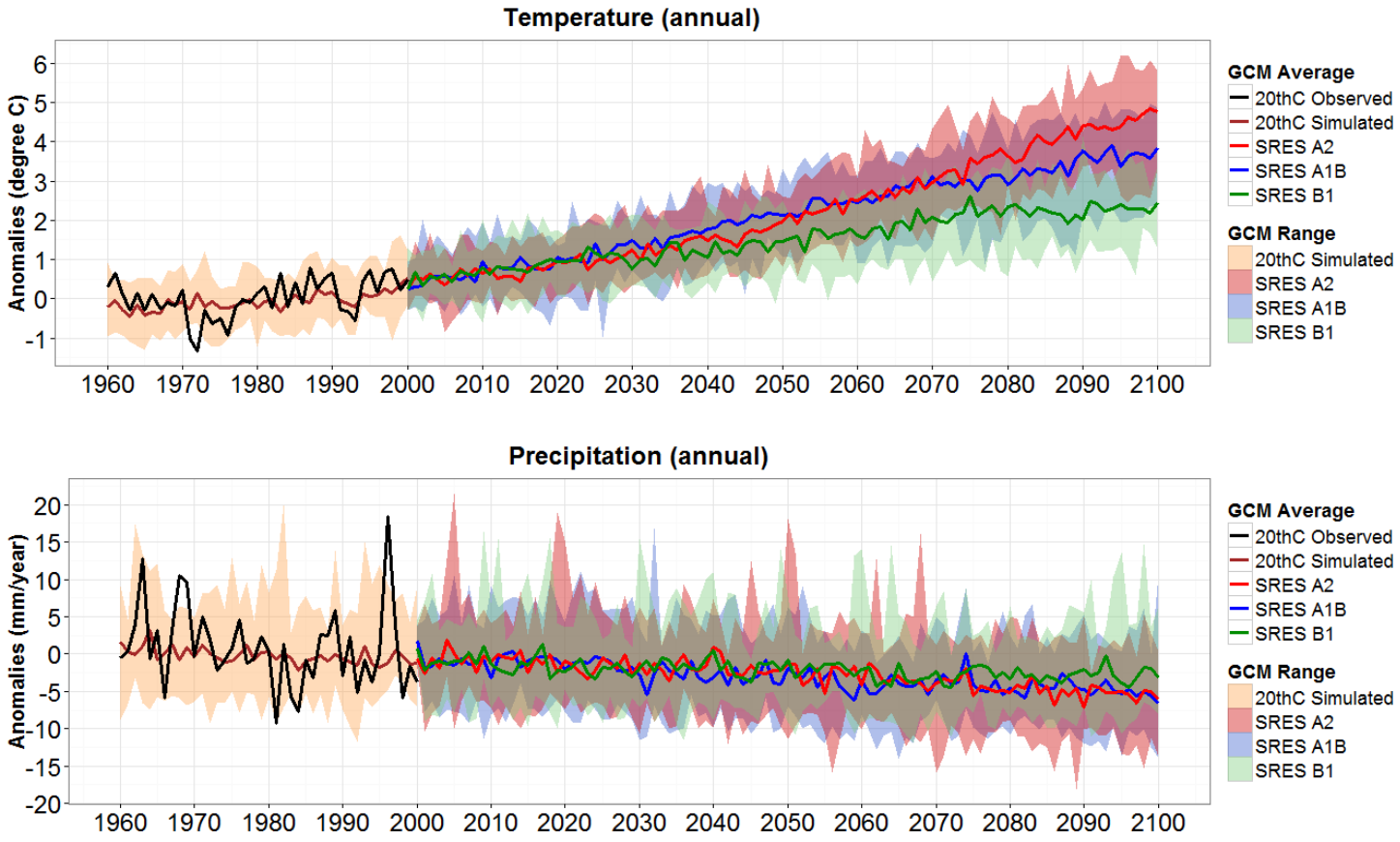

Figure 2.9 Evolution of Observed and Simulated Projected Average Annual Temperatures and Precipitations by SRES Scenario for Morocco

Source: Author's adaptation (Data source: UNDP Climate Change Country Profiles: Morocco)

Note : Indicated values are anomalies with respect to the mean 1970-1999

Additionally, the magnitude of projected average temperatures and precipitations display even larger magnitudes seasonally. Nonetheless, the trend is robust across models, which display a general increase in the former and decrease in the latter (Figure A2.5a and A2.5b, Appendix A).

In terms of 'hot'[6] days and nights, projections depict an increasing frequency of annual occurrence. For instance, by the 2060s the frequency of 'hot' days annually is estimated to range between 15 to 28% and 16 to 39% by the 2090s. A similar trend is observed for the frequency of occurrence of 'hot' nights, which is projected to reach 16-30% by the 2060s and 19-41% by the 2090s. Inversely, frequency of occurrence of 'cold'[7] days and nights is projected to decline by 5% and 4% respectively by the 2090s. But as was the case with average temperature and precipitation, the projections display quite large fluctuations across seasons. For example, the highest frequency of occurrence of 'hot' nights is projected to occur during the July-August-September (JAS) period and is projected to reach 31-91% (McSweeney et al., 2010; UNDP, 2010).

2.4 Climate in Morocco

As previously discussed, the climate in Morocco changes from dry and arid to humid and wet as we move from southern to northern latitudes and from eastern to western longitudes. As a consequence of the great dependence on precipitations as the only source of water in Morocco, sudden deficits in terms of annual precipitations can

[6] 'Hot' days (nights) are defined as the temperature exceeded in 10% of days (nights) in current climate of region and season of interest.
[7] 'Cold' days (nights) are defined as the temperature below which 10% of days (nights) are recorded in current climate of region and season of interest.

have substantial impacts on Moroccan agriculture and the wider economy. This dependency is clearly depicted by the strong correlation between annual variations in yields (especially for cereals) and precipitations (Figure A2.2, Appendix A).

Morocco ranks among the highest countries susceptible to frequent droughts occurrence as noted by numerous studies that suggest an increase in the frequency and intensity of drought spells (Morton and Sear, 2001; Chbouki, 1992; Stour and Agoumi, 2008). Climate change is expected to exacerbate this trend. Historically, droughts caused by extreme shortages of rainfall had devastating effects on the Moroccan agricultural sector and the wider economy. For instance, during the 1981-82 drought, the livestock sector incurred huge losses where 25% of cattle and 39% of sheep herds were sold or died. Additionally, the 1995 drought caused a loss of 82% of cereal production from the previous year. Aggregate agricultural output fell by 45%, and rural employment by 60%, resulting in the loss of 100 million work days in agricultural employment (Shetty, 2006; Ouassou et al., 2007). Hence, and considering the projected effects of climate change as a drought-reinforcing mechanism, the vulnerability risk associated with water shortages in agriculture increases. In addition, other factors compound the risk for agriculture such as increased demand for water use from the residential and the non-agricultural sectors.

2.5 Summary

This chapter described the evolution of the Moroccan economy and particularly of the agricultural sector before and after independence. From this historical perspective, a number of conclusions emerge. First, the agricultural sector, despite its decreasing share in the economy, remains a sector of strategic importance for Morocco given the strong

linkages with the labor market and the increasing dependency on food imports. Second, the productivity in the sector remains low despite the enormous efforts deployed at the policy-making level to enhance the latter. Low productive technologies (especially in rainfed areas), poor infrastructure, contradicting objectives at the policy-making level, and a strong dependence on climate fluctuations are but a sample of the major causes of the poor performance observed in terms of productivity in the Moroccan agricultural sector.

In terms of climate change, recent projections of temperature and precipitation depict an environment of increasing aridity in the weather. This translates into increased vulnerability of the agricultural sector, which is already evolving in a constrained environment.

CHAPTER 3. CLIMATE CHANGE IMPACT ASSESSMENT AND ADAPTATION: A REVIEW OF METHODOLOGIES AND CONCEPTS

3.1 Introduction

In the last decade, the literature on impacts assessments of climate change and adaptation experienced a substantial growth. Improved access to more reliable data in terms of downscaled (statistical and/or dynamic) weather data, increased investment in modeling suites and methods, and the open-source nature of newly developed databases that aim to merge all the information flow helped in spurring the increasing trend in scholarly output in the field. Nonetheless, there exist substantial differentials in the literature in terms of the methods and tools of assessment, the temporal and geographical scopes, the nature of impacts (i.e. the sectoral coverage), and the adaptation policies assessed. The heterogeneous nature of the literature on climate change impact assessment is a reflection of: 1) the very complex nature of climate change as an environmental hazard characterized by far-reaching impacts across natural and human systems, and 2) the diversity of data, methods and tools to analyze and assess impacts and adaptation policies.

In what follows, we provide a scoping review of the recent literature on the topic of climate change impact assessment and adaptation. The objective is to capture the state of the art in terms of scholarly research in the field, which will allow us to situate our own contribution. Nonetheless, and given the agricultural-centric focus of our study, we

will concentrate more on the literature covering the linkages of climate change and agriculture.

3.2 Estimating Climate-induced Impacts: A Review of Methods and Modeling Approaches

The literature of climate change impact assessment is extensive and rich in terms of its conceptual and methodological approaches. We can broadly summarize the latter in three major approaches used to estimate climate-induced impacts (Feenstra, 1998): the biophysical modeling approach, the socio-economic modeling approach, and the integrated assessment modeling approach. The choice of one approach over the other is motivated by the research questions being investigated (i.e. impact assessment only, impact assessment and mitigation and/or adaptation, etc.), and the focus of the study (both in terms of the geographic, temporal and sectoral coverage). Additionally, the choice of methodology depends on constraints in terms of data availability, access to modeling tools and infrastructure, etc.

3.2.1 The Biophysical Approach

The objective of the biophysical modeling approach is to assess directly first-order impacts of climate change on human and natural systems, and translate them into measurable indicators (e.g. yield change, loss of biodiversity, human health hazards, energy and transport infrastructure disruption, etc.). Most applications using the biophysical approach rely on two main modeling structures: process-based models and empirical statistical models.

3.2.1.1 Process-based Models

The process through which process-based models provide estimates of climate change impacts is via modeling the physical laws and first principles governing the linkages between the climate and the exposure unit. Their complexity can vary from simple monotonic formulation of linkages between the climate and the unit of exposure based on long-term averages (e.g. effects of mean daily temperature on excess mortality) to more complex formulations of biochemical processes determining system responses (e.g. dynamic vegetation models, basin-scale hydrological models, etc.) (Carter and Mäkinen, 2011; Friggens et al., 2013). Hence, they can be used irrespective of the geographic and/or climate zone in which the assessment is conducted. This is allowed given the universal nature of the theoretical underpinnings of plant physiology and/or soil-water dynamics. Nonetheless, the biophysical processes involved in climate change are highly uncertain, and especially when including confounding factors (e.g. CO_2 fertilization effects). Additionally, high level of expertise and extensive input data access is required for running simulations, which can be a limiting factor especially in the context of developing countries.

Most process-based modeling applications focus their efforts on impacts on vegetative systems (e.g. crop growth, forestry, etc.). This is hardly a surprise given the direct linkages between environmental stressors such as climate change and the vegetative system (e.g. crop production). But as previously argued, such endeavors remain plagued with limitations and uncertainties due to the dimensional heterogeneity in terms of the geographic and temporal scales, which renders the coupling across frameworks a challenge from the conceptual and technical side (Figure 3.1).

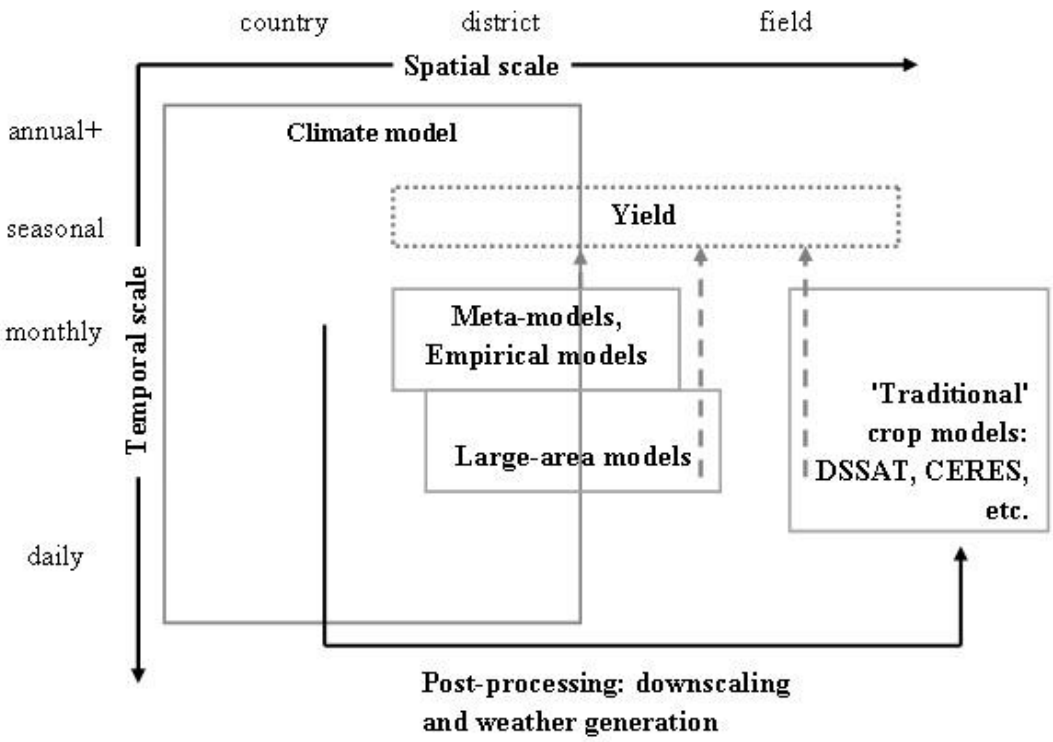

Figure 3.1 Summary of Methodological Framework in Linking Crop and Climate Models
Source: Challinor et al. (2009) (Fig.1.)

Challinor et al. (2009) provide a review of literature spanning the progress, trends and challenges in the context of modeling crop response to climate change. They found that the main source of uncertainty consists of the difficulty in linking climate and crop models. This is due to the discrepancy in terms of the scales at which each model category operates. In general, most crop models were initially developed to study plant physiology in controlled experiment settings at the field-scale level. As for climate models, they generally operate at a much larger scale, i.e. regional and/or country levels. To overcome this scale problem, the literature reviewed indicates two main strategies: 1) statistical downscaling of climate model output to field-scale level to be used as input in

the crop models; 2) develop large-scale crop models for direct use of climate model output.

For the first approach, climate projections from climate models are downscaled using statistical techniques to match the unit of analysis at which most crop models work. Examples of such techniques include regression approaches (Kim et al., 1984; Wigley et al., 1990; Burger, 1996), weather pattern approaches (Yarnal, 1993; White et al., 1991; Martin et al., 1997), stochastic weather generators (Semenov and Barrow, 1997; Zalud and Dubrovsky, 2002; Southworth et al., 2002), and limited-area climate models (Giorgi, 1990; Pielke et al., 1991; Mearns et al., 1995). The main advantages statistical downscaling offers are: generation of high resolution information, inexpensive computationally, and rapid simulation of multiple GCMs. However, downscaling techniques can suffer from bias owing to their sensitivity to underlying assumptions in the treatment of GCM output (Mearns et al., 1997; Mearns, 2003; Mavromatis and Jones, 1998). Also, they require fairly extensive access to climate data and long time series. Hence their applicability can be limited to countries and/or regions with substantial network of weather stations.

Large-area crop modeling in comparison allows for direct usage of GCM output in simulating the climate-induced impact. These models were developed as a response to the limitations previously discussed related to downscaling models. For instance, Challinor et al. (2003) develop a methodological approach to estimate optimal spatial scale for a combined seasonal weather and crop productivity forecasting system. Based on their methodology, Challinor et al. (2004) extend the previous analysis and develop the general large-area model (GLAM) to assess impacts of climate change on annual

crops. The objective is to allow for direct processing of GCM output data into a crop model to circumvent the problem of bias introduction characterizing downscaling techniques. To test their model, they simulated yield for groundnut in India using historical data on 2.5^{o} x 2.5^{o} grid cells from three different states. Subsequently, they aggregate results obtained from the 35 grid cells representing the three states to estimate yield at the country level. Their findings suggest relatively strong correlation between simulated and observed yields, with a coefficient of variation 0.76. Similar analyses were conducted based on the same methodology, but with differing geographic scales (global - Osborne et al., 2013; China - Li et al., 2007 and Challinor et al., 2010).

Nonetheless, there remain great challenges in terms of the ability to account for uncertainty and modeling of adaptation strategies also replication of results for crop categories beyond the traditional ones (e.g. maize, wheat, rice, etc). For example, White et al. (2011) examine in a scoping literature review methodologies for simulations of climate change on crop productivity from a biophysical perspective. They analyze 221 peer-reviewed articles adopting crop models as the primary source of climate-induced impacts on agriculture globally. The main conclusions from their analysis center around the limited geographic coverage of crop modeling in estimating climate change impact, but also the crop coverage. For the former, 55 and 64 out of the 221 peer-reviewed papers and studies centered their application on the US and EU cases. In terms of crop coverage, 170 out of 221 papers focused on crops such as wheat, maize, soybean and rice. Additionally, most of the studies focused on estimating impacts only (111 out of 221), and simultaneous analyses of impacts and adaptation (38 out 221). In terms of impacts assessed, most papers report on climate-induced impacts on yields.

Asseng et al. (2013) analyze the literature of crop modeling of climate change impacts on wheat. The objective of the study was to investigate crop model-based uncertainty which derive from the heterogeneity in model structure and parameter specification.[8] To that effect, they reviewed 27 crop wheat models applied in four different geographical locations. They conclude that given sufficient data input, most crop models investigated are able to reproduce observable grain yield and other crop components relatively well. But when introducing different assumptions about temperature, CO_2, and precipitation trends, the results show that uncertainty in models' projection of yield impacts and the CO_2 effects increases and shows strong dependency on temperature. As a result, their analysis concludes that studies relying mainly on one crop model to simulate climate-induced yield impacts fail to capture the uncertainties underlying crop response to climate change.

Palosuo et al. (2011) conducted a similar analysis for winter wheat, but focusing on Europe. They performed a systematic cross-comparison analysis of eight crop models. The main objective of the study was to evaluate the performance of crop models at the field scale. Particularly, the evaluation is conducted a context of limited information for calibration and simulation, spanning 49 growing seasons in eight different locations spread across northwestern, central and southern Europe. Their conclusions suggest that none of the crop models managed to perfectly reproduce historical observations of yield performance at all sites and in all years. Additionally, robustness of model estimates

[8] Asseng et al. (2013) argue that crop model-based uncertainty is usually ignored in most climate change impact studies. When uncertainty is included, it usually refers to global climate projections-based uncertainty and downscaled-based uncertainty stemming from usage of different SRES and GCM combinations.

across location and crop cultivars using minimal calibration was weak. This is not a surprise given the many sources of uncertainties underlying the task of crop modeling. A major finding from the analysis suggest that the mean of model predictions represents the most robust estimate of observed yield. Hence, using multi-model estimates can be an effective strategy to overcome single-model bias.

3.2.1.2 Empirical Statistical Models

Usage of regression-based models to investigate linkages between weather fluctuations and crop productivity has a long history. In the context of climate change literature, regression-based analyses became popular using the 'Ricardian method'. The Mendelsohn, Nordhaus and Shaw (1994) seminal study (henceforth referred to as MNS) popularized the 'Ricardian' approach to estimate climate-induced impacts, specifically on agriculture. The 'Ricardian' approach uses land prices and/or rents as the most suitable measure that incorporates the final effect of climate change. The MNS paper first applied the 'Ricardian' approach to the United States using cross-sectional data on climate (e.g. seasonal precipitation and temperatures), farmland prices and other control variables (e.g. soil types, erosion, salinity and slopes, etc.) for 3,000 counties. Using a global-warming scenario and comparing their results to the traditional production-function approach, their estimates suggested lower impacts on U.S. agriculture. Since its first application, the 'Ricardian method' has been implemented in a number of recent studies, spanning different regions from global to country-specific: Globe (Lobell et al., 2011), United States (Schlenker, Hanemann and Fisher, 2005; Schlenker and Roberts, 2009), Europe

(Lang, 2007), Latin America (Seo and Mendelsohn, 2008), Asia (Mendelsohn, 2014), Africa (Schlenker and Lobell, 2010; Kurukulasuriya et al., 2006).

Given the relatively low data requirements and speed of application, the 'Ricardian' approach gained a wide audience amongst researchers and especially in the context of developing countries. Nonetheless, simulating crop response to climate change based on regression-based models instead of process-based models (c.f. Section 3.2.1.1) can lead to substantial bias. The source can be attributed to numerous factors such as erroneous statistical records on production and gridded climate data (Soussana et al., 2010), extrapolation errors of statistical relationships under future climate conditions (e.g. effects of CO_2 fertilization, soil moisture dynamics, etc.) (Carter and Mäkinen, 2011), linearization bias in modeling empirical equations of crop yield and failure to account for subseasonal climate variability given their static treatment of crop response within a growing season (Challinor et al. 2006, 2009).

In recognition of those biases, recent studies attempted to tackle all and/or some of the limitations previously discussed. For instance, Schlenker and Roberts (2009) attempt to capture the non-linear linkage documented in the agronomic literature between crop yield and temperatures, controlling for other stressors. Their analysis estimates yield response for corn, soybeans and cotton in the United States. They estimate three empirical models of crop yield response to temperature: a flexible specification using a step function fitting separate growth rate for each three-degree temperature range; an eight-order polynomial function of temperature with adjustment for spatial correlation; and piecewise linear specification based on the agronomic concept of degree days. Under all model specifications, the non-linearity of crop yield response to temperature is

captured and exhibits a positive correlation up until temperature crosses critical thresholds leading to substantial negative effects after that point. This effect is found to be consistently estimated across time, locations, crops, and other climate-related confounding factors. A comparison of the three non-linear specifications with a linear specification exhibits great contrast. For instance, area-weighted average yield impacts before the end of the century varied between -30% to -46% for the slow warming scenario (B1) and -63% to -82% for the most rapid warming scenario (A1FI); whereas the linear model projected yield losses of -16% to +3% (B1) and -30% to +6% (A1FI).

3.2.2 The Socio-economic Approach

The first attempts by economists at eco-environmental modeling occurred in the late 70s, which was stimulated by the Toronto Climate Conference in 1988. Consequently, a important body of literature on the economics of climate change emerged, especially pertaining to cost and benefit analyses of CO_2 abatement. In general, three types of modeling approaches can be identified, which depend mainly on the scale of the analysis (Feenstra, 1998): farm-scale optimization models, sector-scale partial equilibrium models, and economy-wide models.

Farm-scale bio-economic models represent the finest scale at which economic modeling of behavior analyzes the adjustments and responses of single actors to perceived risks and opportunities stemming from environmental stressors. As such, these models can best capture the adaptive capacity at the farm level and simulate the impacts of strategies such as expansion of irrigation, crop-mix switches, changes in planting/sowing dates, etc. Nonetheless, and given the focus of such models on micro-

linkages, analysis of key drivers influencing farm-level decision making is treated exogenously (e.g. change in consumer demand, change in prices, etc.). Additionally, scaling-up of model results to sector level or national level remains a challenge given the sunk cost burden associated with replication and dissemination of models across a wide range of agro-ecological sites with heterogeneous agronomic and climate profiles.

On the other hand, sector and/or economy-wide models can simulate a variety of linkages that occur at the level of the economy as a whole or focus on a particular sector of interest. These models permit analysis of behavioral linkages of a wide range of actors at the sector and/or economy level. Thus, impacts on production outcomes and trade patterns can be estimated. As computer capabilities improved, a shift in modeling techniques occurred, which first consisted in a move from input-output and "macro-Keynesian" models to Applied (or Computable) General Equilibrium (AGE) models and models with both "bottom-up" and "top-down" characteristics (Bosello et al., 1998). The rationale of eco-environmental modeling is to estimate second-order effects on socio-economic system induced by change in environmental stressors (e.g. climate-induced productivity losses in crop yields).

In what follows, we present a review of literature on recent developments in modeling approaches previously introduced, and with a particular focus on the computable general equilibrium (CGE) models given the methodological focus of our analysis.

3.2.2.1 Bio-Economic Farm Models (BEFM)

Janssen and van Ittersum (2007) provide a detailed overview for modeling frameworks that focus on the farm problem. These models were initially used to predict and/or forecast impacts of policy changes on farm activity and management (Berentsen and Giesen, 1994; Bartolini et al., 2007), changes in farm structures, technology adoption and innovation, and linkages with the environment (Abadi Ghadim, 2000), etc. Methodologically, BEFMs are based on constrained optimization procedures and thus suited to analyze the farm problem. Additionally, the flexibility of their configuration allows for a detailed representation of the range of activities, restrictions and technical specification characterizing the farming enterprise such as linkages between crop and livestock production, etc. (Antle and Capalbo, 2001; Weersink et al., 2004). Several other reviews of quantitative tools for farm-scale modeling exist (McCown et al., 2009; Le Gal et al., 2011; Thornton and Herrero, 2001), but they all focus on a limited range of techniques and did not comprehensively cover the whole field of modeling applications, and especially in what pertains to climate change.

van Wijk et al. (2012) tackles this gap in the literature by evaluating a number of household and farm models globally in developed and developing country context. The analysis of the literature spanned 16,000 articles pertaining to 1000 bio-economic models of farming applied to agriculture, fisheries and aquaculture and natural resources management. The main areas of focus were crops (28%), soils (26%) and water (28%). In terms of application domains, most studies focused on analysis of productivity and production optimization of farm systems, emissions and environmental pollution. In addition, applications focusing on adaptation linkages were few and represented only 3%.

In terms of climate-related themes investigated by the studies retained in the final selection, food security was analyzed by one model only, IMPACT-HROM (Zingore et al., 2009; Waithaka et al., 2006). Accounting for climate variability was found to be a common feature to all models. In addition, most models using a mathematical programming (MP) routine were found to tackle issues pertaining to adaptation at the farm-scale level and their environmental linkages (e.g. Thomas et al., 2010; Keil et al., 2009; Quintero et al., 2009). Nevertheless, studies incorporating adaptation are not the norm. In general, the study highlights the fact that farm-scale modeling techniques recently developed are amenable to analyze different aspects related to climate change and adaptation.

3.2.2.2 Partial Equilibrium (PE) Models

Partial equilibrium (PE) models consist of modeling economic linkages pertaining to specific sector and/or region (or country). The main advantage of PE models consists in their ability to capture detailed representation of sector and/or region analyzed. In recent years, a number of partial equilibrium models have been developed with a primary focus on agriculture, with a regional and/or global scope. Most of these modeling frameworks were initially developed to analyze agricultural policies and their environmental linkages, with a policy focus range from farm support policies to trade liberalization reforms.

Britz and Heckelei (2008) present a summary of key developments in the area of agricultural partial equilibrium modeling in Europe. In their literature analysis, they

conclude that the European experience in terms of research development of PE frameworks experienced three major developments: explicit accounting for markets of primary factors, primarily agricultural land, at the regional level (Happe et al., 2006); inter-model linkages to exploit comparative advantages of different components, but with minimal complexity to alleviate high maintenance and management costs (Flichman, 2006; Jansson, 2007); and enhancement of agri-environmental linkages. Nonetheless, there remain areas of improvement of PE modeling frameworks, and especially in the area of extension of product and regional coverage and inclusion of adaptation and mitigation of climate change analysis.

Robinson et al. (2014) summarize the recent developments of PE modeling efforts within the The Agricultural Model Intercomparison and Improvement Project (AgMIP) framework.[9] They latter included four PE models widely used in the literature: IMPACT, GLOBIOM, GCAM and MAgPIE. These models can be divided into two categories, depending on the modeling structure of the supply-side: 'shallow structural models' and 'deep structural models'. The former usually model demand for land and crop yields as a function of prices, with minimal detail in terms of technology modeling and without explicit specification of maximizing behavior by agents (e.g. IMPACT and GCAM); whereas the latter explicitly introduces the optimization problem faced by farmers, with a more detailed treatment of technology (e.g. GLOBIOM and MAgPIE).

Fernández et al. (2013) investigate recent progress of coupling of biophysical and economic models, with a particular focus on global partial equilibrium (PE) models. Among the PE models reviewed in the study are: AGLINK-COSIMPO, FAPRI,

[9] For a detailed discussion of the AgMIP framework, see Rosenzweig et al. (2013).

AGMEMOD, CAPRI, ESIM, GLOBIOM, and IMPACT. Most of the issues analyzed and/or applications of reviewed modeling frameworks revolved around analysis of agricultural outlooks in terms of production and trade trends (OECD/FAO, 2013; FAPRI, 2012; Salputra et al., 2013), effects of biofuel policies (Havlik et al., 2011a, 2011b; Blanco, 2010; Babcock et al., 2013; Elobeid et al., 2011; Burell et al., 2012), the European Common Agricultural Policy (CAP) (van Leeuwen et al., 2011; Erjavec et al., 2011), free-trade agreements (Nekhay et al., 2011) and environmental impacts and climate change (Shrestha et al., 2012; Dumortier et al., 2010; Möller et al., 2011; Möller and Grethe, 2010; Nelson et al., 2010).

3.2.2.3 Computable General Equilibrium (CGE) Models

Historically, the use of Computable (or Applied) General Equilibrium (CGE) models expanded greatly from the early work of Harberger (1962) and Leif Johansen (1960). The widespread usage of CGE models came in part in response to the limitations exhibited by PE models, and the need to analyze consequences of macroeconomic policies and allocation of resources at the economy-wide level (Thissen, 1998). In a CGE framework, economy-wide analysis is achieved through the explicit modeling of cross-sectoral linkages derived from economic theory of welfare maximization and agents' optimization (e.g. utility maximization for consumers and profit maximization for producers).

The range of applied research based on CGE modeling frameworks expanded substantially over time. In the early 90s, CGE models gained wider acceptance among

economists analyzing environmental policy and natural resource management issues. Many environmental problems and policy questions are localized and site-specific, and hence the externalities associated with them are limited in terms of impacts trickling to the rest of the economy (e.g. air quality and noise in urban centers). Thus, one need not adopt an economy-wide analysis in order to analyze potential mitigation measures. Nonetheless, other environmental problems are global in their scope and potentially affect most of the socio-economic and environmental systems. For instance, the "Acid rain" problem caused by emissions of sulfur and nitrogen oxides and "climate change" caused by greenhouse gases emissions are prime examples. Hence, CGE models have been widely used to evaluate policies related to mitigation of these problems (e.g. the GREEN model - Burniaux et al., 1992; Hazilla and Kopp, 1990). Manne (2005) provides an overview of the modeling development in CGE applications to climate change, which accelerated following the adoption of the United Nations Framework Convention on Climate Change (UNFCC) in 1992 and the Kyoto Protocol in 1997.

In terms of climate change analysis, recent applications of CGE models span a wide range of topics and issues, across different regional scales. At the global level, the GTAP model has been used in many studies focusing on the linkages of land use change (LUC), greenhouse gas (GHG) emissions and biofuel globally (Golub et al., 2009, 2013; Birur et al., 2008; Hertel et al., 2008; Taheripour and Tyner, 2012; Taheripour, Hertel and Tyner, 2010). Hussein et al. (2013) for instance used a modified version of the GTAP model, GTAP-AEZ-GHG (Golub et al., 2010) in conjunction with a newly developed poverty module (GTAP-POV - Hertel et al., 2011) to investigate the impact of climate change mitigation policies on poverty in developing countries. Other applications based

on the GTAP modeling framework explored linkages of climate change and health (Bosello et al., 2006), climate change, sea level rise and tourism (Berritella et al., 2006; Bigano et al., 2008; Bosello et al., 2007b), energy demand (Bosello et al., 2007a).

In addition, numerous studies made use of country-specific CGE models to analyze the economy-wide impacts of climate change. Bezabih et al. (2010) develop a dynamic CGE model for the Tanzanian economy to investigate the impacts of climate change on agricultural land productivity by the end of the century. Their main conclusion indicates that despite worsening impacts on agricultural land productivity over the long-run, the economy-wide impacts can potentially be of limited scope. They hypothesize that given the time scales involved and the low starting point of the economy, negative impacts of climate change can be addressed via policies that enhance the ability of farmer autonomous adaptation (e.g. substitution of low productivity factors such as land for more capital and labor).

Kuik et al. (2011) used the newly developed MOSAICC model[10] by the Food and Agriculture Organization (FAO), in partnership with European research institutes. The model allows for country-based climate change impact analysis via its modular platform. The latter include a climate data module, which aims at statistical downscaling of climate data to be used in subsequent modules. Crop and hydrological modules are used to simulate crop growth and river basins hydrology under different climate change scenarios, using data from the previous module. Subsequently, a country-based Dynamic CGE

[10] MOSAICC - Modelling System for Agricultural Impacts of Climate Change (http://www.fao.org/climatechange/mosaicc/en/)

model[11] was employed for the economic analysis of climate change impacts through yield variations. The authors tested the model using Morocco where data projections were used for the period 2001-2030.

Breisinger et al. (2011) investigates the linkages of climate change and adaptation options for Syria at the sub-national level using a dynamic computable general equilibrium (DCGE) model. They develop scenario analyses of long-term trends in key drivers such as world prices for agricultural commodities and energy drawn from the IMPACT model, projected yield changes the DSSAT model, etc. These projections serve as the basis for the sub-national DCGE model to investigate wide-economy effects of climate change. Their results point to overall negative welfare impacts on households - welfare decreased annually by 1.6 to 2.8 percent.

In a similar vein, Lin et al. (2011) develop a sub-regional CGE model for China to investigate interregional linkages of climate change impacts. A key objective is to analyze the change in interregional trade flows. Their results indicate substantial changes occurring by 2030 and 2050 in terms of outflows of tradables from Northwest, South, Central and Northeast China. They argue as a result that storage, handling and transportation infrastructure need to change in order to accommodate the changing geography of interregional trade patterns so as to smooth out supply chocks across the country.

Thurlow et al. (2009) investigate climate variability and its impacts on economic growth and poverty in Zambia. To that effect, they integrate a hydro-crop model with a

[11] The Dynamic CGE model was developed in partnership with the Free University of Amsterdam, and is inspired by the IFPRI DCGE model (Lofgren et al., 2002; Thurlow, 2004).

dynamic DCGE model. Hydro-crop modeling allows for estimating potential yield impacts due to climate change within Zambia's five agro-ecological zones (AEZ). Yield projections are subsequently introduced as productivity shocks in the DCGE model. A key feature in the analysis is the link between the DCGE model and a micro-simulation module based on the 2004 Living Conditions Monitoring Survey (LCMS4). Their results suggest that climate variability costs the country US$ 4.3 billion over a 10-year period, with maximum loss attaining US$ 7.1 billion under the worst rainfall scenario. Additionally, they estimate that 300,000 people drop below the national poverty line by 2016. When considering the impact of climate change on historical climate variability, the findings suggest that negative effects are enhanced by a factor of 1.5. As a result, an additional 30,000 people drop below the poverty line.

Dudu and Cakmak (2014) use a Dynamic Computable General Equilibrium (DCGE) for Turkey to quantify the economy-wide effects of climate change in Turkey for the period 2010-2099. To that effect, yield projection scenarios were developed using a crop water requirement module. Key findings suggest that the negative effects of climate change on the economy will not materialize until late 2030s; thus suggesting a window of opportunity for policy-makers to adopt appropriate adaptation measures. Post 2030s, the climate-induced impacts will be substantial, with agriculture and food processing sectors incurring most of the cost.

3.2.3 The Integrated Assessment Models (IAMs) Approach

The current trend in climate change studies point to the increasing popularity of Integrated Assessment (IA) frameworks and their associated models known as Integrated

Assessment Models (IAMs). The basic idea behind IAMs is to take account of the different channels through which climate change operates, and hence generate comprehensive assessments of the totality of the impacts, which might exceed the sum of estimates from sectoral analyses. Moreover, placing the impacts stemming from climate change in broader context such as natural resource management, ecosystem sustainability, or economic growth represents a key objective of the IAMs (Feenstra, 1998). As such, we could argue that IAMs by design are more ambitious than the methods previously discussed as their purpose is to create direct linkages among different systems (e.g. coupling of climate and earth system models with models of social and economic behavior).

The development process of IAMs usually puts greater demands on component studies using area-specific modeling tools, and integrating them into a single framework. Thus, multidisciplinary effort is required, and presents important challenges in terms of building feedback linkages among differing assessment methods and the treatment of insufficient and/or limited information. As such, most IAMs are characterized by increased level of complexity, which renders their validation and assessment of performance a difficult task (Schwanitz, 2013).

In recent years, development and/or improvements to IAMs modeling experienced a considerable growth. Hertel and Lobell (2014) review some of the major developments, with a particular focus on economic-oriented intertemporal IAMs. A primary focus of their review is to assess the extent of IAMs' ability in integrating adaptation processes and provide feedback on trade-offs among different alternatives.

Among the IAMs reviewed is the Dynamic Integrated model of Climate and the Economy (AD-DICE) and AD-WITCH model which builds on the World Induced Technical Change Hybrid (WITCH) model. De Bruin et al. (2009) first introduced adaptation explicitly in the DICE, which is rooted in the seminal work of Nordhaus (2008). A major objective is the derivation of adaptation cost functions, which were implicit in the DICE model. This is achieved by explicitly identifying protection (or adaptation) costs and residual damages in the DICE model. They tentatively conclude that the implicit treatment of adaptation in the DICE framework does not affect the final assessment in terms of mitigation results. Nonetheless, explicitly including adaptation sheds light on the different trade-offs facing policy-makers in terms of strategies to follow. For instance, they argue that in the short-run, adoption of adaptation strategies is more beneficial than mitigation.

Bosello et al. (2010) first introduced adaptation into the WITCH model developed by Bosetti et al. (2006, 2009). The WITCH model was developed initially to analyze the evolution of future energy scenarios and their linkages with reduction targets in GHG emissions, and the potential impacts of climate policy. The model draws from the neoclassical insight in terms of long-term optimal growth theory, and combined with a rich representation of energy input detail. Adaptation enters the WITCH model through a separation of residual damage from adaptation expenditures, which become policy variables. The authors distinguish three types of adaptive responses: investment in anticipatory adaptation, expenditure in reactive adaptation, and investment in innovation for adaptation. A key result from the analysis is that adaptation and mitigation

complement each other in terms of reduction of climate-induced damages in an optimal scenario. Nonetheless, adaptation provides the bulk of damage reduction.

The AD-DICE and AD-WITCH models represent a tightly integrated approach to the analysis of climate change. Nonetheless, there exist other modeling frameworks characterized by a "loose" linkage among its components. Hertel and Lobell (2014) distinguish this family of IAMs as "Linked Integrated Assessment Modeling Frameworks". The main modeling platforms reviewed include the PIK suite (Popp et al., 2011), GLOBIOM (Havlik et al., 2013), the MIT suite (Paltsev et al., 2005), GCAM (Calvin et al., 2012) and IMAGE IAM framework (Bouwman et al., 2006). Most of these models combine different modules (e.g. crop growth modules, global land use modules, livestock modules, forestry modules, etc.) at varying geographical scales for the assessment of climate change impacts. Cross-module linkage is operated through the estimation of impacts, and introduced as exogenous shocks (e.g. crop growth models generate yield projections that are fed into the economic module as productivity shocks). The majority of these frameworks consider autonomous adaptation through endogenous modeling of technical change in agriculture, intensification of production, irrigation, change in crop mixes, etc.

3.3 Adaptation in Impact Assessment of Climate Change

As previously argued, mitigation was the focus of most early studies of impact assessment of climate change. Indeed, earlier work on IAMs did not incorporate explicitly adaptation modules. Most of the research effort tended to lean towards analyzing mitigation strategies based on trade-off analyses of climate-induced costs and

mitigation costs. The need to incorporate adaptation became necessary as a consensus on cuts to and/or stabilization of GHG emissions as a mitigation strategy failed to emerge at the international level. Hence, the research effort shifted its focus into incorporating adaptation in their modeling frameworks as a second best strategy (Burton et al., 2002).

The shift to include adaptation as a viable alternative to cope with the impact of climate change was not well received within the scientific research community (Schipper, 2006a; Klein, 2003). The concern was that by focusing on adaptation, the risk of forgoing mitigation strategies aiming at curbing GHG emissions would fade away from the policy-making agenda. Nonetheless, as evidence of unavoidable climate-induced impacts mounts and in the face of the protracted character of the politics of mitigation, adaptation became a viable option especially among the climate change and the development assistance communities (IPCC, 2007: 18; DFID, 2005; UNDP, 2004; AfDB et al., 2003).

Basset and Fogelman (2013) provide a recent analysis of the historical evolution of the concept of adaptation. To that effect, they conduct a literature review spanning the four IPCC reports (IPCC, 1990, 1996, 2001, 2007) and four scholarly journals spanning the 1996-2011 period[12]. They notice that the concept of adaptation experienced a momentous comeback in recent years. This is in contrast with its relative abandonment some 30 years ago owing to the severe critique it encountered from the cultural ecology and natural hazards literatures (Robbins, 2004: 40). Historically, the resurgence of the adaptation concept coincided with the emergence of a large body of literature in the climate change arena. They argue that it started initially with the second and especially

[12] The four journal are: Global Environmental Change, Climatic Change, Climate and Development, and Mitigation and Adaptation Strategies for Global Change.

with the third Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2001). For instance, they found that of the 558 papers reviewed from the selected journals, 68% appeared in the period 2007-2011. Moreover, most studies reviewed (70%) depict an interpretation of adaptation along the line of the IPCC definition which considers adaptation as adjustments to climate stimuli. A similar critique is leveled by Lobell (2014). He argues that current conceptualizations of adaptation are vague and broad, and risks deviating from the key purpose of assessing the impacts of GHG emissions.

In the context of agriculture, Hertel and Lobell (2014) distinguish between three levels of adaptation drawing from the work of Antle and Capalbo (2010). The main distinctions between these levels of adaptation are based on the portfolio of available technology, timing of dissemination and the investment costs associated with them. The first level of adaptation concerns the change in managerial behavior related to intensity of use of inputs, without adoption of new technology. This form of adaptation is typical of short-term responses by producers and can be observed under different circumstances (e.g. increased groundwater extraction during rainfall shortages), and environments (Mendelsohn et al., 2006; Deryng et al., 2011; Claessens et al., 2012).

The second level of adaptation involves adoption of new technologies. This option usually induces a substantial and permanent modification of the production structure. Technological breakthroughs greatly enhanced productivity worldwide and especially in developing countries (Olmstead and Rhode, 2011). Nonetheless, it remains evident that the level of risk associated with this level of adaptation present great challenges. Indeed, producers' ability to gain access to new technologies is a function of

availability of the technology, the cost of investment, and increasingly the uncertainty characterizing climate change impacts.

The third level of adaptation involves decision-making at the policy level, which affects greatly the institutional environment within which the producer is operating. Macroeconomic policies bear considerable impacts on perceived (or expected) gains to be had by producers owing to their effects on prices of output and input. For instance, Babcock (2014) estimated that in the wake of the 2012 drought in the US, federal crop insurance pay-out doubled compared to payments under conventional forms of disaster relief. Of course, climate change has the potential to further exacerbate price fluctuations, not only locally, but at the regional and global scale (Hertel et al., 2010). Other forms of government intervention can help farmers cope with climate disruptions. For instance, investment in early warning systems and/or information systems on weather outcomes, pests, etc. and their dissemination to farmers can influence adaptation behavior (Jarvis et al., 2011; Moorhead, 2009; Farrow et al., 2011). Infrastructure upgrading to ensure market access can play a major role in the adaptive capacity of farmers, especially in developing countries (Burgess and Donaldson, 2010; Ahmed et al., 2012).

In the climate change literature, the three levels of adaptation discussed can be grouped based on whether they are ‘autonomous’ or ‘planned’, or a mix of both. Clearly, the first level falls within the ‘autonomous adaptation’ category as it relates mainly to reactive actions taken by private agents in the face of a change in underlying conditions. The second level of adaptation can be categorized as blend of private and public actions, where changing patterns of crops tenure and location, and development of new varieties by private R&D is a result of market signals especially in industrialized countries;

whereas in developing countries, most research and development is publicly conducted. The third level by its very nature belongs to the ‘planned adaptation’ category.

3.4 Summary

In this chapter we provided a review of major methodological approaches in impact assessment of climate change, and their ability of inform mitigation and/or adaptation. The main modeling approaches identified were: the biophysical approach, the socio-economic approach and the integrated assessment approach. Each approach has strength and weaknesses in terms of its modeling capacities and range of applications. Additionally, we reviewed the evolution of the concept of adaptation and its different forms.

In terms of sectoral focus, the majority of methods and tools reviewed focus on assessing climate-induced impacts on agriculture and by extension ecosystem services. Challenges remain in terms of choice of modeling tools and approaches to provide estimates of impacts, and the geographic and temporal coverage of such methods. These challenges mainly center on data quality, availability and scalability, which are more acute in developing countries context. Recent trends in modeling suggest a shift towards adoption of integrated approaches, or as Wicke et al. (2014) refers to "model collaboration" in the case of the growing literature on the bio-based economy. The objective is to improve linkages among existing modeling approaches. Current frameworks are characterized by the heterogeneity of their modeling perspectives ranging along the spectrum of short vs. long term, local vs. global and/or economic vs. physical impact analyses. In addition, there are numerous limitations specific to the modeling

structure which center around the partial sectoral representation, lack of geographical details, and aggregated technological representation. To achieve model collaboration, a number of arbitrages need to occur. Key among them are ensuring data consistency across platforms, model complexity, collaboration and validation on one hand, and on the other achieving credibility of the results.

For our analysis, we identified CGE-based methods as the most suited tool of analysis for our purpose. The choice of methodology is motivated by the nature of the questions tackled by our analysis and its objectives. We focus on analyzing economy-wide effects of climate change through the agricultural channel in Morocco, which exhibit strong linkages to the rest of the economy. Hence, adopting a partial equilibrium method or sector-focused approach would not allow us to capture the GE effects that can be large. Additionally, as part of our analysis is the assessment of identified adaptation strategies, which primarily revolve around 'top-down' (or as discussed 'planned adaptation') policy reforms in the agricultural sector in Morocco. Therefore, we argue that using a general equilibrium approach best fits our needs.

CHAPTER 4. CLIMATE CHANGE, AGRICULTURE AND THE ADAPTATION POTANTIAL OF THE 'PLAN MAROC VERT' IN MOROCCO: A CGE ANALYSIS

4.1 Introduction

In Chapter 4, our objectives are twofold: first, we attempt to map the extent of climate change impacts on Moroccan agriculture by 2050 and its trickle effects on the wider-economy. Second, we investigate the adaptation potential of the new Moroccan agricultural investment strategy, namely the "Plan Maroc Vert" (PMV).[13] To this effect, we develop a country-based CGE model of the Moroccan economy. As we previously argued, Morocco's climate and landscape is characterized by its heterogeneity, and hence the diversity of cultivars across regions. Thus, we try to capture the regional diversity by introducing a regionalized structure to the model. A key objective of the analysis is to capture the uncertainty characterizing the potential impacts of climate change. Therefore, we adopt a scenario-based simulation strategy of climate change under a set of identified agricultural productivity pathways, with the aim of capturing the most important impacts.

Despite the fact that the agricultural sector in Morocco is projected to be negatively affected by climate change, the literature contains few empirical studies providing estimates in terms of potential impacts (Kuik et al., 2011;). Moreover, empirical studies that aim at assessing potential adaptation policies in Morocco are sparse,

[13] The "Plan Maroc Vert" will be referred to as "PMV" henceforth.

or non-existent. To our knowledge, we are the first to analyze the PMV's adaptation potential in a CGE framework.

4.2 The Morocco Country-based CGE Model

We develop a regionalized general CGE model for Morocco. The model development follows IFPRI CGE modelling framework (Lofgren et al. 2002) and the Turkish regional CGE model developed by Dudu and Cakmak (2011). The model includes a number of features critical to analyses focusing on developing countries such as modules on household consumption of non-marketed (or 'subsistence') commodities, and multi input-output production structure that allows for any activity to produce multiple commodities and any commodity to be produced by multiple activities.

Production is modeled under the assumption of profit maximization subject to a production technology (Figure A4.1, Appendix A). The model specification allows for flexibility in terms of production technology to be used. At the top level, the technology is specified as constant elasticity of substitution (CES) function or, alternatively, a Leontief function of the quantities of value-added and aggregate intermediate input. For the purpose of our analysis, we use the default specification of a Leontief technology. We assume that each activity at the aggregate level uses bundles of value-added and aggregated intermediate inputs to produce a unit of output according to fixed yield coefficients.

Solving the profit-maximizing problem implies that factors are used up to the point where marginal revenue product of each factor is equal to its wage (or factor price). In the model, an economy-wide wage variable is free to vary to assure that the sum of

demands from all activities equals the quantity of factor endowments, which is assumed to be fixed at the observed level. Output price for each activity is then derived from the price of value-added and intermediate inputs, in addition to any output taxes or subsidies imposed by the government.

The CGE model includes an institutional structure represented by households, the government and the rest of the world. Household consumption is modeled via a Linear Expenditure System (LES). The utility maximization problem for the representative household is solved using a Stone-Geary utility function subject to a consumption expenditure constraint. Household consumption covers marketed commodities, purchased at market prices, and home commodities, which are valued at activity specific producer prices.

Government collects taxes (fixed at ad valorem rates) and receives transfers from other institutions, which constitute its revenue. Government consumption expenditures are assumed to be fixed in real terms, transfers to domestic institutions are CPI-indexed. As for government savings, which represent the difference between government spending and income, they are computed as a flexible residual.

For the rest of world, transfer payments from and to domestic institutions and factors are fixed in foreign currency. The difference between foreign currency spending and receipts captures the current account deficit.

The flow of marketed commodities in the model is described in Figure A4.2 (Appendix A). Total domestic supply comes from total aggregate output across activities. The aggregation across activities is obtained via a CES function that accounts for the imperfect substitution among different outputs due to differences in quality, distance

between locations, etc. In order for market clearance to occur, an activity-specific price serves to clear the implicit market for each disaggregated commodity. Producers can substitute between production for domestic market and foreign (or export) markets. This behavior on the part of producers is governed by a constant elasticity of transformation (CET) function, which allows the differentiated response of producers to market signals (i.e. domestic prices, export prices, etc.).

Non-exported domestically produced commodities supply the domestic market. Domestic demand is made up of the sum of demands from households, government, investments, and intermediate inputs. The model allows for substitution between domestic and imported goods. A CES function using the Armington assumption (Armington, 1969) governs the behavior of the economic agent in terms of consumption preferences between domestic and imported goods.

Given the relatively small weight of Morocco in the world economy, we make use of the small-country assumption. It follows that Moroccan agents face perfectly elastic world demand, hence world export prices for Moroccan goods are fixed at world prices. Thus, the endogenous interaction of relative prices of exports and domestic goods determines the final composition of aggregate output. Moroccan exports are disaggregated by destination region, which allows for substitution based of the returns associated with exporting to a particular region.

The small-country assumption operates in a similar manner on the import side. Morocco faces a perfectly elastic world supply with fixed world prices. The cost-minimization process of domestic agents determines the final composition of final demand based on the interaction between import prices and domestic prices. Similar to

exports, imports are disaggregated regionally to allow for substitution among different sources of imports based on relative price interaction (inclusive of tariffs at fixed ad valorem rates).

4.3 Description of Regionalization Assumptions and Data

As previously mentioned, the model regional disaggregation is based on the administrative and economic regional disaggregation of Morocco (Figure 4.1).

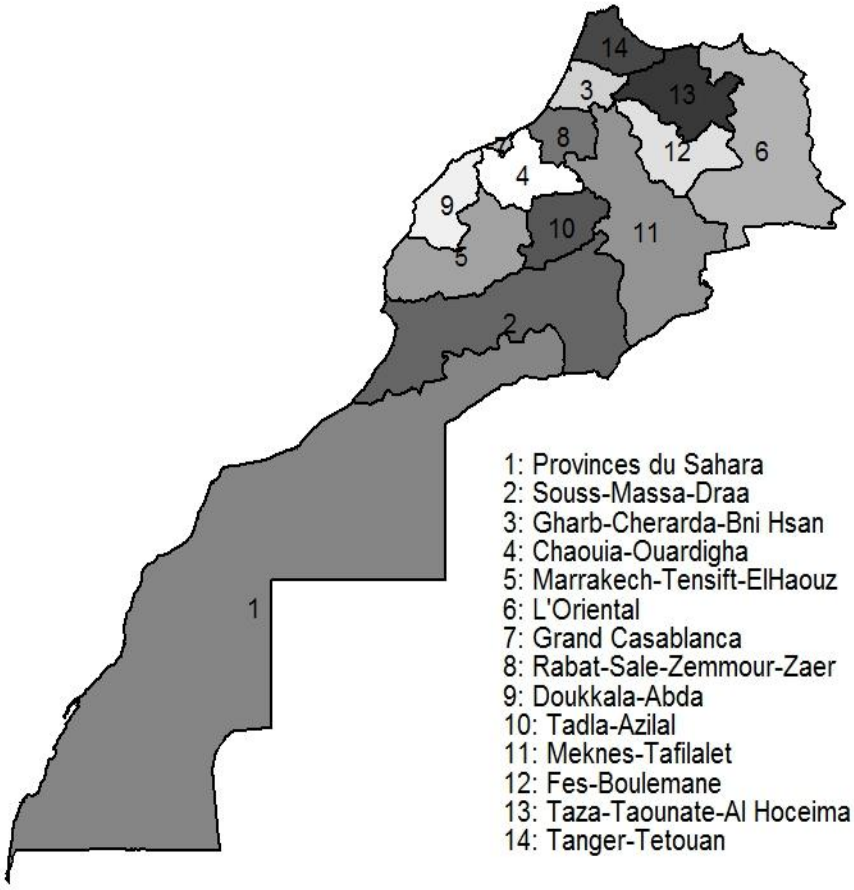

Figure 4.1 Administrative and Economic Regions in Morocco

Source: Authors' construction

The data used in the model is based on a national social accounting matrix (SAM) for 2003 developed by Rachid Doukkali of IAV/Hassan II in Rabat, Morocco, and as modified by Dominique Van der Mensbrugghe.[14] The initial SAM identifies 67 activities and 68 commodities (Tables B4.1 and B4.2, Appendix B). The institutional block in the data is represented by household, value-added, taxes, government, investment-savings, and rest of the world accounts (Table B4.3, Appendix B).

Given the regional dimension adopted in the model, it was necessary to reduce the dimension of the SAM accounts in order to facilitate the modelling and analysis, and handling of the results. Tables B4.4, B4.5, and B4.6 (Appendix B) summarize the new structure of the SAM accounts. Crop production is captured through 11 activity accounts each producing a corresponding commodity. Livestock, forestry, and fishery accounts remain unchanged. The food processing sectors are represented by eight activity accounts; whereas the industry and manufacturing and services accounts remain unchanged represented by four and two activity accounts, respectively.

Activity/Commodity accounts. In order to regionalize the data in the social accounting matrix (SAM), we used data from regional survey statistics on agricultural production, household expenditures and other regional data collected from a wide range of government agency databases. For example, agricultural crop production activities (x11 activities) regionalization draws on data from the Agricultural Survey of Major Crop Production for the agricultural campaign 2002-2003, which corresponds to the base year of our SAM. For the livestock sectors (x4 activities), regional statistics on livestock

[14] Professor van der Mensbrugghe is Research Professor and Director of the Center for Global Trade Analysis (GTAP) at Purdue University, where his research focuses on the economy-wide impacts of global trade and environmental policies.

headcount for 2004 of cattle and sheep were used to regionalize production activities for bovine and ovine meat production (HCP, 2005); whereas for poultry meat production, regional statistics pertaining to 2005[15] were used as a basis for regionalization. Table B4.7 (Appendix B) summarizes the regionalization assumptions and data used for all production activities and institutions as represented in the SAM. For the commodity accounts, the regionalization assumptions and data are similar to the activity accounts.

Household accounts. In the SAM, there are two types of representative households: rural and urban. To regionalize households, we use data on regional household expenditures obtained from the 2000-2001 Household Consumption and Expenditures Survey (HCP, 2007). Based on the survey data, we estimate the share of each region's representative household in aggregate expenditure (Table 4.1).

[15] Data was provided by Dr. Abdellah MDAFRI,
Head of the Central Zone Division, Project Management Department, Agricultural Development Agency (ADA), Morocco.

Table 4.1 Regional Households Share in Total Expenditure

Regions	Share in total expenditure		
	Urban	Rural	Regional
Oued Ed-Dahab-Lagouira/Laâyoune-Boujdour-Sakia El Hamra/Guelmim-Es-Semara	0.035	0.012	0.029
Souss-Massa-Draâ	0.080	0.139	0.096
Gharb-Chrarda-Beni Hsen	0.038	0.072	0.047
Chaouia-Ourdigha	0.035	0.073	0.045
Marrakech-Tensift-Al Haouz	0.058	0.124	0.076
Oriental	0.056	0.056	0.056
Grand Casablanca	0.267	0.018	0.197
Rabat-Salé-Zemmour-Zaër	0.123	0.033	0.098
Doukala-Abda	0.040	0.091	0.056
Tadla-Azilal	0.033	0.077	0.045
Meknès-Tafilalet	0.062	0.062	0.062
Fès-Boulmane	0.059	0.029	0.051
Taza-Al Hoceima-Taounate	0.028	0.127	0.056
Tanger-Tetouan	0.086	0.087	0.086
National	1.000	1.000	1.000

Source: Author's adaptation (Data source: ENCDM 2000/2001, (http://www.hcp.ma/Enquete-nationale-sur-la-consommation-et-les-depenses-des-menages_a95.html - Last accessed 4/21/2015)

The data distinguishes between rural and urban households, and hence allows for capturing the differentiated level of expenditure along the urban/rural splits adopted in the model. Nonetheless, the disaggregation of expenditure across commodities within each region assumes the same structure as the national one captured in the SAM.

Government expenditures and transfers. Data on regional distribution of government expenditures for 2010 were obtained from the Ministry of Economy and Finance (MEF). We compute regional shares based on aggregating the two categories of expenditures (Table B4.8, Appendix B). But similarly to the case for household expenditures, we keep the same disaggregated structure of government expenditures across commodities as identified at the national level in the SAM. For government transfers to households, we regionalize based on the regional population shares calculated from the 2004 population survey (RGPH, 2004).

Tax accounts. For tax revenues generated from taxes levied on household consumption, we compute regionalization shares using regional household expenditure. For tax revenues stemming from taxation of production activities, the regional distribution is based on the activities accounts regional disaggregation. One of the main features of the model is the interregional trade structure adopted in order to account for the flows of commodity accounts to activity accounts at the regional level. Currently, they are computed as a residual, assuming no transaction costs. This is achieved in the model by calculating the difference between a region's production and consumption. The resulting residual, if a surplus, is then distributed to other regions based on their demands. We assume that for regions with surpluses, the latter consume only their own products, and export the rest to regions with commodity deficits. As for the importing regions, imports are subtracted from the region's production to keep the balance between consumption and production (Dudu and Cakmak, 2011).

4.4 Yield Projections and Scenarios Analysis for Morocco

4.4.1 Climate-induced Yield Projections

Yield estimates were obtained from the study conducted by the World Bank (WB) and the Moroccan Ministry of Agriculture, Rural Development and Fisheries (MPAM), in collaboration with National Institute for Agricultural Research (INRA), the Food and Agriculture Organization (FAO) and the National Meteorology Authority (DMN). From this point forward, we will refer to the previous study as the WB/Morocco/FAO study for ease of reference.

Yield projections were developed through a multi-step process. First, using a statistical downscaling procedure, projected change in temperature and precipitation were obtained for Morocco at the agro-ecological zone (AEZ) level. Projected change in temperature and precipitation were obtained using Hadley Centre Coupled Model version 3 (HadCM3), which is a global climate model (GCM) used in many studies.[16] Downscaling was performed for two of the Intergovernmental Panel on Climate Change (IPCC) scenario family for greenhouse gas (GHG) emissions: SRES A2 and SRES B2. The SRES A2 is characterized by a heterogeneous world where the focus is on self-reliance and preservation of local identities. Hence, convergence in fertility rates across regions converge very slowly. Therefore, global population is increasing continuously. Economic growth priorities are focused at the regional level, and technological change is

[16] HadCM3 was developed in 1999 and was the first unified model climate configuration not to require flux adjustments (artificial adjustments applied to climate model simulations to prevent them drifting into unrealistic climate states). It was one of the major models used in the IPCC Third and Fourth Assessments, and also contributes to the Fifth Assessment (http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/hadcm3)

fragmented and slower compared to other scenarios. The SRES B2 is described as a world where the emphasis is on solving local economic, social, and environmental sustainability problems. Global population is projected to increase continuously, albeit at a slower rate compared with SRES A2.

Second, the results of the downscaling procedure in terms of projected change in temperature and precipitation were used to infer impacts on variables pertaining to crop growth such as evapotranspiration and water stress indicators. The Crop Specific Soil Water Balance (CSSWB) model was used to simulate projected yields under climate change including the effects of CO_2 fertilization (Allen, R.G. et al., 1998). Estimated impacts on crop yields were provided for four time horizons, which include: "current period" (or baseline) covering the years 1979-2006, "2030" (from 2011 to 2040), "2050" (from 2041-2070) and "2080" (2071-2099). Projected impacts on yield are provided with confidence intervals capturing low, medium and high impacts. For the purpose of the study, we used the projected yield data pertaining to the period "2050".

Table 4.2 summarizes the moment distribution of projected impacts of climate change for Morocco for temperature and precipitation in absolute and percent change by 2050. The results are based on data obtained from UNDP country profiles for Morocco, which covers three SRES scenarios: A1B, A2 and B1. The HadCM3 GCM used by the WB/Morocco/FAO study falls in most cases within the highest percentile range in terms of projected impacts on precipitation and temperature for all scenarios.

Table 4.2 Percentile Distribution of Climate Change Impacts on Precipitation and Temperature by 2050

		Anomalies		Percentage	
		Precipitation (in mm)	Temperature (in ˚C)	Precipitation (in mm)	Temperature (in ˚C)
SRES A2	min	-11.43	0.82	-56.90	4.80
	25th	-5.95	1.75	-37.48	9.45
	median	-1.42	1.97	-12.70	11.20
	75th	2.35	2.25	16.18	12.15
	max	18.05	2.61	86.00	15.00
	HadCM3	**-11.43**	**1.92**	**-52.00**	**10.80**
SRES A1B	min	-7.01	1.05	-47.50	6.30
	25th	-4.45	1.80	-34.13	10.00
	median	-1.91	2.12	-10.50	11.30
	75th	0.07	2.73	1.28	15.20
	max	6.33	3.30	43.70	19.40
	HadCM3	**2.26**	**2.81**	**10.30**	**15.80**

Source: Author's construction (Data Source: UNDP Climate Change Country Profiles: Morocco)

Note : Indicated values are anomalies and percent change with respect to the mean 1970-1999

Table 4.2 Percentile Distribution Of Climate Change Impacts On Precipitation And Temperature By 2050 (Continued)

		Anomalies		Percentage	
		Precipitation (in mm)	Temperature (in ˚C)	Precipitation (in mm)	Temperature (in ˚C)
SRES B1	min	-9.17	0.60	-41.30	3.60
	25th	-3.49	1.40	-25.98	7.23
	median	-0.81	1.45	-5.20	8.70
	75th	0.43	2.00	2.40	10.63
	max	7.61	2.50	36.20	14.30
	HadCM3	**1.13**	**1.20**	**5.10**	**6.70**

Source: Author's construction (Data Source: UNDP Climate Change Country Profiles: Morocco)

Note : Indicated values are anomalies and percent change with respect to the mean 1970-1999

Figure 4.2 summarizes the distribution of average yield impacts for SRES A2 and B2 as projected by 2050 for all crops at the national level. Uncertainty bars represent the range of projected yield impacts for each crop. Results are presented in box plots using the 'ggplot2' package in R. The lower and upper borders of the box plot represent respectively the 25th and 75th percentiles of the distribution of yield projections. The upper (lower) whisker extends from the box plot upper (lower) border to the highest (lowest) value that is within 1.5*IQR of the border, where IQR stands for inter-quartile range defined as the distance between the 25th and 75th percentiles. The black lines inside the box plot refer to the median of the distribution. The red dots within the bars represent the average of the distribution. Data beyond the end of the whiskers are outliers and are plotted as points. For a detailed discussion, refer to McGill, R., Tukey, J. W. and Larsen, W. A. (1978).[17]

[17] The explanation provided for Figure 4.2 where we use uncertainty bars (i.e. box plots) remains valid for subsequent figures using the same method to display the results.

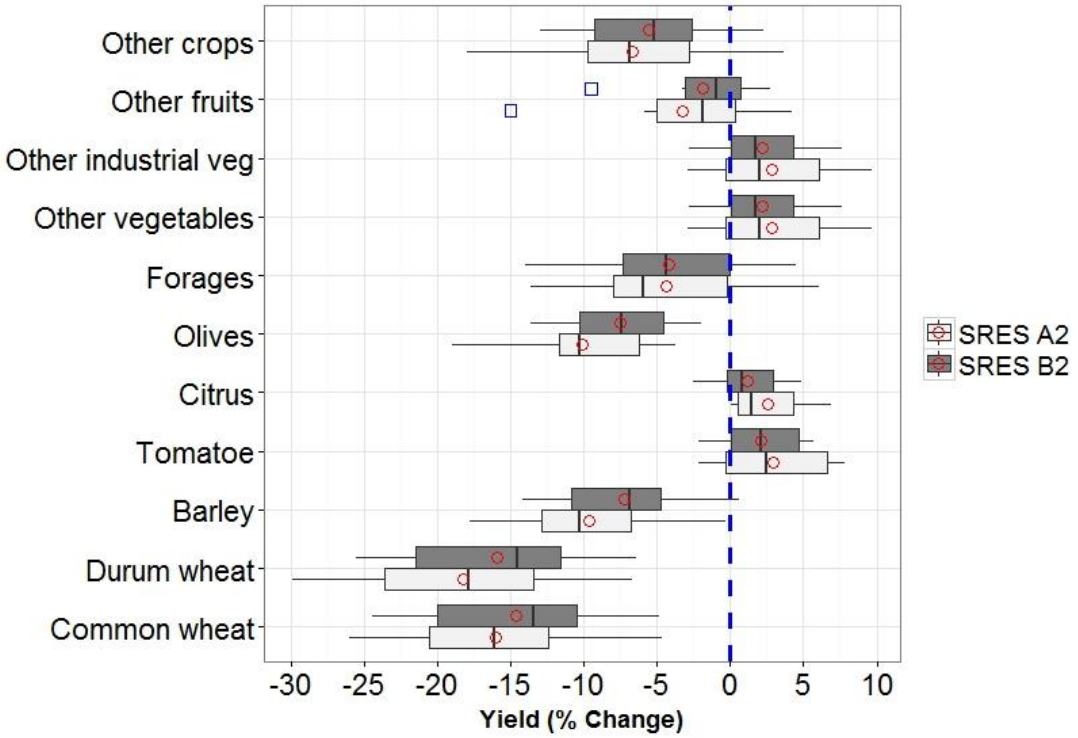

Figure 4.2 Projected Yield Impacts at the National Level for SRES A2 and B2 by 2050
Source: Authors' adaptation based on the WB/Morocco/FAO study (Gommes et al. 2009)

At the national level, projected yields depict variation across crops and climate scenarios. If we consider the median of climate change impacts on yield, we can divide the crops into two categories: negative yield impacts and positive yield impacts. The main difference between the two categories lies in the fact that crops affected negatively by climate change are grown under rainfed conditions; whereas crops in the second category are produced under irrigated conditions. The first category includes wheat (durum and common), barley, olives, forage crops, other fruits and other crops which are negatively affected by climate change under both scenarios. The second category consists

of tomatoes, citrus, other vegetables and other industrial vegetables where yields are projected to increase on average.

Nevertheless, the range of impacts can be substantial. For instance, yield impacts for the first category range from -8% to -27% for wheat (durum and soft), -2% to -15% for barley, -4% to -15% for olives, -11% to +1% for forage crops, -9% to +2% for other fruits and -0.3% to -14% for other crops. Whereas for the second category, yield impacts for vegetables (i.e. tomatoes, other vegetables and other industrial vegetables) and citrus range from -1% to +5% and from -1% to +4% respectively.

Additionally, there is a substantial differential in projected yield impacts within each SRES scenario when comparing with and without CO_2 fertilization cases. Figure 4.3 summarizes the percentile distribution of projected yield impacts for all crop categories for SRES A2 and B2, with and without CO_2 fertilization effects at the national level.

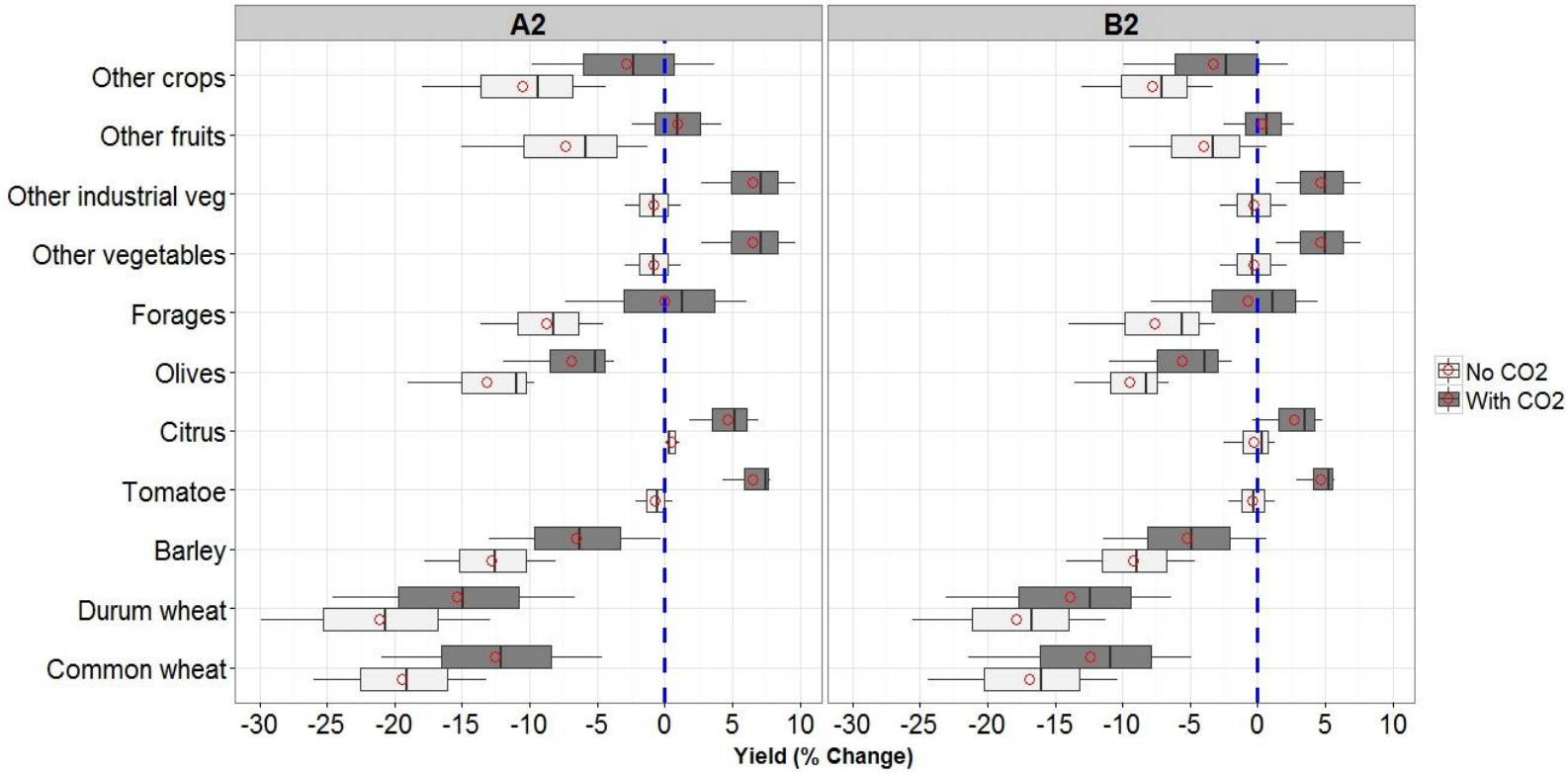

Figure 4.3 Projected Yield Impacts by 2050 at the National Level for SRES A2 And B2 with and without CO2 Fertilization Effects

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

Using the median of the distribution of yield impacts without the CO_2 fertilization effects, all crops are negatively affected except for citrus which exhibits a slightly positive effect for both SRES scenarios. The CO_2 fertilization effect plays an important role in enhancing and/or offsetting partially and/or totally the positive and/or negative impacts of climate change, which varies widely depending on the growth conditions of crops. For instance, CO_2 fertilization effect on average totally offsets the negative effect of climate change on yields for tomatoes, citrus, forage crops, other vegetables, other industrial vegetables and other fruits. Indeed, the net impact of CO_2 fertilization across the aforementioned crops ranges from +2% to +13% under SRES A2 and +2% to +7% under SRES B2. For the remaining crops (i.e. mainly rainfed crops such as cereals and olives), despite net gains in yield productivity associated with the CO_2 fertilization effect, the final impact remains negative on average. This is in line with findings from numerous impact studies in the literature that suggest that irrigated crops will experience positive impacts due to climate-induced CO_2 fertilization effects owing to higher concentrations of CO_2 in the atmosphere.

Nevertheless, using national averages can be misleading in the Moroccan case. Agricultural production across regions is diverse due to climate and land-crop tenure heterogeneity. Most regions on average exhibit negative impacts of climate change on crop productivity. For example, regions with the highest productivity located within the favorable agro-ecological zones are expected to be the biggest losers from climate change. Indeed, average productivity losses across all crops in Chaouia-Ouardigha [4], Marrakech-Tensift-ElHaouz [5], Rabat-Sale-Zemmour-Zaer [8], Meknes-Tafilalet [11], Fes-Boulemane [12], and Taza-Taounate-Al Hoceima [13] are in excess of 10% under

the climate scenario SRES A2 without CO2 fertilization effect. These regions represent the bread basket of Morocco with 57% of total cereals production (69% of rainfed production and 19% of irrigated production). Under the climate scenario SRES B2, only four out the previous six regions display productivity losses in excess of 10%. If we account for the CO_2 fertilization effect, the negative effects are reduced and/or offset on average in regions characterized by the dominance of irrigated crop production (e.g. the region of Souss-Massa-Draa [2]) (Figures 4.4 and 4.5).

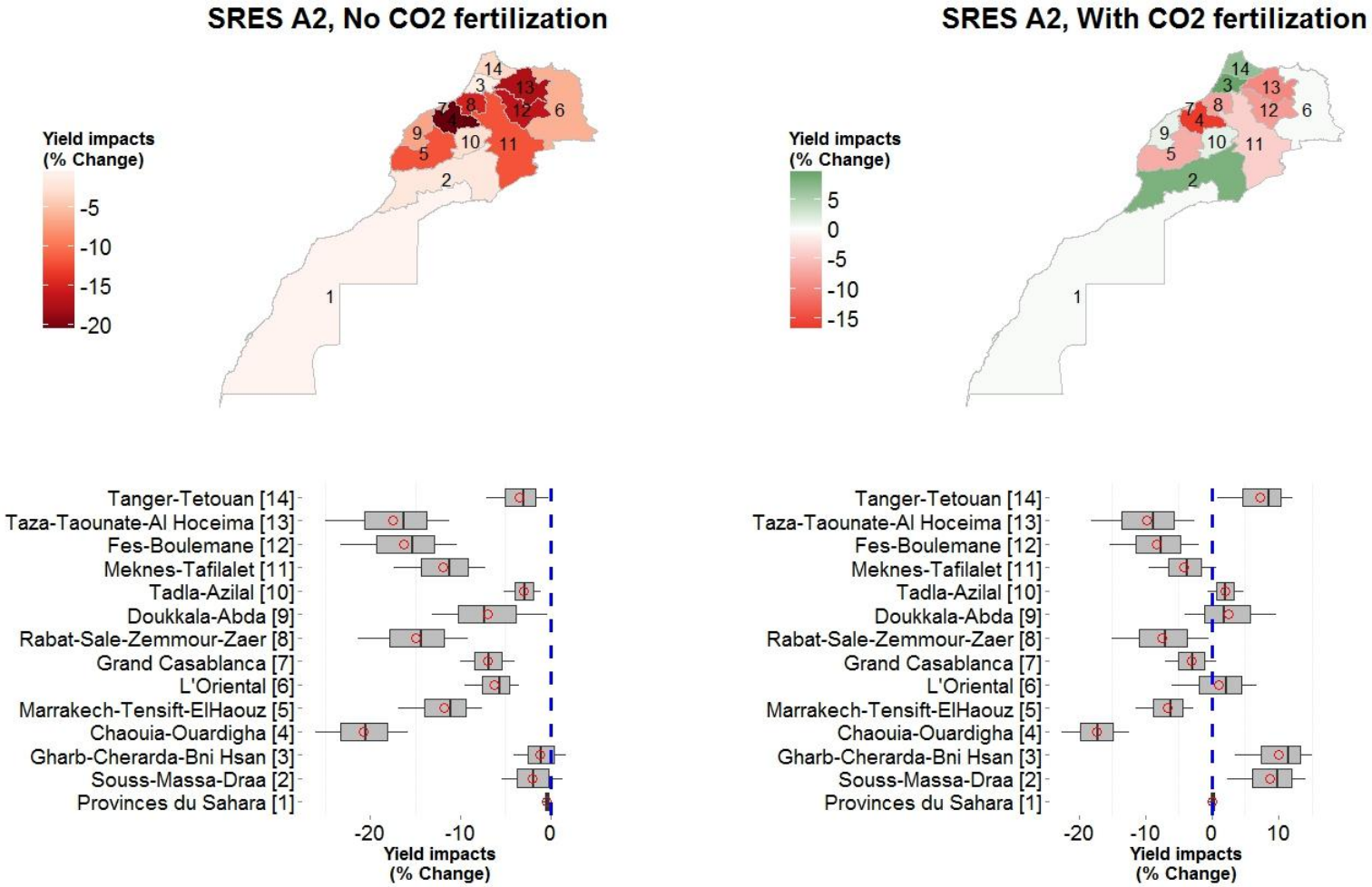

Figure 4.4 Distribution of Average Projected Yield Impacts by 2050 across Crops under the SRES A2 by Region

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

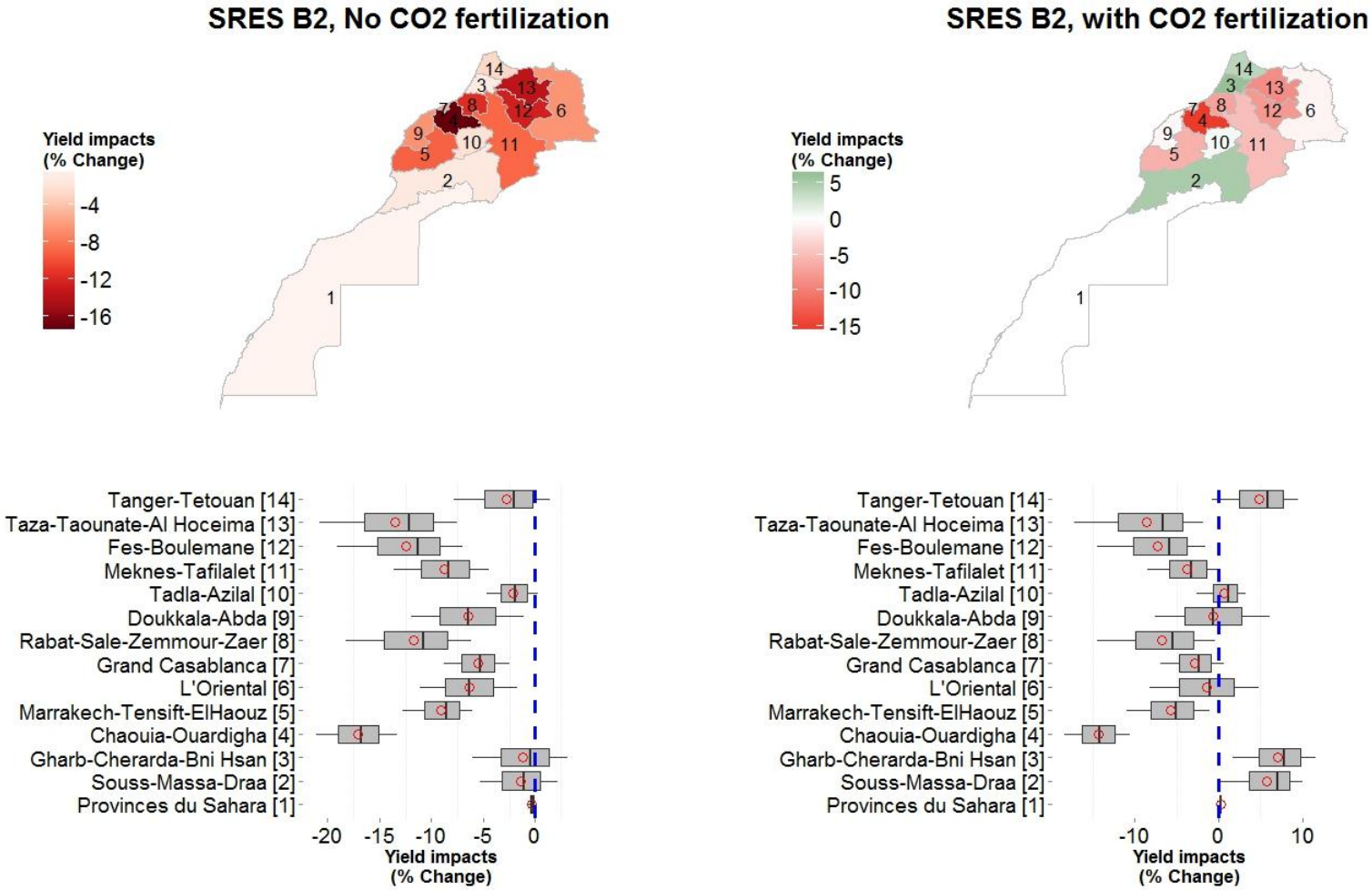

Figure 4.5 Distribution of Average Projected Yield Impacts by 2050 across Crops under the SRES B2 by Region

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

At the crop level, climate-induced productivity impacts display a wide range of potential outcomes at the regional level. For instance, projected yields for durum wheat are expected to fall for all regions and all SRES scenarios. Among the hardest hit are Chaouia-Ouardigha [4], Doukkala-Abda [9], Meknes-Tafilalet [11], and Taza-Taounate-Al Hoceima [13], which respectively account for 19%, 17%, 9%, and 16% of total durum wheat production. These regions are projected to have yield declines ranging from -21% to -40%, -28% to +14%, -12% to -22%, and -11% to -31% respectively across all scenarios without accounting for the CO_2 fertilization effects. The impacts are somewhat dampened when including the CO_2 fertilization effects, but remain largely negative. The same patterns hold for common wheat where the overall impact is largely negative to slightly positive in the main producing regions of Ghard-Cherarda-Bni Hsan [3], Chaouia-Ouardigh [4], Tadla-Azilal [10] and Meknes-Tafilalet [11].A similar trend in terms of projected yield impacts is observed for barley in Chaouia-Ouardigha [4], Marrakech-Tensift-El Haouz [5], l'Oriental [6], Doukkala-Abda [9], and Taza-Taounate-Al Hoceima [13] (Figures 4.6, 4.7 and 4.8)

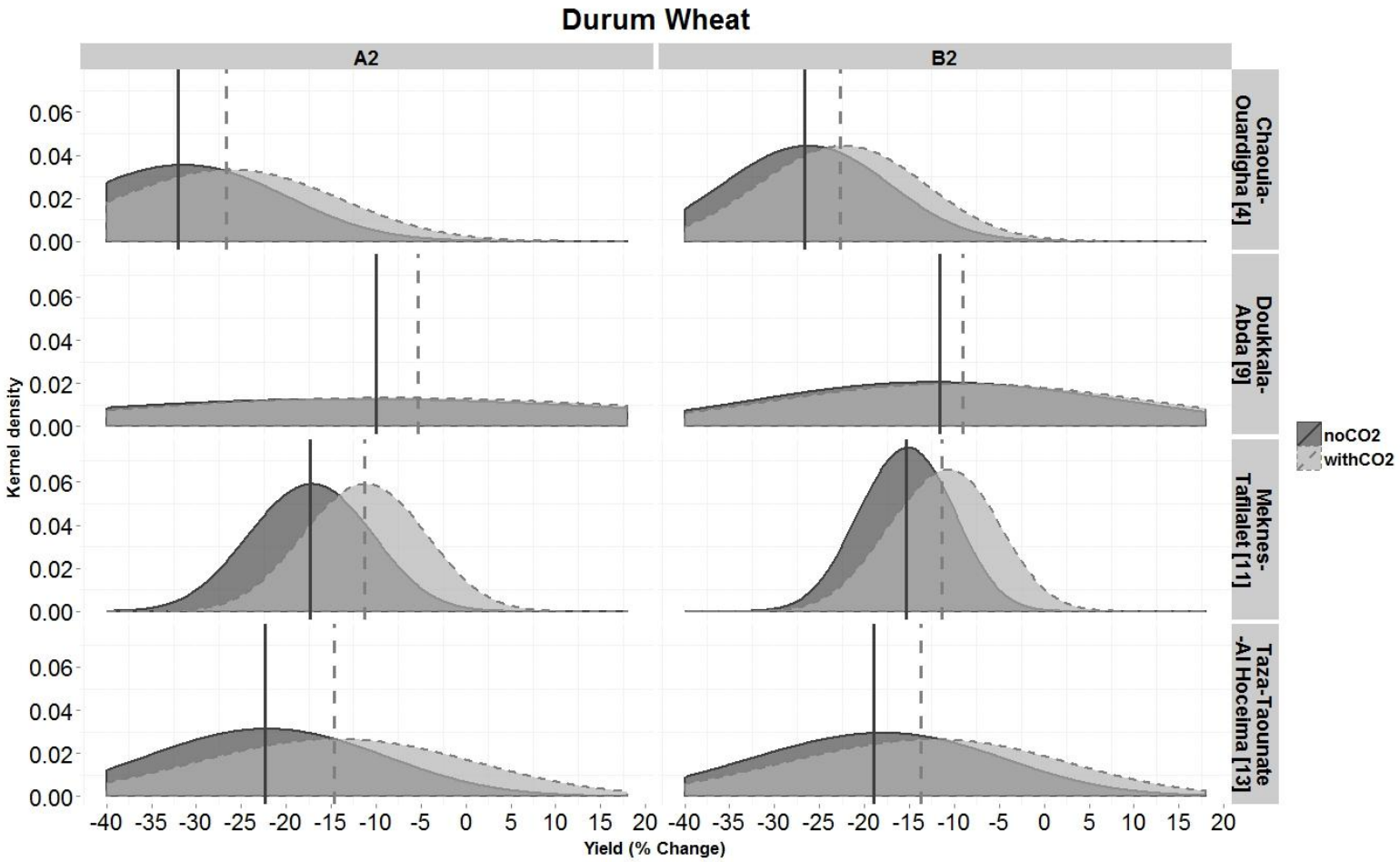

Figure 4.6 Kernel Distribution of Projected Yield Impacts for Durum Wheat by 2050 by SRES scenario in Major Producing Regions

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

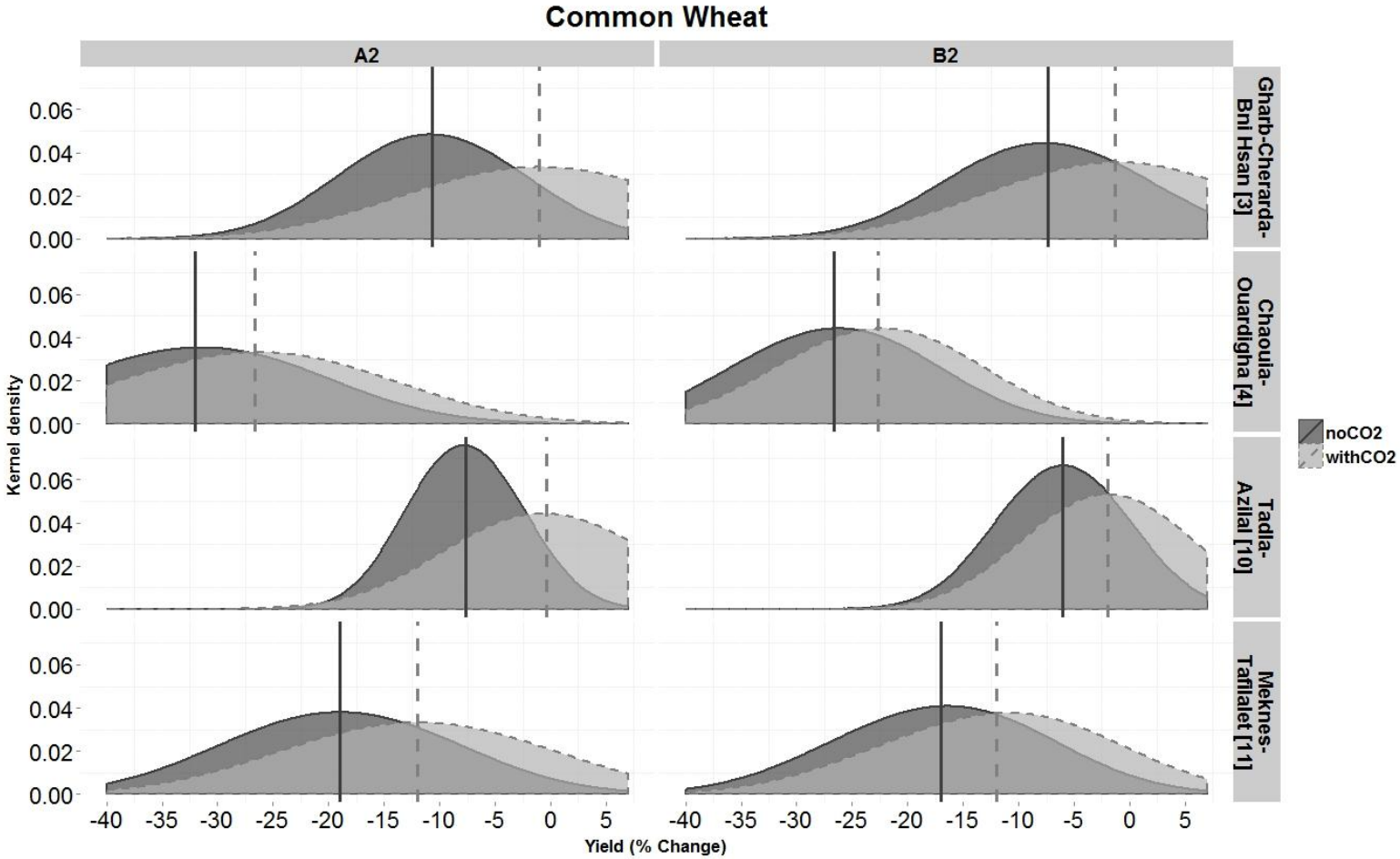

Figure 4.7 Kernel Distribution of Projected Yield Impacts for Common Wheat by 2050 by SRES scenario in Major Producing Regions

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

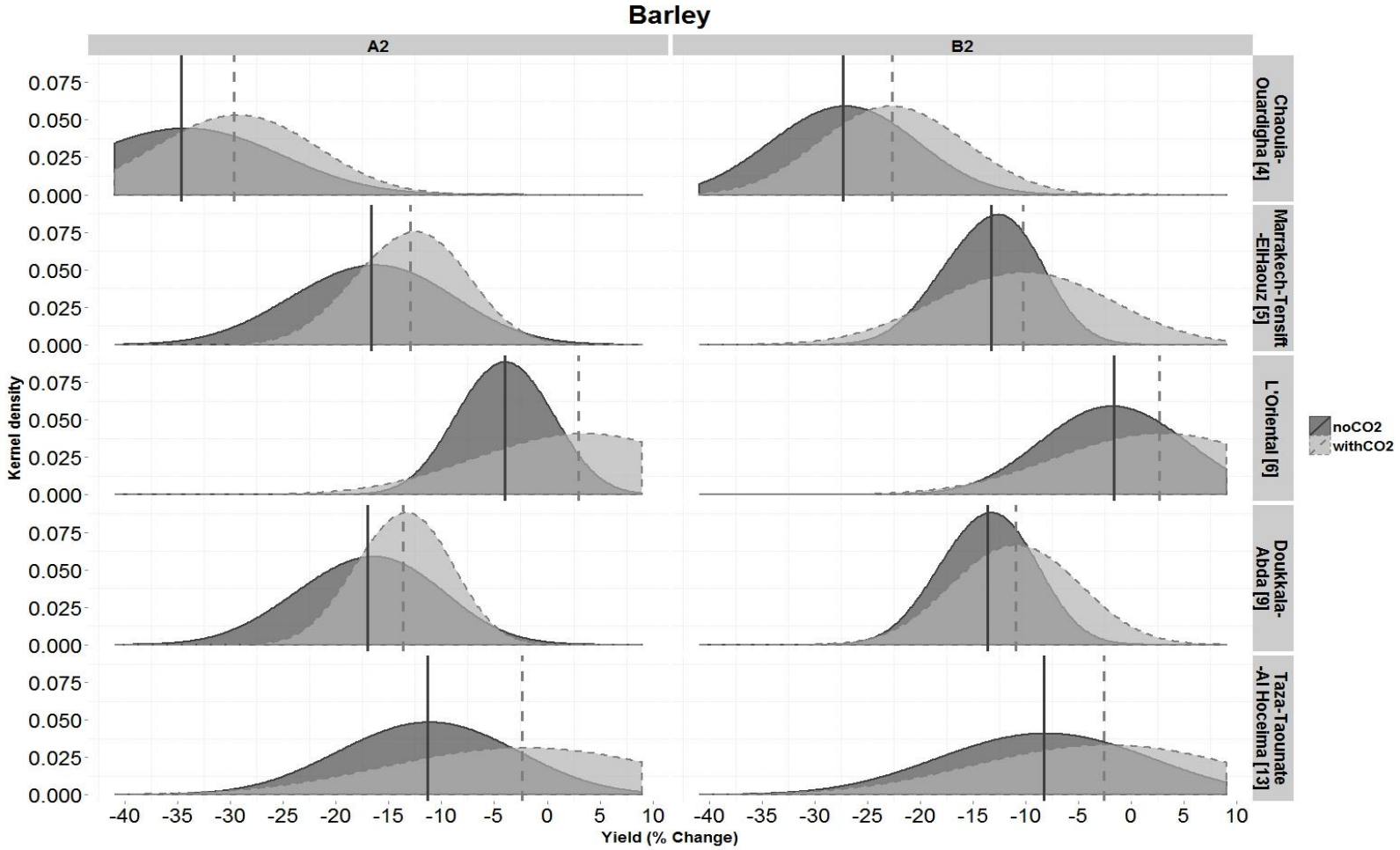

Figure 4.8 Kernel Distribution of Projected Yield Impacts for Barley by 2050 by SRES scenario in Major Producing Regions

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

For tomatoes, the yield projections in most regions depict slightly negative impacts for all SRES under the no CO_2 fertilization case, and substantial yield gains when it is included. In the main producing regions, i.e. Souss-Massa-Draa [2], Gharb-Cherarda [3], and Doukkala-Abda [9] regions (which respectively account for 46%, 22%, and 10% of total production), yield impacts range respectively from -3% to +20%, -5% to +21%, and -2% to +9% across all SRES scenarios, with and without CO_2 fertilization effects (Figures 4.9).

For citrus, average impact of climate change on yields and without accounting for CO_2 fertilization effects, is expected to be negative in two out of four major producing regions; namely, the Souss-Massa-Draa [2] and l'Oriental [6] which represent 50% and 15% of total production respectively. On average, citrus yields are projected to decline in both regions by -4% to -6% across climate scenarios. In the Gharb-Cherarda-Bni Hsan [3] and Tadla-Azilal [10] regions, citrus yields are projected to increase by 2% to 5% on average respectively. When CO_2 effects are included, the impacts on yields are positive on average and ranges from +2% to +17% across all four regions and climate scenarios (Figures 4.10).

For olives, projected impacts are negative and large in the main producing regions in Marrakech-Tensift-ElHaouz [5], Fes-Boulemane [12] and Taza-Taounate-Al Hoceima [13]. For example, yield impacts range from -12% to -21% across all the regions and climate scenarios. Despite the gains from CO_2 effects, they remain insufficient to significantly modify the overall impact which remains largely negative (Figure 4.11).

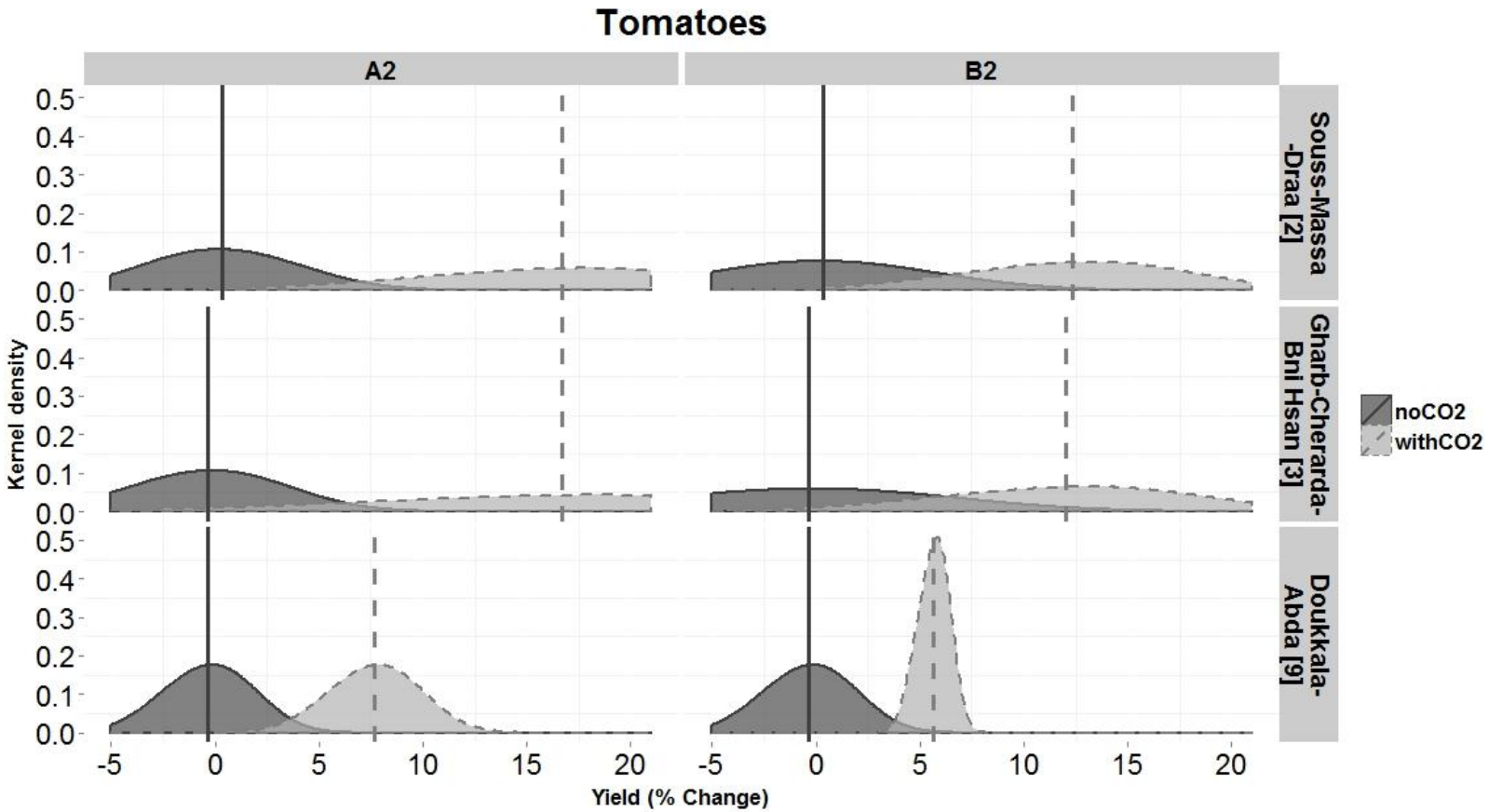

Figure 4.9 Kernel Distribution of Projected Yield Impacts for Tomatoes by 2050 by SRES scenario in Major Producing Regions

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

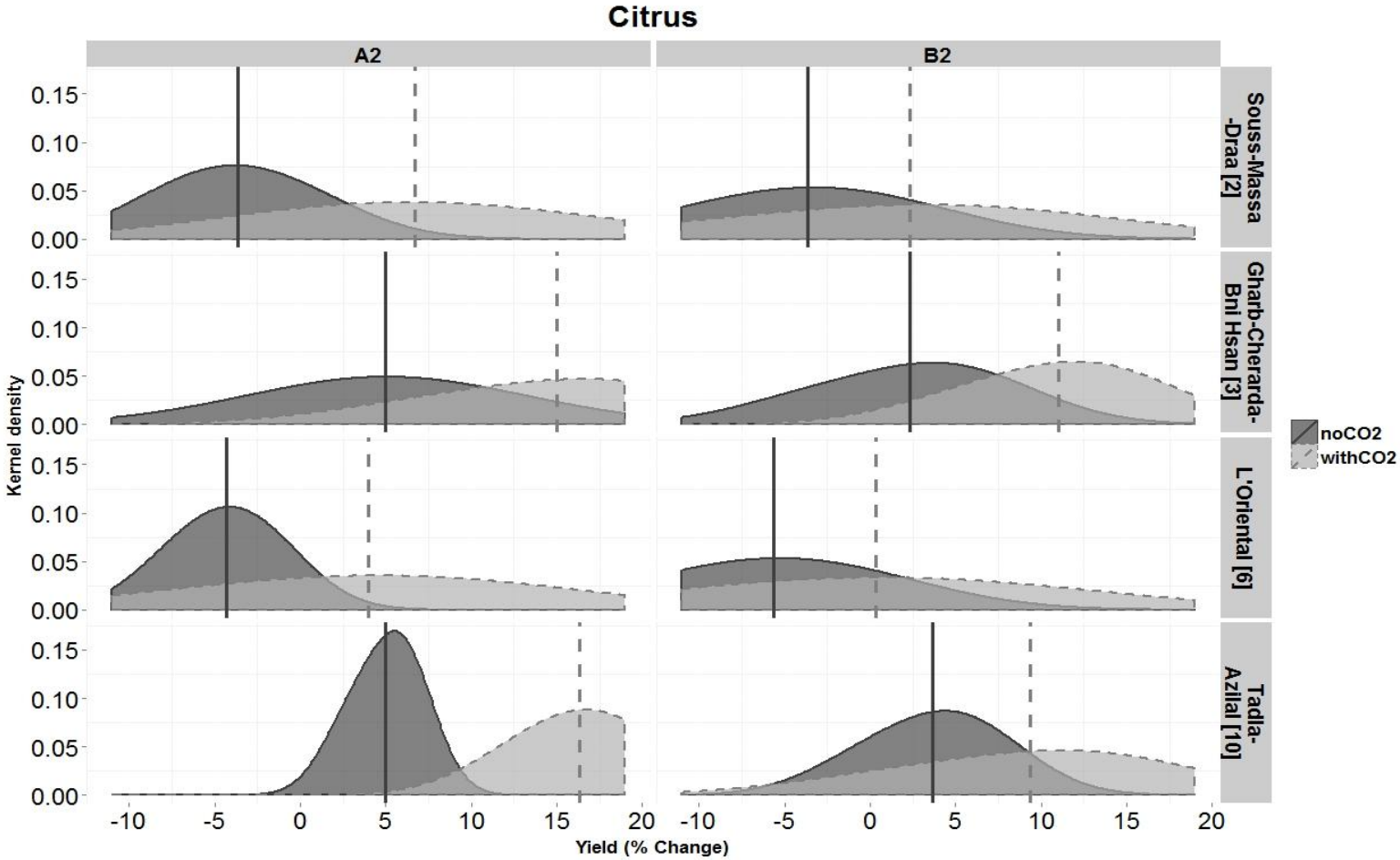

Figure 4.10 Kernel Distribution of Projected Yield Impacts for Citrus by 2050 by SRES scenario in Major Producing Regions

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

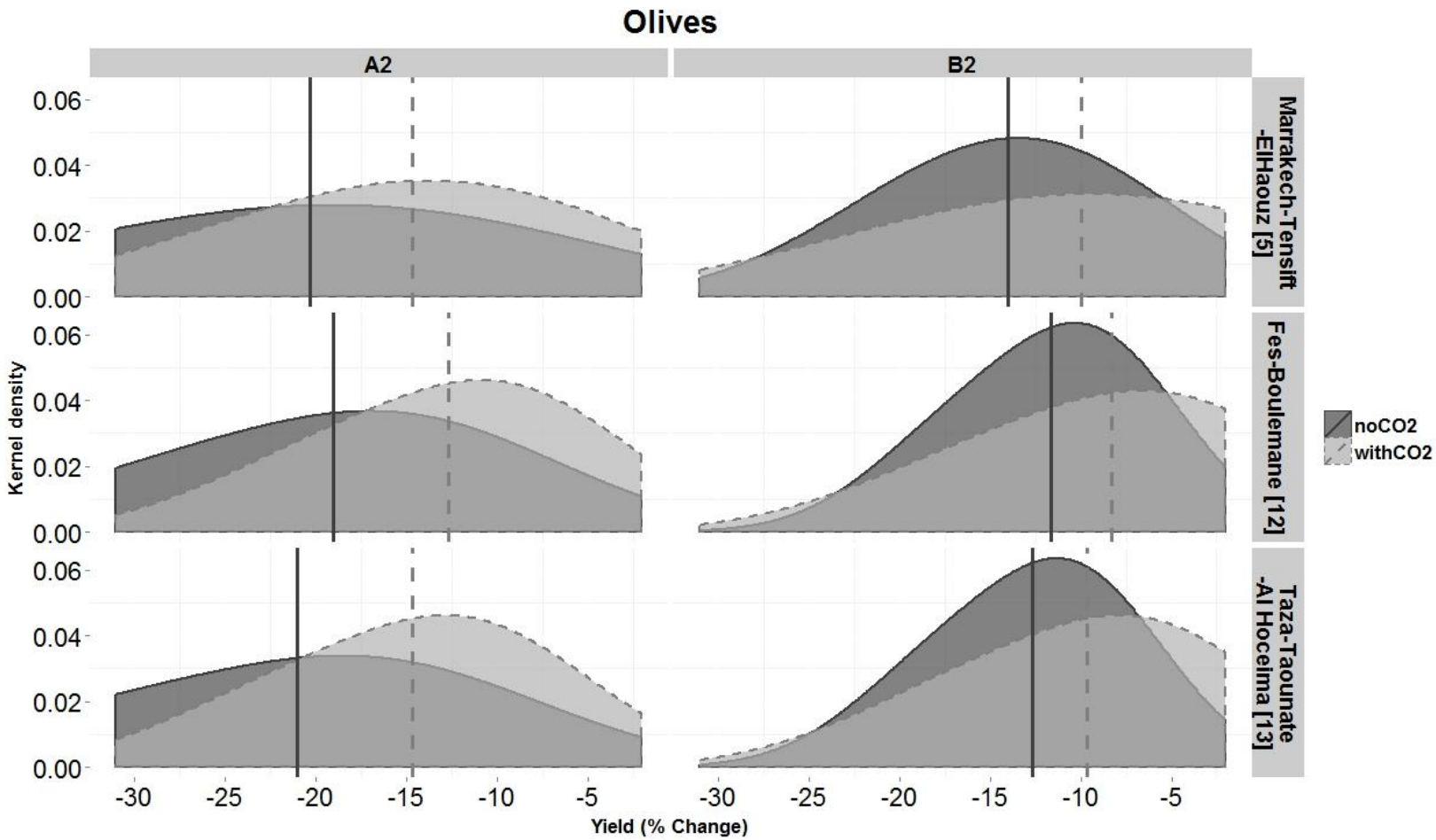

Figure 4.11 Kernel Distribution of Projected Yield Impacts for Olives by 2050 by SRES scenario in Major Producing Regions

Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes et al. 2009)

In conclusion, the results depict the wide range of variability that exists in terms of projected yield impacts at the national and regional levels. Capturing this variability, and accounting for its economic impacts is key to understanding the potential inter-regional linkages in terms of climate change, and how they translate into welfare impacts.

4.4.2 Scenario Analysis and the PMV Strategy

In this section, we discuss the scenarios identified for the analysis. We will briefly discuss the identification and implementation procedure. Additionally, we will introduce a brief discussion of the PMV strategy and its objectives at the national and regional levels.

4.4.2.1 Scenario Analysis for the Morocco CGE model

We have identified eight scenarios for the analysis. They are defined based on the climate-driven yield shocks to be introduced for selected crops, and refer to each SRES used in the analysis (A2 and B2), as well as the adaptation policies to be investigated in our analysis.

With respect to the climate-induced yield impacts, the objective is: a) to capture the uncertainty underlying the projections in yield responses to climate change across SRES scenarios and across regions in Morocco, and b) to evaluate the impacts of the underlying uncertainty within each climate scenario, which is achieved through a percentile distribution based on low, medium and high values for projected yields as estimated for each SRES scenario. In this case, “low” represents the worst case scenario

in terms of impacts on yield, and “high” represents the best case scenario, whereas “medium” represents the 50th percentile represented by the median.

Modeling impacts of climate change on agriculture in the context of CGE models usually involves the introduction of shocks to the technical coefficients pertaining to the production function (or technology) in the model. The production function is a formalized characterization of the technology adopted by producers. It describes the mix of primary and intermediate inputs used in the production process. This process is governed by the optimization behavior of the producer, which consists of profit maximization (or cost minimization) subject to a constraint represented by the technology used - i.e. the production function and market prices for inputs.

In our model, primary inputs are referred to as the bundle of value-added inputs which comprise: capital goods, labor and land for the crop production sectors. Hence, solving the profit maximization problem of the producer allows us to determine factor demand equations governing the demand behavior for primary inputs. In model notation, the derived demand for primary inputs is defined as follows:

$$QVA_a = \alpha_a^{va}\left[\sum_{f\in F}\delta_{f,a}^{va}.\,QF_{f,a}{}^{-\rho_a^{va}}\right]^{\frac{1}{\rho_a^{va}}}$$

$$\begin{bmatrix} quantity\ of \\ aggregate \\ value\ added \end{bmatrix} = CES\begin{bmatrix} factor \\ inputs \end{bmatrix}$$

where:

- QVA_a: denotes aggregate quantity of value-added bundle used by activity a;

- α_a^{va}: denotes the shift parameter for CES activity production function for activity a;
- $\delta_{f,a}^{va}$: denotes the share parameter of factor f for CES activity production function for activity a;
- $QF_{f,a}$: denotes the quantity demanded for factor f from activity a;
- ρ_a^{va}: denotes the CES activity production function exponent.

The key parameter of focus in our simulation is the shift parameter, α_a^{va}, which is altered in line with climate-induced yield shocks. The latter are assumed to represent a shock to the productivity of the primary inputs. Thus, we shock the shift parameter under the assumption of a Hicks-neutral productivity shock, which is a non-biased form of technological change characterizing the productivity within a particular sector (Figure 4.11).

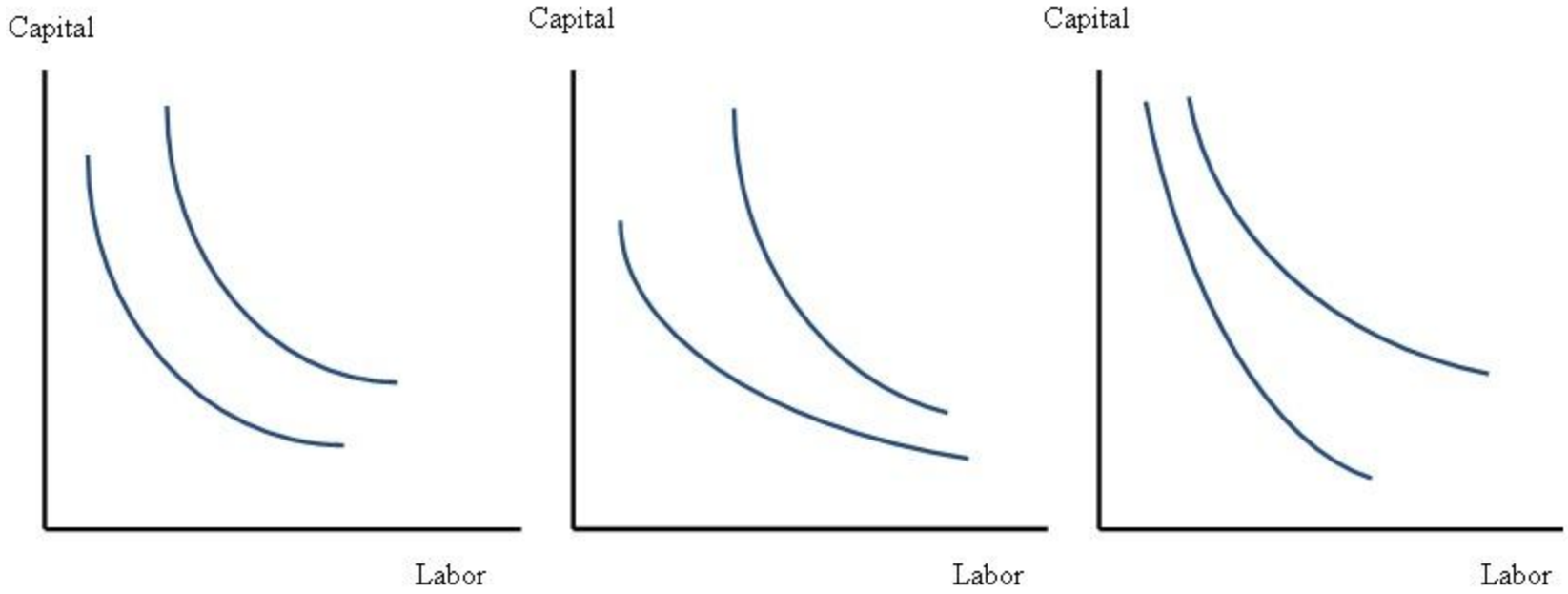

Figure 4.12 Technical Change in Factor Input Productivity: Neutral Technological Progress (Left), Capital Saving Technological Progress (Middle) and Labor Saving Technological Progress (Right)

Source: Author's construction

4.4.2.2 A Discussion of the Plan Maroc Vert (PMV) Strategy

With respect to adaptation policies to be investigated, the objective is to shed light on the relevancy of policy reforms in the PMV strategy as an adaptive force in the face of climate change. The PMV is the agricultural investment strategy adopted by Morocco in 2008. It lays down a vision of transforming the agricultural sector by 2020 to ensure a sustainable path of productivity growth, consolidate integration with local and international markets, job creation and mitigate poverty impacts (especially in the rural areas).

In terms of its general objectives, the PMV strategy aims by the 2020 horizon to increase the agricultural GDP from MAD 38 to ~100 billion, add 1.5 million jobs, increase exports from 1.35 to 4.6 million tons/year, increase area equipped with localized irrigation from 154 to 692 thousands hectares and double or triple agricultural revenues in rural areas. The PMV strategy emphasizes the latent potential for development of the sector owing to availability of low-cost labor, proximity to the European market, and its comparative advantage in high value-added crop sectors (e.g. vegetables, fruits, etc.).

The PMV strategy is articulated around two main pillars: Pillar I and Pillar II. Each of the pillars have different objectives and targets, and a differentiated role for the State and the Private sector. Pillar I of the PMV aims at developing a modern agricultural sector through investments in industrial-scale agriculture around high value-added crop varieties. As such, the private sector is expected to play the lead role in terms of capital investments, with the State providing institutional and financial assistance. The main strategy adopted revolves around the "aggregation strategy". It is based on the idea of contractual partnerships between small and medium scale exploitations with large-scale

farming exploitations (> 100 ha/farm) to form industrial-scale farming poles (200 to 2000 ha/farm). Thus, increasing the size of the exploitation would facilitate access to finance in order to invest in agricultural capital, and hence take advantage of economies of scales.

Pillar II on the other hand targets primarily small and medium-scale farmers, especially in the unfavorable and/or peripheral rural areas. Its main objectives are increasing farmers' revenue and poverty reduction. Hence, the State intervenes as the leading player and its intervention revolves around three main axes:

- reconversion projects in terms of land tenure which aim to assist farmers to switch from climate-sensitive crop production (e.g. cereals) to less climate-sensitive and high value-added crop production such olives, almonds, cactus, etc.;
- diversification projects aiming at generating additional revenues, and especially from the development of "Local products" ("Produits du Térroir");
- intensification projects centered around adoption of best practices techniques to enhance productivity and enhance production value.

In addition to Pillar I and II, the PMV strategy is supported by "transversal actions" structured around policy and legal reforms focused on:

- land property rights reforms, which include privatization of public and collective lands, continuation and acceleration of efforts of land property registration, and ease of bureaucratic procedures to facilitate the aggregation strategy in the PMV and the public-private partnerships;

- reform irrigation water policy by adopting preferential tariffs within the private perimeters, enhance the decentralization of irrigation water management, etc;
- promote the "Made in Morocco" brand through the accompaniment of the private sector efforts to access foreign markets, promote new free trade agreements, etc.
- modernize local distribution networks through the reinforcement of large-scale retail, etc.

Table 4.3 summarizes the regional distribution of projects and projected investments (in million MAD). First, investments are concentrated mainly in regions within the favorable agro-ecological zone (AEZ) in Morocco. Indeed, the regions of Gharb-Cherarda-Bni Hsan [3], Meknes-Tafilalet [11], Doukkala-Abda [9], Fes-Boulemane [12], Marrakech-Tensift-Al Haouz [5] and Chaouia-Ouardigha [4] represent collectively 64% of total projected investments for the period 2009-2020. Second, the structure of projected investments is strongly skewed toward Pillar I projects at the expense of Pillar II projects. At the national level, investments associated with Pillar I projects represent 80% of total investments. At the regional level, a similar trend is observed for most regions except for the regions of the Sahara Provinces [1] and Taza-Taounate-Al Hoceima [13] where Pillar II projected investments account for 53% and 48% of total investment respectively.

Table 4.4 summarizes the investment volumes and number of projects scheduled by the PMV strategy by activity sectors at the national level. As previously mentioned, the PMV strategy primarily focuses on Pillar I projects, which aim at the intensification

of the agricultural sector. Hence, high value-added sectors (e.g. vegetables and fruits, sugar crops, livestock, etc.) feature prominently on the investment agenda. For example, investment projects in citrus and sugar crops sectors are all under Pillar I. A similar trend is observed for the vegetables and fruits sector where 91% of total investments are projected under Pillar I of the PMV and 9% under Pillar II. For the livestock sectors, investments in dairy and white meat sectors are concentrated under the Pillar I category given their capital-intensive production structure; whereas for red meat and other livestock sectors, investments across the two pillars of the PMV strategy are balanced. This is explained by the fact that these sectors in Morocco play an important role in income generation for small scale farmers as alternative sources of revenue. In terms of the regional breakdown of the PMV projected investments by sector, a similar trend to the national level figures can be seen(Table B4.9, Appendix B).

Table 4.3 Regional Distribution of Projected Investments under the PMV Strategy by Pillar by 2020 (in Million MAD and in % Share)

Region	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)	Investment costs (in % share across Pillar)		Investment costs (in % share by region)		Total cost (in % share)	Rank analysis of regional shares of investment cost		
	Pillar I	Pillar II	Pillar I	Pillar II		Pillar I	Pillar II	Pillar I	Pillar II		Pillar I	Pillar II	Total
Provinces du Sahara [1]	29	22	2,484	2,834	5,318	46.7%	53.3%	3.1%	14.0%	5.3%	11	1	10
Souss-Massa-Draa [2]	24	56	4,855	1,542	6,397	75.9%	24.1%	6.0%	7.6%	6.4%	8	7	7
Gharb-Cherarda-Bni Hsan [3]	91	22	17,322	831	18,153	95.4%	4.6%	21.5%	4.1%	18.0%	1	11	1
Chaouia-Ouardigha [4]	230	65	4,528	1,889	6,417	70.6%	29.4%	5.6%	9.3%	6.4%	9	6	6
Marrakech-Tensift-Al Haouz [5]	82	59	6,200	2,210	8,410	73.7%	26.3%	7.7%	10.9%	8.3%	5	3	5
L'Oriental [6]	41	19	5,102	956	6,058	84.2%	15.8%	6.3%	4.7%	6.0%	6	9	8
Grand Casablanca [7]	20	15	1,784	149	1,933	92.3%	7.7%	2.2%	0.7%	1.9%	14	14	14
Rabat-Sale-Zemmour-Zaer [8]	58	39	2,923	876	3,799	76.9%	23.1%	3.6%	4.3%	3.8%	10	10	12
Doukkala-Abda [9]	83	13	10,100	417	10,517	96.0%	4.0%	12.6%	2.1%	10.4%	2	13	3
Tadla-Azilal [10]	38	32	4,965	584	5,549	89.5%	10.5%	6.2%	2.9%	5.5%	7	12	9
Meknes-Tafilalet [11]	103	67	8,606	2,577	11,183	77.0%	23.0%	10.7%	12.7%	11.1%	3	2	2
Fes-Boulemane [12]	85	23	7,144	2,187	9,331	76.6%	23.4%	8.9%	10.8%	9.3%	4	4	4
Taza-Taounate-Al Hoceime [13]	34	41	2,067	1,934	4,001	51.7%	48.3%	2.6%	9.5%	4.0%	13	5	11
Tanger-Tetouan [14]	43	72	2,395	1,266	3,661	65.4%	34.6%	3.0%	6.3%	3.6%	12	8	13
National	961	545	80,475	20,252	100,728	79.9%	20.1%	100.0%	100.0%	100.0%			

Source: Author's compilation

(Data Source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php - Last accessed 2/4/2015)

Table 4.4 Sectoral Distribution of Projected Investments under The PMV Strategy by Pillar by 2020 (in Million MAD and in % Share)

Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)	Investment costs (in %share across Pillar)		Investment costs (in %share by sector)		Total cost (in % share)
	Pillar I	Pillar II	Pillar I	Pillar II		Pillar I	Pillar II	Pillar I	Pillar II	
Cereals sector (incl. seeds)	184	57	9,218	3,216	12,435	74.0%	26.0%	11.5%	15.9%	12.3%
Citrus sector	54	0	8,980	0	8,980	100.0%	0.0%	11.2%	0.0%	8.9%
Olive oil sector (incl. olives)	145	169	9,628	7,808	17,436	55.0%	45.0%	12.0%	38.6%	17.3%
Vegetables and Fruits sector	116	24	15,372	1,454	16,826	91.0%	9.0%	19.1%	7.2%	16.7%
Sugar crops	5	0	6,178	0	6,178	100.0%	0.0%	7.7%	0.0%	6.1%
Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	52	111	8,885	3,256	12,141	73.0%	27.0%	11.0%	16.1%	12.1%
Crop sectors total	**556**	**361**	**58,261**	**15,734**	**73,995**	**79.0%**	**21.0%**	**72.4%**	**77.7%**	**73.5%**
Dairy sector	87	23	12,755	1,204	13,959	91.0%	9.0%	15.8%	5.9%	13.9%
Red meat sector	267	101	3,354	2,820	6,174	54.0%	46.0%	4.2%	13.9%	6.1%
White meat sector (incl. eggs)	46	34	5,732	121	5,853	98.0%	2.0%	7.1%	0.6%	5.8%
Other livestock (incl. apiculture, cuniculture, etc.)	5	26	373	374	746	50.0%	50.0%	0.5%	1.8%	0.7%
Livestock sectors total	**405**	**184**	**22,214**	**4,518**	**26,732**	**83.0%**	**17.0%**	**27.6%**	**22.3%**	**26.5%**
Total	**961**	**545**	**80,475**	**20,252**	**100,727**	**79.9%**	**20.1%**	**100.0%**	**100.0%**	**100.0%**

Source: Author's compilation

(Data Source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php - Last accessed 2/4/2015)

Given that the analysis focuses on the analysis of climate change impacts on crop productivity and the adaptation potential of the PMV strategy, we limit the sector coverage in the PMV to crop production only and with a special focus on key crops. Table B4.10 (Appendix B) summarizes the current and projected impacts of the PMV strategy at the regional level on agricultural area, production and yields for four key crop categories: cereals, vegetables and fruits, citrus and olives. The PMV projects seek to attain production targets for the different crop categories through a combination of strategies such as arable land reallocation from cereals to high value-added crops, adoption of new seed varieties (especially in the cereal sectors), and adoption of modern irrigation techniques, etc.

Using data on current area and production, we derive current yields. Subsequently, projected yield impacts are calculated using data of projected changes in area and production targets to be achieved under the PMV strategy. Hence, we can infer the projected impacts on yields associated with the PMV by computing percent changes between current and projected yields. Finally, the PMV projected yields will be introduced in the model as Hicks-Neutral output-increasing technical change that compensates for the projected climate-induced yield changes.

Table 4.5 and 4.6 provide respectively a description of the scenarios in the analysis and a summary of the projected estimates of productivity gains under the PMV strategy by region and as adjusted. It is worth mentioning at this point that the PMV strategy's impacts on yield productivity as captured in Table 4.5. represent assumptions about projected outcomes, which are as much targets as projections. Hence, we are not able to assess realistically the degree to which these objectives will be met. Additionally,

we do not explicitly incorporate in our modeling the investment costs discussed in Tables 4.3 and 4.4.

Table 4.5 Description of Scenario Analysis

Scenario	Description
A2_noCO_2	Projected yield impacts by 2050 under SRES A2, with no CO2 fertilization effect and no adaptation
B2_noCO_2	Projected yield impacts by 2050 under SRES B2, with no CO2 fertilization effect and no adaptation
A2_wCO_2	Projected yield impacts by 2050 under SRES A2, with CO2 fertilization effect and no adaptation
B2_wCO_2	Projected yield impacts by 2050 under SRES B2, with CO2 fertilization effect and no adaptation
A2_noCO_2_PMV	Projected yield impacts by 2050 under SRES A2, with no CO2 fertilization effect and with PMV adaptation
B2_noCO_2_PMV	Projected yield impacts by 2050 under SRES B2, with no CO2 fertilization effect and with PMV adaptation
A2_wCO_2_PMV	Projected yield impacts by 2050 under SRES A2, with CO2 fertilization effect and with PMV adaptation
B2_wCO_2_PMV	Projected yield impacts by 2050 under SRES B2, with CO2 fertilization effect and with PMV adaptation

Source: Author's construction

Table 4.6 Projected Impacts on Crop Yields under the Plan Maroc Vert (PMV) for Strategic Crops by Region by 2020

Regions	PMV - Crop sectors targeted			
	Cereals	Vegetables	Olives	Citrus
Souss-Massa-Draa [2]	n.a.	47%	59%	33%
Gharb-Cherarda-Bni Hsan [3]	73%	n.a.	63%	67%
Chaouia-Ouardigha [4]	69%	68%	91%	n.a.
Marrakech-Tensift-El Haouz [5]	52%	n.a.	80%	30%
L'Oriental [6]	n.a.	n.a.	26%	96%
Grand Casablanca [7]	86%	80%	n.a.	n.a.
Rabat-Sale-Zemmour-Zaer [8]	87%	68%	83%	n.a.
Doukkala-Abda [9]	93%	62%	n.a.	n.a.
Tadla-Azilal [10]	38%	n.a.	79%	50%
Meknes-Tafilalet [11]	80%	n.a.	78%	n.a.
Fes-Boulemane [12]	93%	57%	92%	n.a.
Taza-Taounate-Al Hoceima [13]	85%	n.a.	44%	77%
Tanger-Tetouan [14]	n.a.	n.a.	53%	79%

Source: Author's Adaptation

(Data Source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

The total cost of investments projected by the PMV reaches 100 billion MAD. As discussed earlier, the PMV was officially launched during the agricultural campaign of 2008-09 for the next twelve year period (2009-2020). Assuming a uniform distribution of the cost of investment per annum, Table 4.7 summarizes the resulting evolution of the PMV investments as a share of observed performance in the agricultural sector and as captured by agricultural value-added in recent years. The share of the PMV investments in agricultural value-added is relatively stable when assuming a uniform per annum

disbursement schedule. Nevertheless, its temporal evolution is contingent upon the year-to-year performance of the agricultural sector, which is strongly affected by weather conditions.

Table 4.7 Evolution of the PMV Investment Costs for the Period 2009-2013 (in billion MAD and in % Share)

	2009	2010	2011	2012	2013
PMV Investment - Total	100.7				
PMV Investment - Annualized (1)	8.4	8.4	8.4	8.4	8.4
Agricultural, VA (2)	103.5	101.5	107.2	97.7	116.2
%Share = (1)/(2)	8%	8%	8%	9%	7%

Source: Author's construction

In terms of the introduction of the productivity shocks associated with the PMV, it is worth mentioning that the shocks associated with cereals and vegetables will be modeled for hard wheat (durum wheat) and soft wheat (common wheat), and tomatoes. In order to evaluate the adaptation potential of the PMV, we will adopt a scenario-based structure in our analysis. First, we will simulate the impacts of climate change in Morocco through the introduction of yield shocks as productivity shocks. This step will represent the without PMV adaptation scenario and we will refer to it as climate change without PMV adaptation ("CC-Only"). Second, we will introduce the PMV shocks as specified in Table 4.5 based on the 2003 Social Accounting Matrix (SAM) used as our baseline. This will allow us to update the baseline in order to generate an updated SAM. Subsequently, climate change shocks are introduced using the updated SAM, which will

represent the with PMV adaptation scenario referred to as climate change with PMV adaptation ("CC-PMV").[18]

Therefore, the objective is to contrast two states of nature with respect to climate change: one in which the PMV is not implemented ("CC-Only") vs. one in which the PMV is implemented ("CC-PMV").

It is important to note that we limit the analysis to the PMV strategy's impact on crop production. Hence, we ignore potential impacts on livestock sectors as they are not included in the climate change productivity shocks to be simulated.

In what follows, we will start by discussing the implications of the PMV on the Moroccan economy in general assuming no climate change occurring. We will report some key macroeconomic and welfare results. Subsequently, we will discuss the results of climate-induced productivity shocks and their economy-wide implications for Morocco by contrasting the CC-Only and CC-PMV scenarios.

4.5 Simulation Results and Discussion

4.5.1 Welfare and Macroeconomic Impacts of the PMV Strategy

The results suggest that the PMV strategy induces an expansion in the economic activity in Morocco. Table 4.8 summarizes aggregate economic impacts on key macroeconomic variables. In terms of welfare indicators such as total absorption[19] and

[18] From this point forward, we will refer to the scenario of the analysis identified pertaining to the climate change without and with PMV adaptation by their acronyms, "CC-Only" and "CC-PMV" respectively.

[19] Total absorption is measured as the total value of domestic final demands, which equals GDP at market prices plus imports minus exports (Lofgren et al., 2002) [Refer to the PDF of the IFPRI CGE model].

consumption by households, the PMV induces a significant increase. In addition, exports increase as well, albeit at a lower rate compared with imports. This suggests that, *ceteris paribus*, the PMV strategy's objective at reducing dependency on foreign markets might not be effective.

Table 4.8 Macroeconomic Impacts of the PMV Strategy by 2020 (in millions MAD and % change)

	BASE	PMV	% Change
Consumption (C)	272,986	281,920	3.3
Investment (I)	133,622	136,852	2.4
Government (G)	85,485	86,462	1.1
Exports (X)	139,736	141,075	1.0
Imports (M)	-153,254	-156,457	2.1
Gross Domestic Product (GDP)	478,574	489,853	2.4

Source: Simulation results

The increase in household consumption can be explained by investigating the dynamic of incomes. Table 4.9 summarizes the impacts of the PMV strategy on incomes, level of expenditure and welfare for rural and urban households. Overall, household incomes increase, with incomes for rural households marginally higher than their urban counterparts. As a result, household consumption expenditure increases, which induces a general appreciation in household welfare.

Additionally, the increase in rural households' expenditures is higher compared to urban households, and the welfare impacts exhibit a similar trend. This occurs despite incomes for both type of households increasing in somewhat similar magnitudes. The explanation to this outcome lies in the fact that rural households tend to spend more on

food compared to urban households. In Addition, the majority of rural households in Morocco, although generating most of their income from agriculture, tend to be net-buyers of food. On the other hand, the PMV strategy with its positive impacts on crop productivity induces market prices to decline, especially for the food commodities. Consequently, rural households' purchasing power increases as they can allocate the extra-income to expand and diversify their food basket. This in turn yields higher utility levels which are captured by the welfare results we discussed.

Table 4.9 PMV Impacts on Household Income, Real Consumption Expenditure and Welfare by Household Type and Region (in millions MAD and % Change)

	Income				Real consumption				Equivalent Variation (EV)			
	Rural		Urban		Rural		Urban		Rural		Urban	
	BASE	PMV (%Δ)	BASE	PMV (%Δ)	BASE	PMV (%Δ)	BASE	PMV (%Δ)	BASE	PMV (%Δ)	BASE	PMV (%Δ)
TR1	2,226	1.57	8,140	1.46	973	4.5	6,718	2.6	973	4.2	6,718	2.4
TR2	7,392	3.27	26,116	3.20	11,265	4.4	15,356	3.1	11,265	4.2	15,356	3.0
TR3	5,231	1.79	18,418	1.77	5,835	5.2	7,294	3.4	5,835	4.6	7,294	3.1
TR4	5,434	0.92	19,162	0.90	5,916	4.5	6,718	3.1	5,916	4.0	6,718	2.8
TR5	6,925	1.35	24,444	1.31	10,049	3.4	11,133	2.1	10,049	3.1	11,133	2.0
TR6	6,367	1.98	22,973	1.89	4,538	2.2	10,749	2.0	4,538	2.1	10,749	1.9
TR7	23,032	1.57	84,279	1.46	1,459	9.2	51,249	3.2	1,459	8.8	51,249	2.9
TR8	8,672	1.37	32,022	1.25	2,674	6.1	23,609	3.2	2,674	5.6	23,609	2.9
TR9	5,490	1.85	19,252	1.83	7,375	5.4	7,678	3.6	7,375	4.8	7,678	3.3
TR10	3,333	0.92	11,641	0.92	6,240	3.4	6,334	2.1	6,240	3.1	6,334	2.0
TR11	6,023	1.55	21,643	1.48	5,025	5.0	11,901	2.9	5,025	4.5	11,901	2.6
TR12	4,825	1.56	17,755	1.43	2,350	6.2	11,325	3.3	2,350	5.5	11,325	3.0
TR13	3,389	-0.41	11,478	-0.40	10,292	3.9	5,374	2.1	10,292	3.3	5,374	1.8
TR14	7,500	0.93	27,162	0.87	7,051	2.6	16,507	1.9	7,051	2.5	16,507	1.9
National	95,838	1.54	344,485	1.47								

Source: Simulation results

At the sectoral level, the PMV strategy has positive impacts on agricultural crop productivity and positive impacts on the rest of the economy. Table 4.10 summarizes the percentage changes observed. As we would expect, agricultural value-added increases significantly given the magnitude of the PMV productivity shocks, especially for crop production. Other sectors exhibit relatively lower impacts ranging from +0.1% to +1.4%, except for the food processing sector where value-added increases by 4%. This result is not surprising given the direct linkage that exists between agricultural production and the food processing sector.

Table 4.10 Impacts of the PMV Strategy on Sectoral Value-Added by 2020 (in millions MAD and % Change)

	BASE	PMV	% Change
Agriculture	69,445	77,786	12.0
- Agricultural Crops	52,047	60,227	15.7
- Forestry & Fishery	6,137	6,143	0.1
- Livestock	11,260	11,416	1.4
Non-Agriculture	355,208	359,059	1.1
- Food Processing	22,751	23,664	4.0
- Other industries	99,567	100,076	0.5
- Services	232,890	235,319	1.0

Source: Simulation results

At the sectoral level, sectors targeted by the PMV strategy exhibit an expansion in production. Hence, prices decline and consumption increases. As production in these sectors becomes more efficient, factors of production are bid up by more constrained sectors that benefit from the reduction in the economy-wide wage factor. The decline in

the land rental for agricultural crop sectors is especially pronounced. This is observed primarily for non-export oriented sectors. For export-oriented crops such as tomatoes and citrus, we actually observed an increase in the rental rate for land. This is driven in part by the increase in domestic demand, but also in export demand which exhibits larger increases.

4.5.2 Macroeconomic Impacts of Climate Change without the PMV (CC-Only) and with the PMV (CC-PMV)

Table 4.11 reports the macroeconomic results characterizing the impacts of climate change without the PMV (CC-Only) and with the PMV (CC-PMV). The results include the average across the percentile distribution ("Avg") and the range of impacts captured by the maximum ("Low") and the minimum ("High").[20] The CC-PMV base displays larger levels in terms of the macroeconomic indicators compared to the CC-Only based. This is due to the fact that the CC-PMV base represents a snapshot of the economy after the introduction of the PMV productivity targets, which was discussed in the previous section, while the CC base represents only the post climate change economy.

Simulation results suggest that macroeconomic impacts under the CC-Only case, i.e. climate change only, can be large on average. In terms of impacts on gross domestic product (GDP), impacts vary between -1% to -2% across climate scenarios without CO2 fertilization. A similar trend is observed for the rest of macroeconomic variables. For instance, private consumption and investment decline by -2% to -3% on average. The

[20] The maximum ("Low") boundary point in terms of climate change impacts represents the case where agricultural productivity is assumed to be at its lowest, and vice-versa for the minimum ("High") boundary point.

impacts on the rest of GDP components exhibit lesser magnitudes, with government expenditures and imports declining by -1% to -2%. For exports, impacts are slightly positive and vary from +0.6% to +0.8%. If the CO_2 fertilization effects are accounted for, the general trend does not change. Nevertheless, the magnitude of the declines observed are dampened owing to the compensating effect that CO_2 fertilization has on yield losses due to climate change.

The distribution of impacts due to climate uncertainty displays a relatively wide range. For example, GDP change varies from -3% ("Low") to -0.5% ("High") across climate scenarios under the without CO_2 fertilization case. Impacts for the SRES A2 climate scenario are usually higher in magnitude compared to the SRES B2. The effect of CO_2 fertilization on productivity in the agricultural sector can produce a positive shift in the distribution of impacts. For both SRES climate scenarios, the effect on GDP depicts a positive shift. For instance, GDP varies between -1% to +0.4% under SRES A2 and -1% to +0.3% under SRES B2 (Table 4.11).

Private consumption and investment exhibit the largest variation in terms of impacts. Indeed, the impacts of climate change on consumption vary from -4.5% to -1%; whereas investment varies from -4.3% to -1% across both climate scenarios, SRES A2 and B2. For government and imports, impacts vary by -3% to -0.6% and -3.3% to -0.8% respectively. The exception is exports where they exhibit a positive impact, but with no significant variation. The magnitude of the reported increase varies from +0.4% to +1% across scenarios. Similar to GDP, when accounting for the CO_2 fertilization effects, the results suggest a noticeable appreciation. Nevertheless, the results remain negative owing

to the fact that the CO_2 effects do not compensate enough the climate-induced damage on crop productivity (Table 4.11).

Under the CC-PMV case, i.e. climate change with the PMV, macroeconomic impacts are marginally lower in magnitude than the CC-Only case for GDP. For instance, the net effect of the PMV on GDP are slightly positive and vary on average between +0.02% to +0.03% across climate scenarios when comparing the CC-Only and CC-PMV cases. A similar result is observed for investment where the PMV induces a net increase varying between +0.02% to +0.06%. Nevertheless, the largest net impacts of the PMV are observed at the level of trade. Indeed, impacts on exports vary from -0.2% to +0.04% across climate scenarios. A similar trend is observed for imports with relatively higher magnitudes compared to exports. The impacts vary from -0.25% to -0.4%. For private consumption and government, the PMV induces slight net negative impacts varying from -0.04% to -0.09% (Table 4.11).

Table 4.11 Macroeconomic Impacts of Climate Change — Without and With the PMV Strategy by 2050 (in % Change from BASE)

		Climate change impacts (in % Change from BASE)											
		Without CO_2 fertilization						With CO_2 fertilization					
	BASE(*)	A2			B2			A2			B2		
		Avg	Low	High	Avg	Low	High	Avg	Low	High	Avg	Low	High
CC-Only													
Consumption - C	272,986	-2.82	-4.48	-1.45	-2.06	-3.45	-0.89	-0.85	-2.26	0.38	-0.83	-2.19	0.29
Investment - I	133,622	-2.82	-4.43	-1.51	-1.99	-3.22	-0.95	-1.17	-2.34	-0.14	-1.01	-2.13	-0.08
Government - G	85,485	-1.69	-2.63	-0.92	-1.22	-1.97	-0.60	-0.76	-1.48	-0.13	-0.66	-1.34	-0.08
Exports - X	139,736	0.84	1.23	0.54	0.64	0.84	0.49	1.02	1.14	0.88	0.78	0.89	0.67
Imports - M	-153,254	-1.84	-2.79	-1.06	-1.29	-2.13	-0.60	-0.62	-1.38	0.01	-0.51	-1.24	0.08
Gross Domestic Product (GDP)	478,574	-1.86	-3.01	-0.91	-1.35	-2.29	-0.54	-0.45	-1.43	0.41	-0.48	-1.42	0.30
CC-PMV													
Consumption - C	281,920	-2.86	-4.53	-1.48	-2.10	-3.51	-0.92	-0.93	-2.34	0.30	-0.90	-2.25	0.21
Investment - I	136,852	-2.76	-4.35	-1.49	-1.94	-3.14	-0.93	-1.16	-2.27	-0.19	-0.99	-2.05	-0.12
Government - G	86,462	-1.76	-2.72	-0.97	-1.28	-2.05	-0.64	-0.85	-1.57	-0.21	-0.73	-1.43	-0.15
Exports - X	141,075	0.63	0.87	0.45	0.45	0.50	0.43	1.06	0.99	1.10	0.77	0.69	0.82
Imports - M	-156,457	-2.21	-3.32	-1.29	-1.61	-2.61	-0.78	-0.88	-1.80	-0.11	-0.76	-1.64	-0.05
Gross Domestic Product (GDP)	489,853	-1.83	-2.98	-0.89	-1.33	-2.27	-0.52	-0.42	-1.39	0.43	-0.46	-1.39	0.31

(*): BASE values are in 2003 million MAD

Source: Simulation results

With respect to the impact of the PMV, the results depict that private consumption and government expenditure experience a slight additional decline and with small variability. With respect to investment, the net effects of the PMV are positive overall, but with low magnitudes. For private consumption, government and investment, we notice little differential between the without and with CO_2 fertilization cases. The largest impacts of the PMV are captured in trade accounts. Indeed, under the without CO_2 case, the net impacts of the PMV suggest that exports decline further, but with imports exhibiting an even larger drop. This results in a slight improvement in the net trade position in Morocco. These results are improved upon when including the CO_2 fertilization effect and its alleviating impacts on yield losses under climate change. In this case, the distribution of net impacts associated with the PMV shifts to positive territory for exports and remains negative for imports (Figure 4.13).

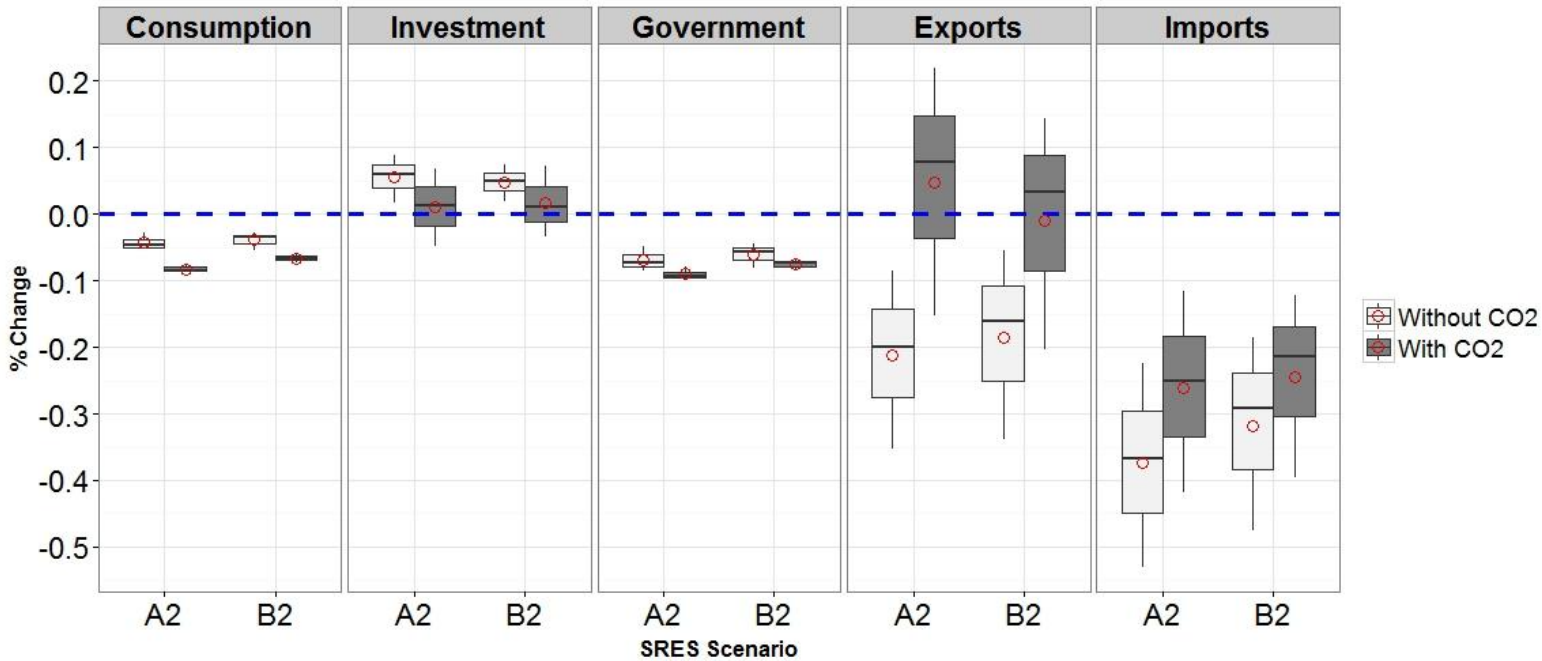

Figure 4.13 Distribution of Net Impacts of the PMV Strategy on GDP Components by 2050 (% Change from BASE)

Source: Simulation Results

Overall, the macroeconomic impacts of climate change without the PMV strategy (CC-Only) do not differ in a major way from the impacts with the PMV strategy (CC-PMV). In other words, the ability of the PMV strategy to mitigate the negative effects of climate change are limited at best, if non-existent. A potential cause for such results is the limited scope in terms of agricultural sector coverage of the PMV simulations. As previously discussed, we limited the PMV simulations to the strategic agricultural crop sectors in Morocco, which include: durum and common wheat, tomatoes, citrus and olives. Jointly, these sectors represent no more than 35% of aggregate agricultural GDP; whereas the rest of the sectors account for 65% (Table 4.12). Hence, the productivity targets of the PMV affect only one third of Moroccan agriculture; whereas climate change effects span the entire agricultural crop sectors.

Table 4.12 Agricultural Gross Domestic product (GDP) by Crop Sector (in 2003 million MAD)

Category	Sector	Value	Share (in %)	Total share (in %)
PMV crops	Durum wheat (HDWHT-A)	4,414	8%	35%
	Common wheat (SFWHT-A)	8,005	15%	
	Tomatoes (TOMAT-A)	1,859	4%	
	Citrus (AGRMS-A)	2,225	4%	
	Olives (OLIVE-A)	1,828	4%	
Non-PMV crops	Barly (BARLY-A)	4,558	9%	65%
	Forage crops (FORAGS-A)	2,795	5%	
	Other vegetables (XVEGTS-A)	7,963	15%	
	Other industrial veg (XVGIN-A)	160	0%	
	Other fruits (XFRUTS-A)	10,993	21%	
	Other crops (XCROPS-A)	7,248	14%	
Total		52,047	100%	

Source: Author's adaptation (Data source: 2003 Social Accounting Matrix)

4.5.3 Climate Change Impacts on Household Income, Consumption and Welfare Without (CC-Only) and With (CC-PMV) the PMV Strategy

The dynamic with respect to households' incomes, real expenditure and welfare impacts resembles the performance of GDP. On average, the differential between scenarios in terms of income is not significant. In addition, the impacts on rural and urban households' income appear to be similar across scenarios and regions. Nevertheless, some regions depict a significant change in terms of household incomes when comparing the without CO_2 and with CO_2 fertilization results.

For instance, impacts on incomes switch from negative under the without CO_2 case to positive under the with CO_2 case in the regions of Souss-Massa-Draa [R2], Gharb-Cherarda-Bni Hsan [R3] and Tadla-Azilal [10]. These regions represent the leading agricultural production regions in Morocco, and specialize - especially in the case of the Souss-Massa-Draa [R2] - in intensive agricultural production such as vegetables and fruits. As previously discussed, the structure of production in these regions is dominated by crops sectors that are projected to benefit from climate change. And hence, it is not surprising that we observe positive effects on households' income (Table B4.11, Appendix B).

Upon investigating the percentile distribution across regions, the results display important regional differentials. For rural households, it varies from -4% to +0.3% across SRES climate scenarios A2 and B2 under the without CO_2 fertilization case. When accounting for CO_2 fertilization, the distribution across regions is further skewed toward positive territory with the impacts on income ranging from -3% to +1%. Similar results hold for urban households in general (Figures A4.13a and A4.13b, Appendix A).

To investigate the impacts of the PMV strategy on incomes, we compared the CC-Only and CC-PMV cases. The effect of climate change on incomes remain negative even after accounting for the PMV strategy. Nevertheless, and in comparison with the CC-Only case, the final net effects are slightly positive, which suggests that the PMV induces a partial alleviation in incomes losses experienced under the climate change only case (CC-Only). Net impacts on incomes vary from -0.2% to +0.7% for rural households and similarly for urban households across regions (Figure 4.14).

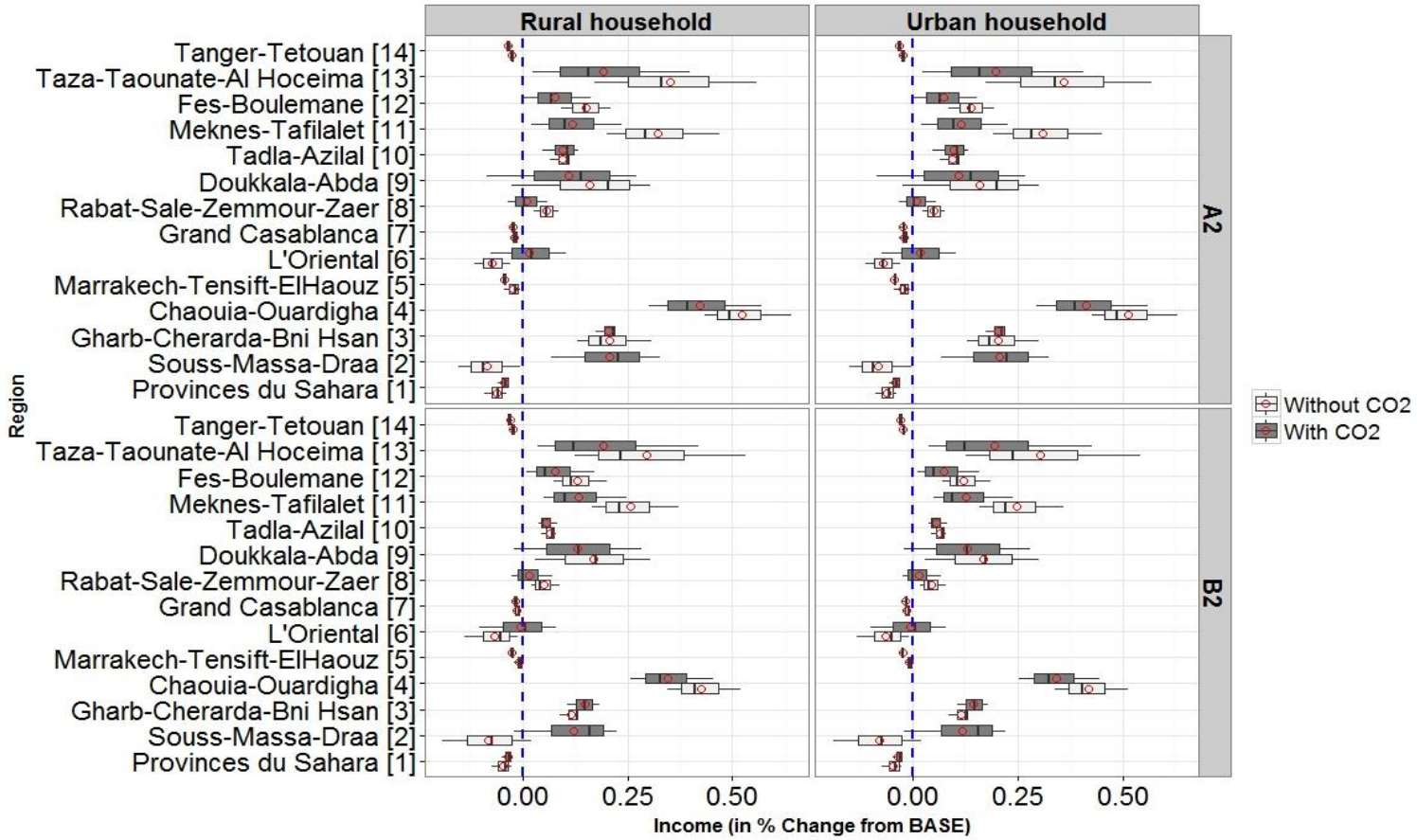

Figure 4.14 Distribution of Net Impacts of the PMV Strategy on Rural and Urban Households Incomes by 2050 (% Change from BASE)

Source: Simulation Results

Despite similar impacts on rural and urban incomes due to climate change, there exist a substantial differential in terms of other welfare measures such as consumption expenditures and welfare. In general, consumption expenditures for rural households tend to decrease more compared with urban households in all regions and across climate scenarios. For instance, rural households' consumption expenditure declines by 13% on average in the Grand Casablanca [R7] region under the SRES A2 and when CO_2 fertilization effects are not included; whereas it declines by 3% for urban households (Table B4.12, Appendix B).

Overall, this dynamic is observed across all regions and all scenarios. These results are not surprising given the expected impacts of climate change on market prices, and especially for the food commodities. Negative productivity impacts affects market supply, and hence induces price hikes. This in turn affects differently rural and urban households. For the former, a significant share of income is allocated to expenditure on food consumption. Therefore, the double whammy of decreased incomes and increased prices affects rural household more. The results suggest that the net impacts of the PMV on households' real expenditure are marginally negative across regions (Figure 4.15).

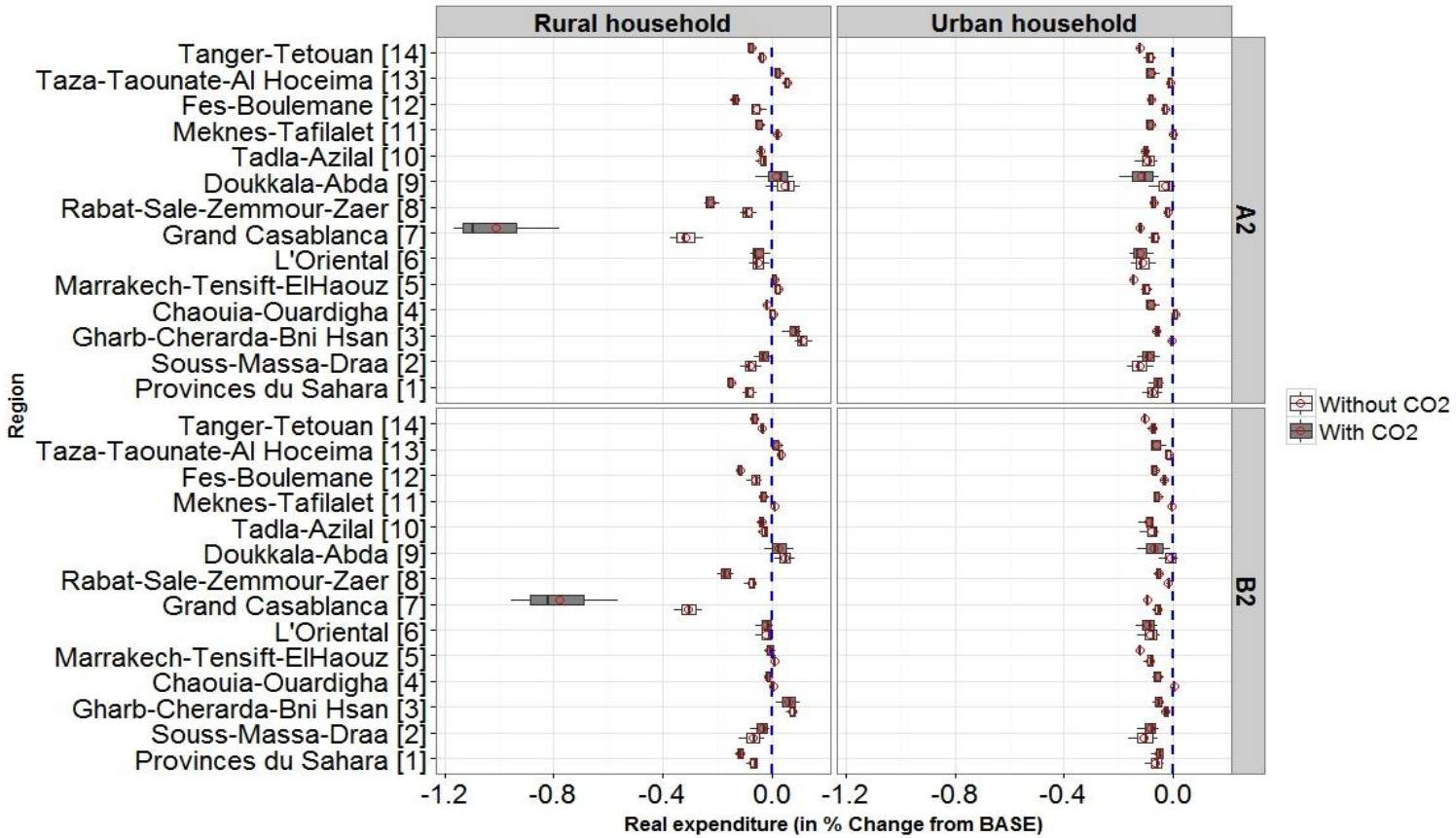

Figure 4.15 Distribution of Net Impacts of the PMV Strategy on Rural and Urban Households Real Expenditure by 2050 (% Change from BASE)

Source: Simulation Result

The income dynamic and its effect on level of expenditure by household induces similar impacts on welfare. In general, climate change induces negative welfare impacts on average The welfare impacts for urban households are larger than rural households (Table B4.13, Appendix B). This is due to the differential in terms of their respective shares in total income, but also to the fact that rural households would tend to gain from climate change through increased supply prices. Nonetheless, and as discussed previously, higher supply price would greatly benefit rural households who are net sellers of food and which represent a minority in Morocco. In what pertain the net impact of the PMV, the results suggests that it induces marginal welfare losses across regions (Figure 4.16).

The net negative impacts on households' real expenditure and welfare associated with the PMV strategy can be explained by exploring the market conditions underlying supply and price dynamics. We will discuss the characteristics of the different outcomes in market equilibrium conditions under the CC-Only and CC-PMV cases to highlight key drivers of the observed results in the following section.

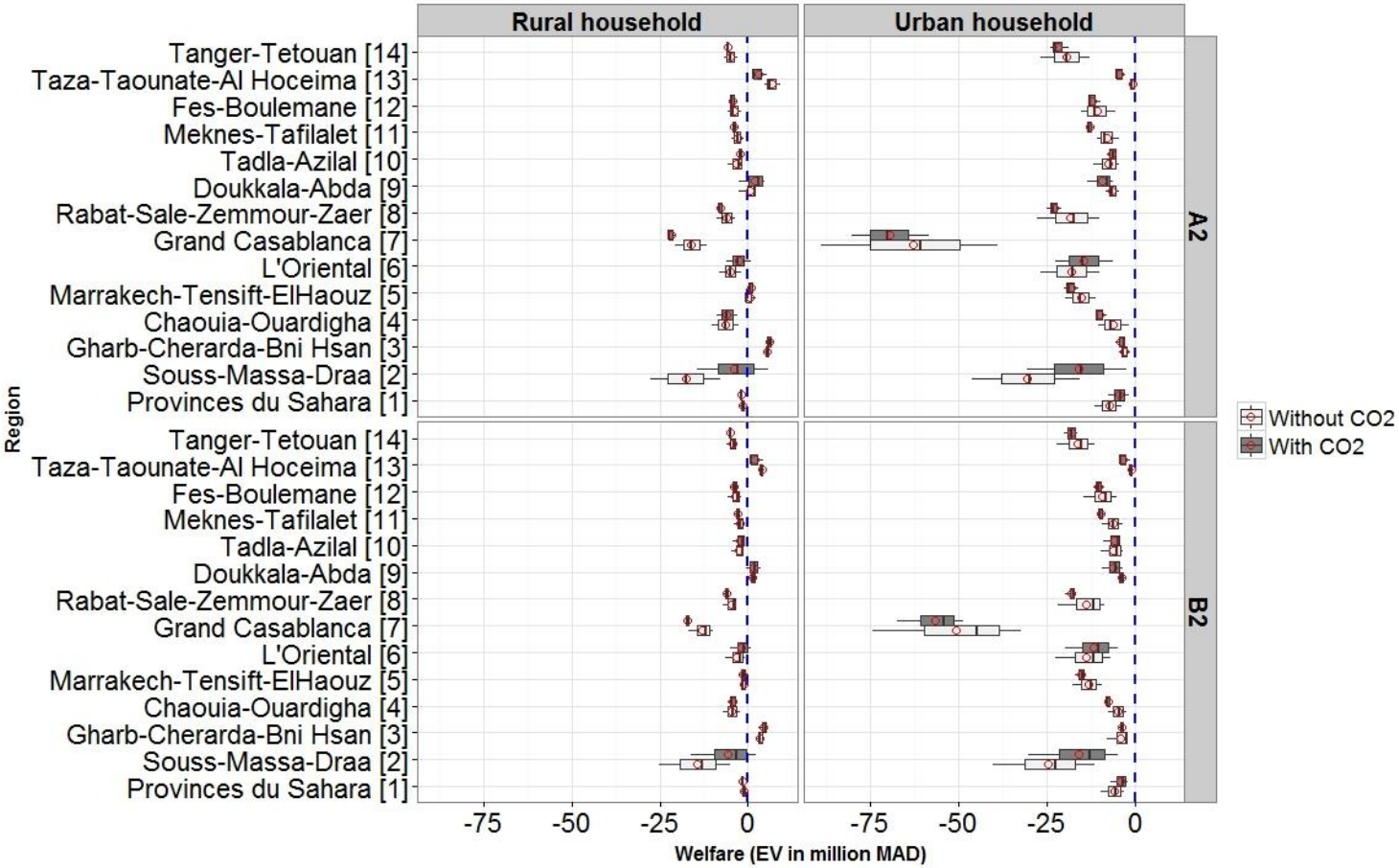

Figure 4.16 Distribution of Net Welfare Impacts of the PMV Strategy on Rural and Urban Households by 2050 (in million MAD)

Source: Simulation Result

4.5.4 Sectoral Impacts

As discussed in the previous section, climate change induces a general contraction in economic activity as suggested by the macroeconomic impacts and the impacts on incomes and welfare. This contraction in the level of economic activity is clearly depicted in our sectoral results (Table 4.13).

Table 4.13 Average Impacts of Climate Change on Sectoral Value-Added—Without and With the PMV Strategy by 2050 (in % change from BASE)

		Climate change impacts - without CO_2 fertilization		Climate change impacts - with CO_2 fertilization	
	BASE(*)	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
CC-Only					
Agriculture	69,445	-7.22	-5.45	-1.36	-1.80
– Agricultural Crops	52,047	-8.77	-6.60	-1.52	-2.13
– Livestock	11,260	-3.49	-2.69	-1.08	-1.05
– Forestry & Fishery	6,137	-0.99	-0.74	-0.49	-0.41
Non-Agriculture	355,208	-0.85	-0.61	-0.27	-0.25
– Food Processing	22,751	-3.94	-2.95	-1.33	-1.30
– Other industries	99,567	-0.07	-0.01	0.00	0.02
– Services	232,890	-0.89	-0.64	-0.28	-0.26
CC-PMV					
Agriculture	68,728	-6.16	-4.54	-0.47	-1.02
– Agricultural Crops	50,692	-7.40	-5.43	-0.30	-1.07
– Livestock	11,816	-3.52	-2.70	-1.15	-1.10
– Forestry & Fishery	6,220	-1.05	-0.78	-0.57	-0.48
Non-Agriculture	362,877	-1.00	-0.73	-0.36	-0.33
– Food Processing	24,018	-4.00	-2.99	-1.46	-1.39
– Other industries	101,200	-0.19	-0.10	-0.06	-0.05
– Services	237,659	-1.04	-0.77	-0.38	-0.35

(*): BASE values in 2003 million MAD
Source: Simulation Results

As one might expect, the agricultural sector (specifically the crop production sectors) is the hardest hit due to the direct impact on crop yields. On average, output from

agricultural value-added falls by -1.4% to -7%, across climate scenarios for the without and with CO_2 fertilization cases. Livestock and food processing sectors exhibit a decrease in value-added which ranges from -1.1% to -3.5% and -1.3% to -4% respectively. These results are expected given the strong linkages between crop production on one hand, and food processing and livestock on the other through the intermediate input dynamics. The impact on other sectors follows a similar trend as they exhibit a relatively moderate decline.

The impacts of climate change with the PMV (CC-PMV) are slightly higher in comparison to the without PMV case (CC-Only). The exception is the agricultural crops sectors which exhibit lower impacts. On average, the PMV accounts for a net gain in agricultural crop sectors' value-added ranging from +0.8% to +1.1%. For the non-agricultural sectors, the net impacts of the PMV are slightly negative.

In terms of climate-induced uncertainty, the percentile distribution within the climate scenarios displays large magnitudes for the agricultural, livestock and food processing sectors, and marginally for the rest of the sectors. For example, impacts on agricultural crop value-added range from -3% to -14% across climate scenarios under the without CO_2 fertilization case and from -7% to +3% under the with CO_2 fertilization case. For livestock, the magnitude of impacts is smaller ranging from -1% to -5% without CO_2 fertilization, and -3% to +1% with CO_2 fertilization. The impacts for food processing value-added are similar where they range from -1% to -6% without CO_2 fertilization and -3% to +1% with CO_2 fertilization. The impacts for the rest of the sectors are not large, but remain negative (Figure 4.17).

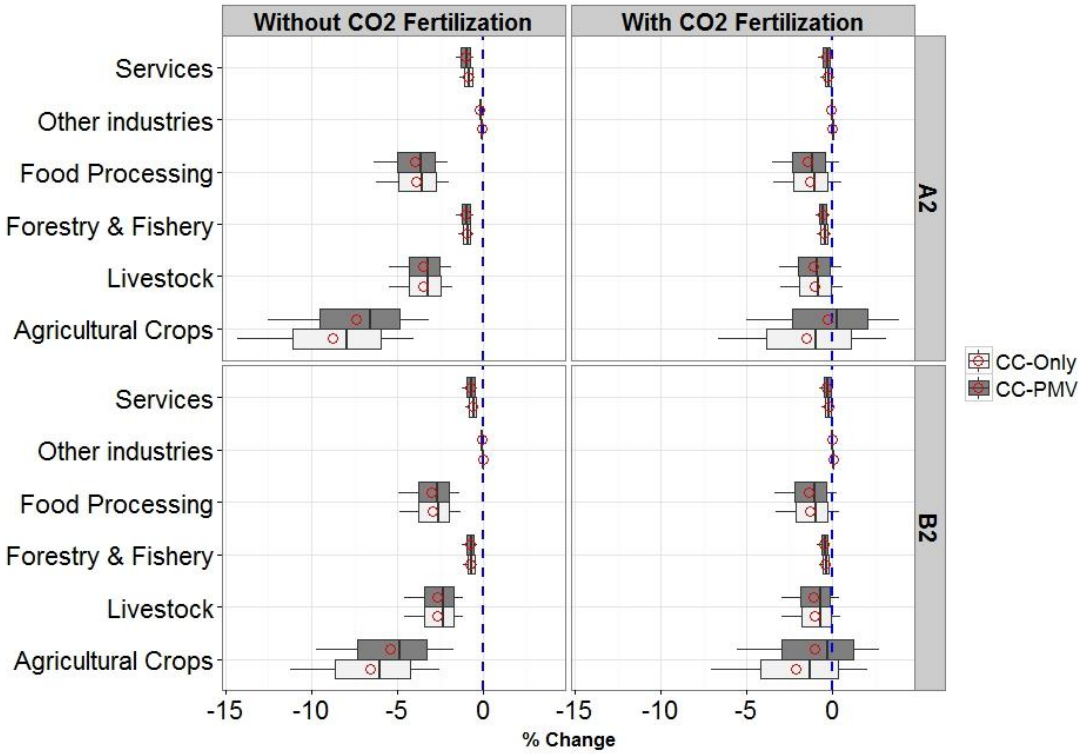

Figure 4.17 Percentile Distribution of Climate Change Impacts on Sectoral Value-Added — With and Without the PMV Strategy by 2050 (% Change from BASE)

Source: Simulation Results

The PMV strategy induces some gains in terms of mitigating the climate change impacts on climate-sensitive sectors. For instance, the net impacts associated with the PMV on agricultural crops value-added vary from +1% to +2% across climate scenarios. For the remaining sectors, the net impacts of the PMV are marginally negative. For example, food processing value-added exhibits a net decline ranging from -0.04% to -0.12% across climate scenarios. The rest of the sectors depict a similar trend where the net impacts vary from a minimum of -0.02% to a maximum of -0.3% across sectors and climate scenarios (Figure 4.18).

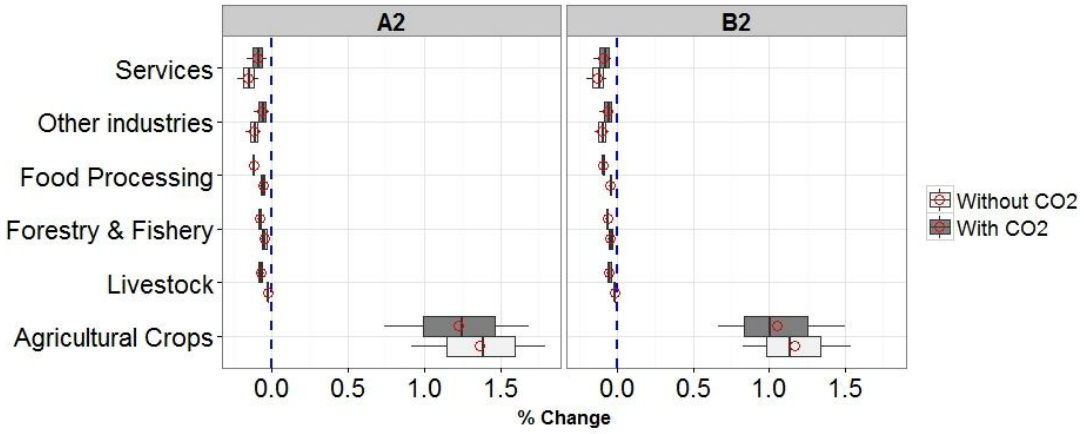

Figure 4.18 Percentile Distribution of Net Impacts of the PMV Strategy on Sectoral by 2050 (% Change from BASE)

Source: Simulation Results

Tables B4.14 and B4.15 (Appendix B) summarize the impacts of climate change on a number of key variables at the activity level for the agricultural crop and food processing sectors.

For most crop sectors under the CC-Only case, decline in yield productivity lowered production, and hence market supply. As a result, commodity prices exhibit significant increases, which affects negatively consumption. For instance, impacts are especially large for the cereal sectors. This is not surprising given the climate-induced productivity losses in those sectors are large owing to a predominantly rainfed production structure as argued previously. On average, the decline in domestic production across climate scenario (without and with CO_2 fertilization) vary from -9% to -15%, -8% to -14% and -3% to -8% respectively for the three main cereals, i.e. durum wheat, common wheat and barley. As a result, supply prices on average increase by +12% to +19% for durum wheat, +9% to +15% for common wheat, and +12% to +24% for barley. Consequently,

we observe a substantial drop in consumption demand for domestic production, which is alleviated by large increases in imports. For example, imports for durum wheat, common wheat and barley increase by +28% to +37%, +17% to +30% and +43% to +95% respectively across climate scenarios (without and with CO_2 fertilization).

These effects tend to be marginally dampened by the offsetting impacts of CO_2 fertilization effect on yield productivity losses. Nevertheless, the crop sectors benefitting the most from it remain few and are export-intensive. Under the with CO_2 fertilization case, exports tend to increase by +18% to +25% and +5% to +11% respectively for tomatoes and citrus. This is driven by the fact that the yield response to CO_2 fertilization effects for these crops is large enough to offset the productivity loss and induce important gains given their irrigated mode of production. In turn, production increases, which drives down the domestic price. As a result local consumption increases, but at a lower magnitude compared to output. This is due to the fact that producers of tomatoes and citrus export a significant share of their output to international markets in order to capture higher returns.

For food processing sectors, the impacts follow a similar trend to the agricultural crop sectors, but with lower magnitudes. The highest impacts are concentrated in sectors where the link with the crop sectors is strongest. This is the case for the mill industries for durum and common wheat, and for the olive oil processing sectors. These sectors are direct users of primary raw material in terms of agricultural crops; hence, the effect of climate change on market supply and prices affects the cost structure within these industries as it increases the cost of intermediate inputs. For the rest of the sectors, the level of impacts varies depending on the strength of linkages with the agricultural sector.

The impacts on factor markets for the agricultural sectors occur mainly via the effect on the rental rate on agricultural land (irrigated and rainfed), labour and capital; whereas for the rest of the sectors, labour and capital are the only factors of production. In general, the employment of capital and labour increases significantly for the agricultural crop sectors, especially for cereals which represent the dominant crop. For instance, employment demand for capital and labour increases on average by +10% to +19% and +4 to +17% respectively across climate scenarios (without and with CO_2 fertilization) for the three main cereals. The increase in the demand for capital is due to the decrease in its price. Indeed, as climate change increases prices of intermediate inputs for the non-agricultural sectors, productivity of factors declines. Hence, as production falls, supply of capital increases and induces a general fall in its price.

A similar dynamic unfolds for labour. On the other hand, the agricultural commodity price increase incentivises producers in the agricultural sector to expand and intensify production. As a result, we observe a reallocation of factors of production to the agricultural sectors, which increases their employment demand for labour and capital. Coincidentally, demand for irrigated and rainfed land increases as well as suggested by the increase in its rental rate. Nevertheless, due to the limited size of agricultural labour and capital market, increase in demand does not translate into an increase in their economy-wide rate. Hence, this dynamic affects incomes for households who obtain most of their income from labour and capital as previously discussed.

When comparing the CC-Only and CC-PMV cases, the general trend in results remains largely unchanged. Impacts on the domestic market front exhibit little change in terms of consumption, production and prices for most crop sectors. The exception being

the sectors targeted by the PMV strategy which include the cereal sectors of durum (hard) and common (soft) wheat, tomatoes, citrus and olives, which exhibit lower impacts on production under the CC-PMV case compared to the CC-Only case. Hence, the PMV induces net gains in terms of production, which translates into a net decline in domestic prices (Figure 4.19).

For durum wheat, common wheat, and olives, the net effect of the PMV on production is positive and ranges from +0.5% to +6.5%, +0.5% to +4% and +0.3% to +3.7% respectively across climate scenarios. As a result, the net effect on prices vary from -0.8% to +0.3%, -0.25% to +0.3% and -0.6% to -5.5% respectively. For tomatoes and citrus, the net impacts of the PMV exhibit lesser magnitude compared to the previous crops.

For the food processing sectors, the PMV strategy does not induce substantial changes in market conditions. The exception are the olive oil and whole olives sectors. Net production impacts of the PMV range from +0.6% to +4.4% and from +0.6% to +4.5%, which induce prices to adjust by -0.6% to -6.1% and -0.3% to -3% for olive oil and whole olives respectively (Figure 4.20).

At the level of factor markets, the net effect of the PMV suggest a positive gain in terms of employment demand for labour and capital, and higher returns for agricultural land (irrigated and rainfed). The largest net impacts are concentrated in crop sectors targeted by the PMV. For instance, the net impact of the PMV on returns to agricultural land in the cereal sectors of durum and common wheat vary between +3% to +18% and +3 to +11% respectively across climate scenarios. A similar result is observed for

tomatoes, citrus and olives, albeit with much lower magnitudes. These results explain the net impacts of the PMV observed for incomes as previously discussed.

Nevertheless, it remains evident that the extent toward which the PMV offsets the total damage from climate change remains limited, and not guaranteed.

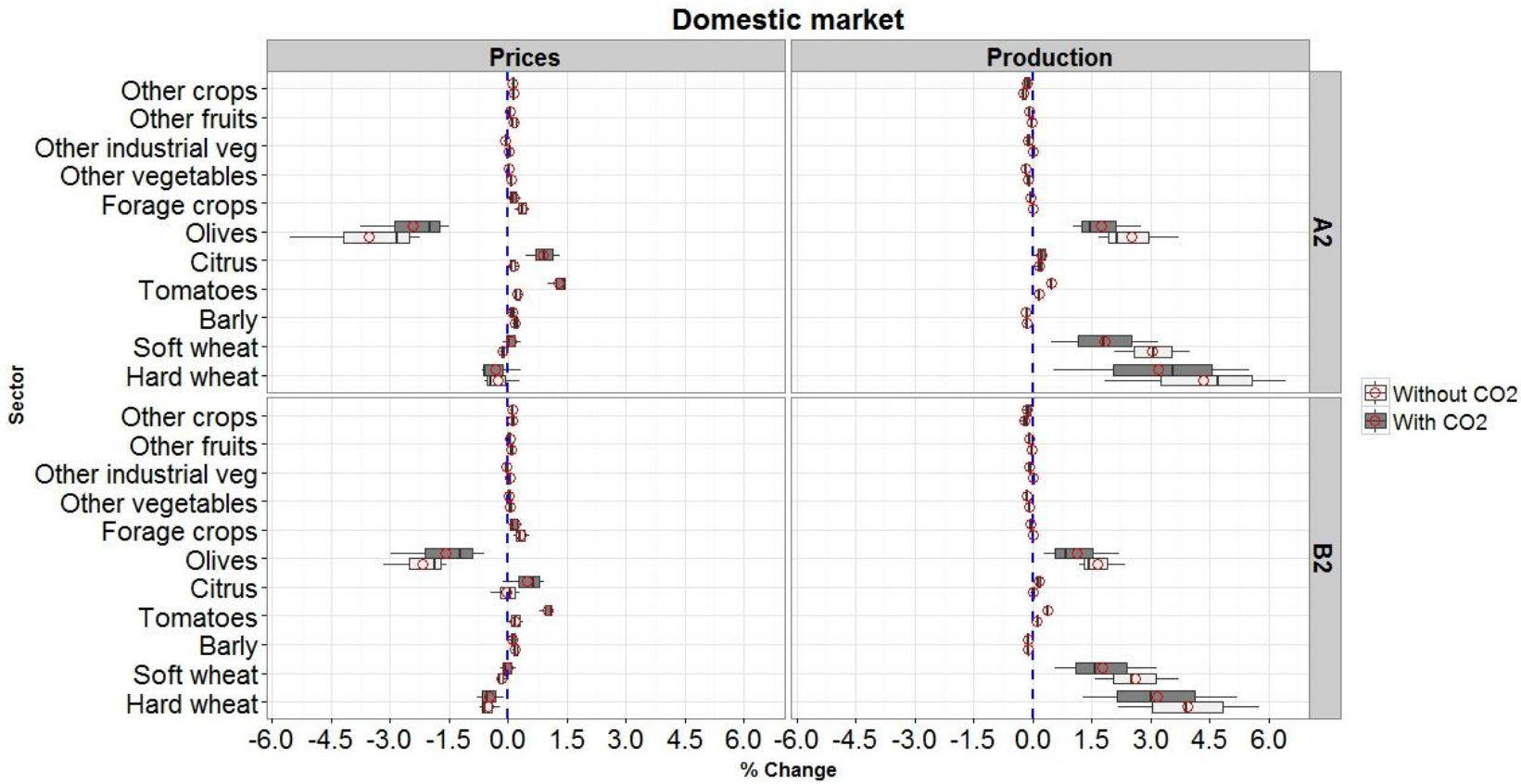

Figure 4.19 Percentile Distribution of Net Impacts of the PMV Strategy on Domestic Prices and Production for Agricultural Crop Sectors by 2050 (% Change from BASE)

Source: Simulation Results

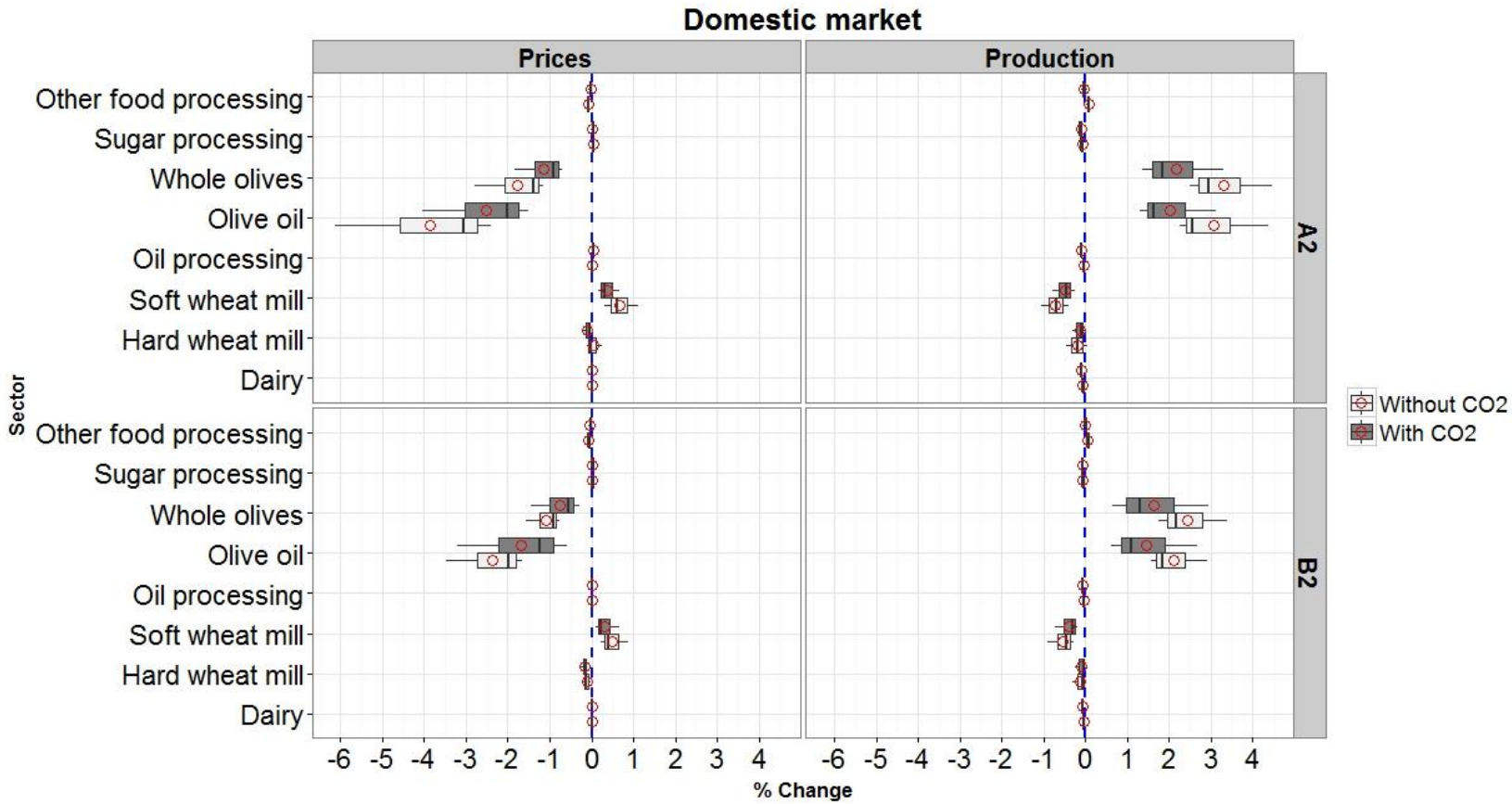

Figure 4.20 Percentile Distribution of Net Impacts of the PMV Strategy on Domestic Prices and Production for Food Processing Sectors by 2050 (% Change from BASE)

Source: Simulation Results

4.6 Summary and Conclusions

The agricultural sector in Morocco consists of a heterogeneous distribution of production activity across regions. This diversity in the regional structure of agriculture brings about complicated linkages in terms of projected impacts of climate change across regions, which in turn trickles through the rest of the economy.

In this chapter, we explored the economy-wide impacts under different climate-driven agricultural productivity scenarios. To that effect, we developed a regionalized country-based CGE model. The first step consisted in modelling the effects of the PMV strategy in Morocco and evaluating its economy-wide impacts. In the second step, we introduce climate change through productivity shocks in the agricultural sector and assess the extent to which the potential gains from the PMV buffers the projected negative impacts of climate change. This is achieved by comparing the impacts on the Moroccan economy under our two states of nature: climate change only (CC-Only) and climate change with PMV (CC-PMV).

The findings suggest that the PMV strategy can boost the economy in a significant manner if the productivity targets are achieved. The macroeconomic impacts suggest a positive impact on GDP, and particularly on the consumption component. This is driven by the observed positive impacts on incomes, which, in turn, improves households' welfare through the improvement in their purchasing power. Higher productivity in the agricultural sector induces an increase in market supply, which causes market prices to decline. In turn, the non-agricultural sectors benefit from the reduction in the cost of intermediate inputs and expand production via increased demand for primary

and intermediate inputs. As a result, wage rates for labour and rental rates for capital and land increase, and this helps explain the income dynamic discussed earlier.

Climate-induced yield losses induce a decrease in domestic output levels of agriculture, and to a certain degree food processing and livestock sectors, are substantially affected by climate change. Depending on the strength of the linkages that exist between the primary sector and the rest of the economy, the former tend to act as a drag on the rest of the sectors through many channels. Under the worst case scenarios, negative productivity shocks on agricultural crop sectors induce substantial supply declines in domestic output. As a result, market prices increase, which affects the non-agricultural sectors productivity through increased costs of production. In turn, market supply of non-agricultural sectors is affected negatively, which results in the fall of productivity of primary factors of production, primarily labour and capital. As a result, wage rates for labour and rental rates for capital decline. In the face of increased agricultural prices, coupled with these rate declines, agricultural producers expand production as suggested by increased employment demand for factors of production. Nevertheless, this feedback effect does not offset the initial damage from climate change. Despite higher demand for labour and capital from agriculture, the final effect on wage rate remains negative.

When we compare the CC-Only and CC-PMV cases at the macroeconomic level, the PMV induces net gains. Nonetheless, the magnitude of net effect of the PMV remains small. Net impacts on GDP vary from +0.02% to +0.04% across climate scenarios. At the sectoral level, agricultural crop value-added exhibits the largest net gains ranging from +0.7% to +2% across climate scenarios. For the food processing sectors, the net impacts

associated with the PMV range from -0.04% to -0.12%. The remaining sectors exhibit marginal net losses ranging from -0.01% to -0.2% across climate scenarios. Additionally, the PMV induces marginal gains in terms of households income owing to the positive impacts on agriculture, which enhances returns to factor of production. Nevertheless, the income gains do not translate into welfare gains as they remain limited in magnitude.

Overall, the PMV strategy's potential for mitigating the climate change impacts seems limited, if not inexistent in light of the result discussions. The very limited scope of the sectoral coverage planned in the PMV targets only a third of total agricultural production; whereas the negative effects of climate change affect all crop sectors.

Additionally, the productivity assumptions from the PMV are suggested estimates and we do not have the means to realistically assess their feasibility. We attempted to evaluate the realism of the PMV assumptions through a benchmark comparison. We used data on corn yield in the United States prior and after the introduction of Genetically Modified Organism (GMO) corn.

Figure 4.21 presents the evolution of corn yields from 1996 to 2014. Between 1996 and 2014, corn grain yields increased by 35%.

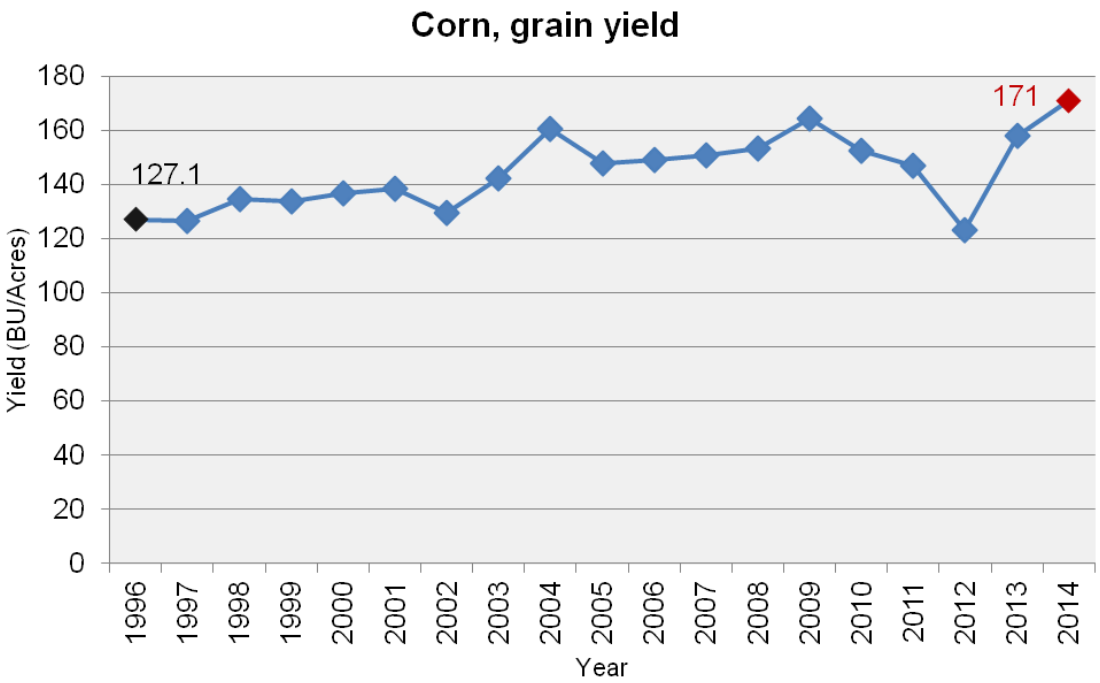

Figure 4.21 Historical Evolution of Corn Grain Yield (in BU/Acres) between 1996-2014
Source: Author's adaptation (Data source: NASS-USDA, 2014 http://www.nass.usda.gov/ - Last accessed 02/03/2015)

Based on the PMV productivity assumptions, average cereal yields at the national level are projected to increase by 76% by the end of the implementation period 2009-2020. Hence, we could argue that the likelihood for achieving such an evolution in yield is low.

Like any research, there are areas for improvement in the future. Currently inter-regional linkages are modelled simplistically through redistribution of excess supply regions to excess demand regions based on their shares. Alternative approaches could be explored. Finally, there is need to update the data used in the analysis. The current model assumes all regional households have the same preferences, but differ only based on their level of expenditure from one region to the other. Access to better household surveys

could provide us with better understanding of consumption patterns and a better evaluation of welfare impacts.

CHAPTER 5. TRADE LIBERALIZATION AND ADAPTATION TO CLIMATE CHANGE IN MOROCCO

5.1 Introduction

Among the economic growth levers for developing countries, international trade is argued to offer a potential for adaptation in the face of climate change. This is achieved through the enabling channels of technological spillovers and enhanced access to capital and infrastructure investments and production specialization. Trade has the potential to alleviate the climate-induced economic burden (especially in the agricultural sector) by bridging the differences between demand and supply conditions globally. Nonetheless, it can also increase climate-induced vulnerability in certain regions which specialize in the production of certain products in which they have a comparative advantage, while relying on imports to meet their demands for other commodities and services.

Trade liberalization is reported to have welfare improving effects (Calzadilla, Rehdanz, & Tol, 2011; Chang, Chen, & McCarl, 2012; Laborde, 2011; Reilly & Hohmann, 1993). However these effects are generally insufficient to compensate the adverse effects of climate change (Randhir & Hertel, 2000; Reilly & Hohmann, 1993). Welfare gains from trade liberalization depend primarily on the elimination of trade barriers such as tariffs and quotas, and subsidies. The effects are not uniform and depend on the geographic location (Calzadilla et al., 2010; Reilly & Hohmann, 1993) and vulnerability of the region to climate change (Reilly & Hohmann, 1993).

In Chapter 4, we analyzed the effect of climate change on Morocco by focusing on the agricultural sector. Furthermore, we evaluated the extent to which the PMV strategy can be a source of adaptation in Morocco. To that effect, we developed a country-specific CGE model. In that work, we ignored the global impacts of climate change and their implications for the Moroccan economy. The impacts of climate change globally are bound to have major effects on Morocco through the international trade linkages and especially given the recent opening of Morocco to the world economy.

Chapter 5 is therefore a complement to our previous analysis in Chapter 4. The objective is first to investigate the effects of climate change globally on Morocco. Second, we evaluate the effect of various trade liberalization scenarios on Morocco and their potential for providing adaptation capacity. We use a global CGE model, the GTAP model, which is a widely used model in the literature for trade policy analysis and more recently extended to climate change applications pertaining to biofuels and energy, land use change, etc. In terms of modeling climate change, the approach is similar to the one adopted in Chapter 4. We introduce climate change via yield productivity shocks obtained from a newly developed database to obtain our baselines. Subsequently, different trade liberalization scenarios are simulated and results are contrasted with the baselines. Section 5.2 describes the features of the modeling framework. It is followed by a discussion of the new yield database and the scenarios identified in the analysis (Section 5.3). In Section 5.4, we present our simulation results and wrap up with summary and conclusions (Section 5.5).

5.2 Modeling Framework: GTAP Model

To estimate the impacts of climate-induced agricultural productivity shocks on the economy and the linkages with international trade, we use the Global Trade Analysis Project (GTAP) general equilibrium global trade model and its accompanying database. The GTAP model is a multi-commodity, multi-region computable general equilibrium model (Hertel, 1997). In the standard GTAP model, we assume markets are perfectly competitive and exhibit constant returns to scale. Each region is represented by a representative household, and account for private consumption, government consumption and savings. Consumers, as represented by the private household, maximize utility where consumption is modeled via a non-homothetic Constant Difference of Elasticity (CDE) implicit expenditure function. Producers are assumed to maximize profits subject to a nested Constant Elasticity of Substitution (CES) production function which bundles primary factors and intermediate inputs to produce final output (Figures 5.1 and 5.2).

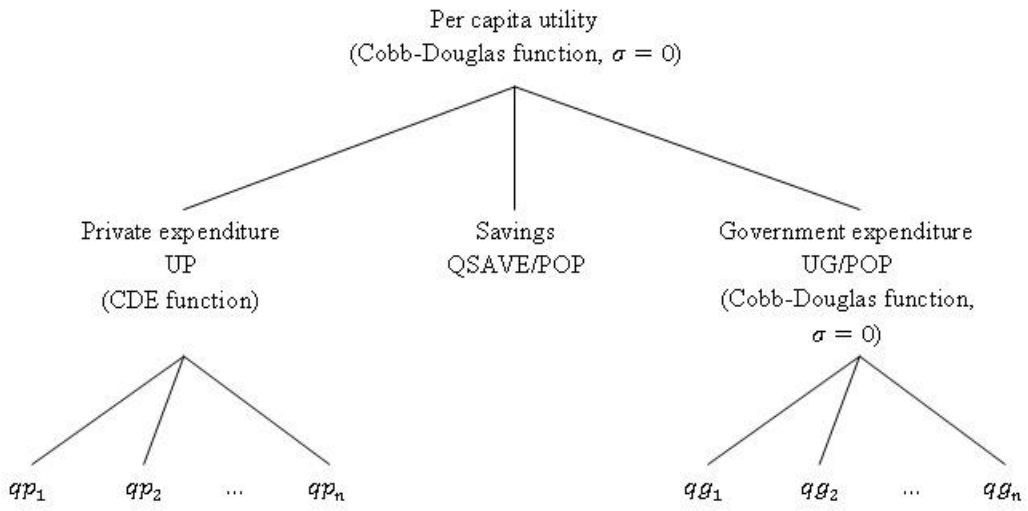

Figure 5.1 Structure of Regional Household and Components of Final Demand in the GTAP Model

Source: Adapted from Brockmeier (2001)

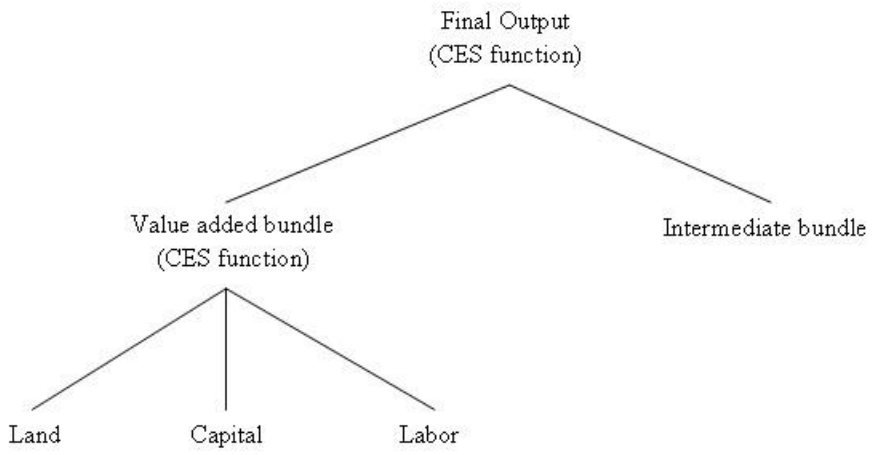

Figure 5.2 Structure of Production in the GTAP Model
Source: Adapted from Brockmeier (2001)

Final demand is a composite of demand for domestic output and imports stemming from private households, government and intermediate demand. Imports from different regions are modeled using the Armington assumption (Armington, 1969). A more detailed discussion of the model structure and features can be found in Hertel and Tsigas (2001) and Brockmeier (2001).

For the purpose of our analysis, a standard neo-classical closure is assumed where producers earn zero-profits, the regional household is on its budget constraint, and global investment equals global savings, with equilibrium imposed in all markets. World price of a given commodity is determined through the global trade balance (Hertel et al., 2010).

We make use of GTAP database (Version 7) which provides a disaggregation of agricultural production and harvested area by agro-ecological zones (AEZ) by using the Food and Agriculture Organization (FAO) 2004 data on production, harvested area and

price, available by country and 159 FAO crop categories.[21] The GTAP database has been aggregated in order to accommodate the needs of the analysis. The new aggregation collapses the dimensions of the GTAP database into 16 regions, 15 sectors, and 5 factor endowments (Table 5.1).

Table 5.1 Regional and Sectoral Aggregation in the GTAP Model

Regions	Sectors
Oceania	Paddy, rice
East Asia	Wheat
Southeast Asia	Coarse grains
South Asia	Vegetables, Fruits
Canada	Oilseeds
United States	Sugar crops
Rest of Latin America	Other crops
Brazil	Dairy, Livestock
OECD Europe	Extract
Rest of the Middle-East	Vegetable oil
Eastern Europe	Other processed food
Former-USSR	Textile, Apparel
Turkey	Manufactures
Rest of North Africa	Utilities, Construction
Morocco	Services
Sub-Saharan Africa	

Source: Author's Adaptation (Source: GTAP Database Version 7)

[21] The AEZ structure in the GTAP model is based on the SAGE (The Center for Sustainability and the Global Environment), database, which was developed by aggregating the IIASA/FAO GAEZ data into 6 categories identified by the length of growing period (LPG). In addition to the LGP break-down, the world is subdivided into three climatic zones, namely: tropical, temperate, and boreal.

5.3 Yield Impacts and Scenario Analysis

For the purpose of the analysis, we develop a global dataset that takes into consideration the inherent uncertainty in terms of regional distribution of impacts on crop productivity and the heterogeneous nature of their magnitude across climate scenarios. We have identified two major sources for the yield impact data: IFPRI Food Security CASE Maps database (IFPRI, 2010) and the Integrated Model to Assess the Global Environment (IMAGE) Version 2.2. Combining the two databases, we create a comprehensive set of projected yield change estimates that provides estimates of productivity shocks on the basis of the regional and sector aggregation adopted in the analysis.

We conduct the analysis in a comparative static mode where projected yield shocks by 2050 are introduced into the model as productivity shocks to the technology parameters in the model. Table 5.2 summarizes the selected simulation scenarios. In order to investigate the effects of trade liberalization, we calculate the net effect of key variables by comparing the results from the climate change only scenario with the results from the climate change plus trade liberalization scenarios.

Table 5.2 Definition of Simulation Scenarios

Scenario	Description
CConly	Climate change only
CCMULTI	CConly + Global tariff elimination on all commodities
CCAGMULTI	CConly + Global tariff elimination on all agricultural commodities
CCTRLIBEU	CConly + Tariff elimination on all commodities between OECD Europe + Eastern Europe and Morocco, and OECD Europe + Eastern Europe and Turkey
CCAGLIBEU	CConly + Tariff elimination on all agricultural commodities between OECD Europe + Eastern Europe and Morocco, and OECD Europe + Eastern Europe and Turkey
CCMENA	CConly + Tariff elimination on all commodities among all MENA regions
CCAGMENA	CConly + Tariff elimination on all agricultural commodities among all MENA regions

Source: Author's construction

5.3.1 The IFPRI Food Security CASE Maps Database

The IFPRI database provides projected yield impacts globally for 6 crops (rice, wheat, maize, cassava, groundnut, and soybean) under a wide range of scenarios based on simulations from the IMPACT model by 5-year increments until 2050 (Nelson et al., 2010).The results are provided for 3 overall scenarios (baseline, optimistic, and pessimistic) that capture the dynamics of economic growth based on assumptions about per capita GPD growth and population growth (Table 5.3).

Table 5.3 GDP and Population Growth Scenarios in IFPRI Database

Category	Pessimistic	Baseline	Optimistic
GDP, constant 2000 US$	Lowest of the four GDP growth rate scenarios from the Millennium Ecosystem Assessment GDP scenarios (Millenium Ecosystem Assessment 2005) and the rate used in the baseline (next column)	Based on rates from World Bank EACC study (Margulis et al. 2010), updated for Sub-Saharan Africa and South Asian countries	Highest of the four GDP growth rates from the Millennium Ecosystem Assessment GDP scenarios and the rate used is the baseline (previous column)
Population	UN high variant, 2008 revision	UN medium variant, 2008 revision	UN low variant, 2008 revision

Source: IFPRI, 2010

The yield impacts are estimated using the DSSAT model version 4.5 using two SRES scenarios that project future greenhouse gas emissions (GHG) (A1B and B1) and two Global Circulation Models for the climate (GCM) (CSIRO and MIROC), the combination of which represent two futures: a dry and relatively cool future under the combination CSIRO A1B and B1, and a wet and warmer future under the combination MIROC A1B and B1.

Hence, combining the scenarios capturing the projected per capita GDP growth and population growth, the SRES scenarios and the GCM climate models, results in 15 potential future pathways that encompass a wide range of plausible outcomes in terms of projected yields. Yield estimates from the IMPACT model are dynamically produced under each of the 15 pathways for irrigated and rainfed systems, and incorporate assumptions about exogenous yield growth (i.e. the intrinsic productivity growth rates,

IPRs) and exogenous area changes (i.e. the intrinsic area growth rates, IARs). Figures 5.3 and 5.4 summarize a sample of the data on yield and IPR for Wheat in the top five producing regions.

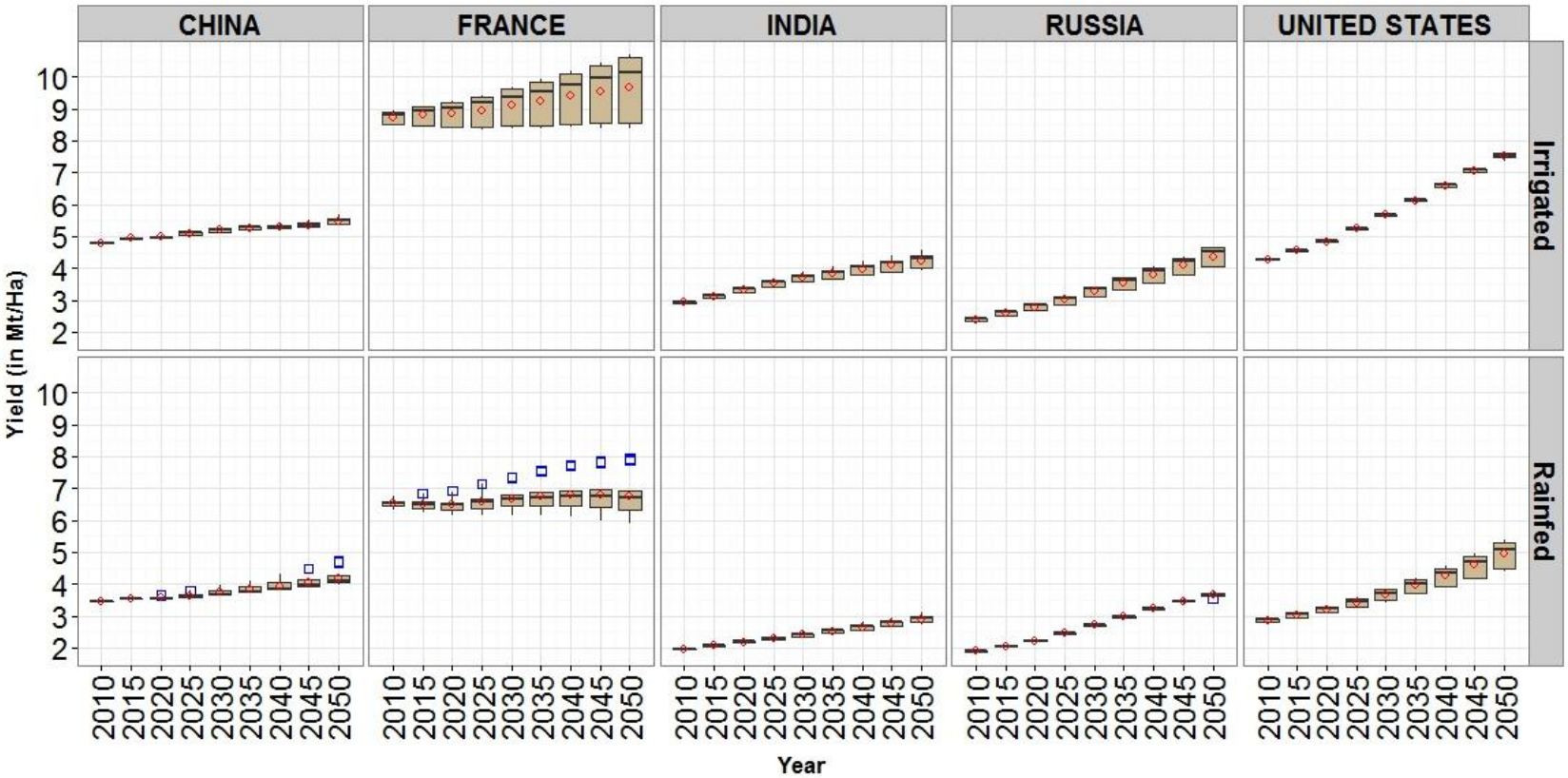

Figure 5.3 Evolution of Distribution across Scenarios of Yield for Irrigated and Rainfed Wheat in the Top Five Producing Countries in IFPRI Database

Source: Authors' adaptation (Data source: IFPRI Food Security CASE maps, 2010)

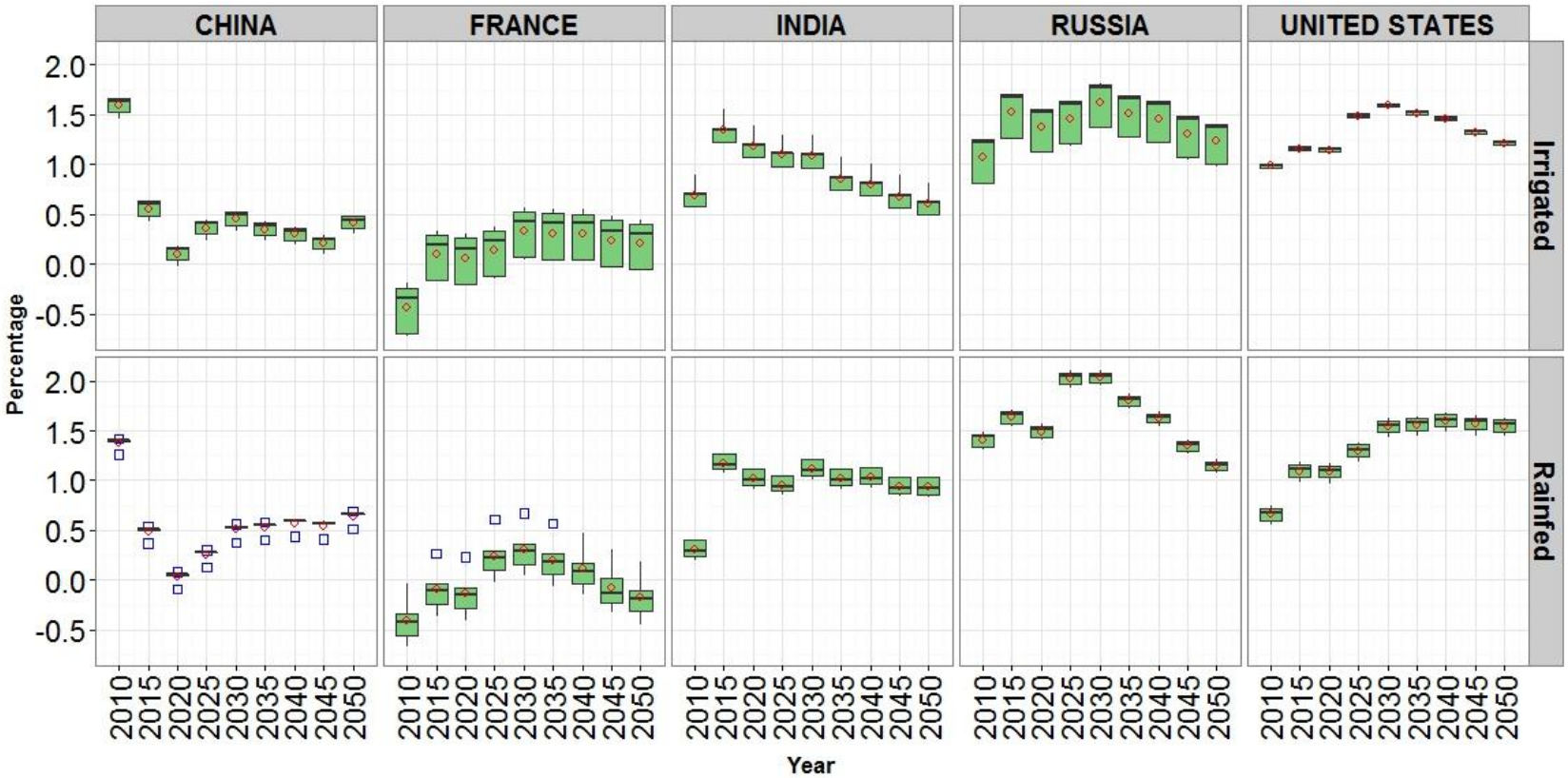

Figure 5.4 Evolution of Distribution across Scenarios of Intrinsic Productivity Growth Rates (IPRs) for Irrigated and Rainfed Wheat in the Top Five Producing Countries in IFPRI Database

Source: Authors' adaptation (Data source: IFPRI Food Security CASE maps, 2010)

To isolate the effect of climate change on yield, we combine the yield and IPR data generated by the IMPACT model. As documented in Nelson et al. (2010), the IMPACT model captures the effects of climate change through the alteration of crop area and yield, represented by Eq. 1 and Eq. 2 as follows:

$$\text{(Eq. 1)} \quad \mathrm{YC_{tni}} = \beta_{\mathrm{tni}} \times (\mathrm{PS_{tni}})^{\gamma_{\mathrm{iin}}} \times \prod_{\mathrm{k}} (\mathrm{PF_{tni}})^{\gamma_{\mathrm{ikn}}} \times (1 + \mathrm{gy_{tni}}) - \Delta \mathrm{YC_{tni}}(\mathrm{WAT_{tni}})^{22}$$

$$\text{(Eq. 2)} \quad \mathrm{AC_{tni}} = \alpha_{\mathrm{tni}} \times (\mathrm{PS_{tni}})^{\varepsilon_{\mathrm{iin}}} \times \prod_{\mathrm{j \neq i}} \left(\mathrm{PS_{tnj}}\right)^{\varepsilon_{\mathrm{ijn}}} \times (1 + \mathrm{ga_{tni}}) - \Delta \mathrm{AC_{tni}}(\mathrm{WAT_{tni}})$$

The key parameters of interest are $\mathrm{gy_{tni}}$ and $\mathrm{ga_{tni}}$. They represent the intrinsic productivity and area growths rates respectively (IPRs and IARs) and enter the model as shift parameters.

For the purpose of isolating the climate change impacts, we ignore the effects on area. From Eq. 1, we assume that the price effects are inconsequential, and that effects on yields pertain only to the climate change impacts and the productivity enhancement associated with the IPRs. The IPRs (or $\mathrm{gy_{tni}}$) represent assumptions about yield productivity enhancement that are exogenous to the model. Estimates are based on factors such as investment in agricultural productivity by the public and private sectors, technology dissemination by research and extension, infrastructure investments, etc. (IFPRI, 2010).

---

[22] β_{tni} - yield intercept for yeat t, determined by yield in previous year; PS_{tni} - output price in year t; PF_{tni} - input price in year t; γ – input and output price price elasticities.

In private E-mail communications with the primary author(s) of the IFPRI study (Nelson et al., 2010) on March 18th 2013, Dr. Nelson indicated that reported yield in the data mainly capture the climate change impacts and the exogenous non-climate productivity effects associated with the IPRs. In other words, the price effect components in $\mathrm{Eq.}\,1$ are assumed to be not important, hence we ignore them. Thus, and given the availability of data on the IPRs, we can isolate the impacts of climate change by assuming the following:

$$\text{(Eq. 3)} \qquad \mathrm{Y_{p+1}} = \mathrm{Y_p}\left(1 + \mathrm{CC_p} + \mathrm{IPR_p}\right)^5$$

with $\mathrm{CC_p}$ the climate change impact associated with period p; $\mathrm{IPR_p}$the exogenous non-climate productivity shift parameter for period p; $\mathrm{Y_p}$ is reported yield for at start of period p; and $\mathrm{Y_{p+1}}$ reported yield at start of period $\mathrm{p} + 1$. Therefore, the climate change impact for period p is expressed as follows:

$$\text{(Eq. 4)} \qquad \mathrm{CC_p} = \left\{\left[\left(\frac{\mathrm{Y_{p+1}}}{\mathrm{Y_p}}\right)^{1/5} - \mathrm{IPR_p}\right] - 1\right\} \times 100$$

We should notice that $\mathrm{CC_p}$, as defined in $\mathrm{Eq.}\,4$, represents the annual percent change in yield due to climate change in period p in the IFPRI database, which is based on five year increments until 2050. Thus, the aggregate period-specific climate change effect $\mathrm{CC_p^{agg}}$ is obtained as follows:

$$\text{(Eq. 5)} \qquad CC_p^{agg} = \left(1 + CC_p\right)^5$$

Using Eq. 5, we obtain climate change impacts for each crop and each period under irrigated and rainfed systems. Given that the base GTAP model does not differentiate between irrigated and rainfed production at the AEZ level, we calculate a production-weighted average of climate change impact using available data on irrigated and rainfed production.

5.3.2 The IMAGE Yield Database

The IMAGE database provides yield impacts globally for 11 crop categories under 10 SRES climate scenarios covering 17 regions/countries until 2100 by five year increments (Table 5.4).

Table 5.4 Description of IMAGE Database Dimensions

Element	Description
Scenarios	A1B, A1F, A1F_high, A1F_low, A1T, A2, B1, B1_high, B1_low, B2
Variables	Yield, Management Factor (MF), Production, Area
Crops	Maize_f, Maize_b, Oil crops, Pulses, Rice, Roots & tubers, Temperate cereals, Tropical cereals, Non woody biofuels, Woody biofuels, Sugar cane
Regions	Canada, Central America, East Asia, Eastern Africa, Eastern Europe, Former USSR, Japan, Middle East, Northern Africa, Oceania, OECD Europe, South America, South Asia, South East Asia, Southern Africa, USA, Western Africa

Source: Authors' adaptation (Data source: IMAGE 2.2, 2010)

The projected yield impacts are generated via the terrestrial models in the IMAGE framework (the Terrestrial Vegetation Model (TVM) and the Land Cover Model (LCM)),

which are coupled to the LEITAP model, by using input data such as CO_2 concentration, cloudiness, temperature, and precipitation as projected under each SRES climate scenario. A detailed description can be found in Hoogwijk et al. (2005). Figures 5.5 and 5.6 present sample data on reported yields and management factor (MF) for the four major producing regions in the IMAGE database.

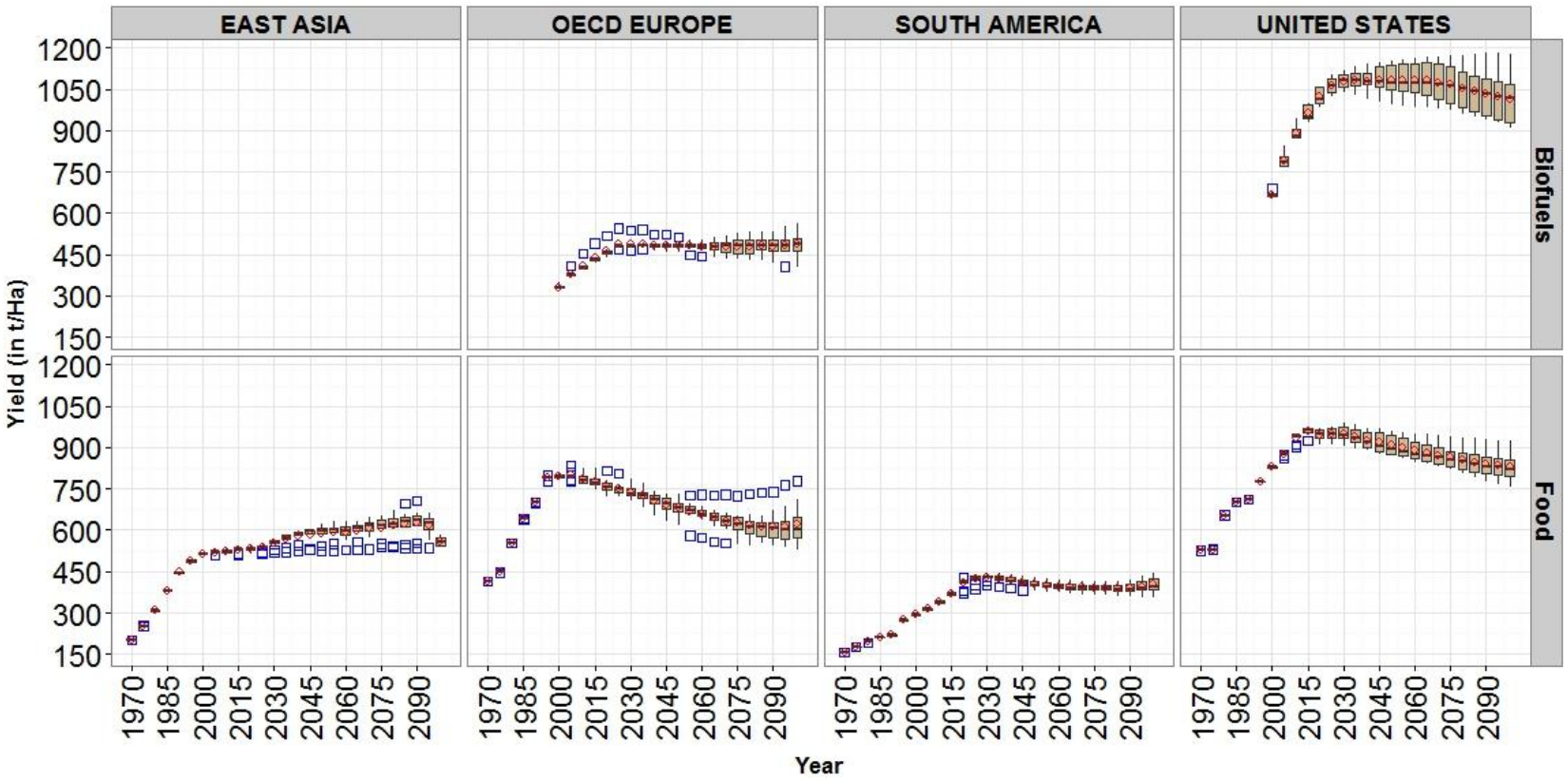

Figure 5.5 Evolution of the Distribution across Scenarios of Yield Data for Maize in the Top Four Producing Regions in the IMAGE Database

Source: Authors' adaptation (data: IMAGE 2.2, 2010)

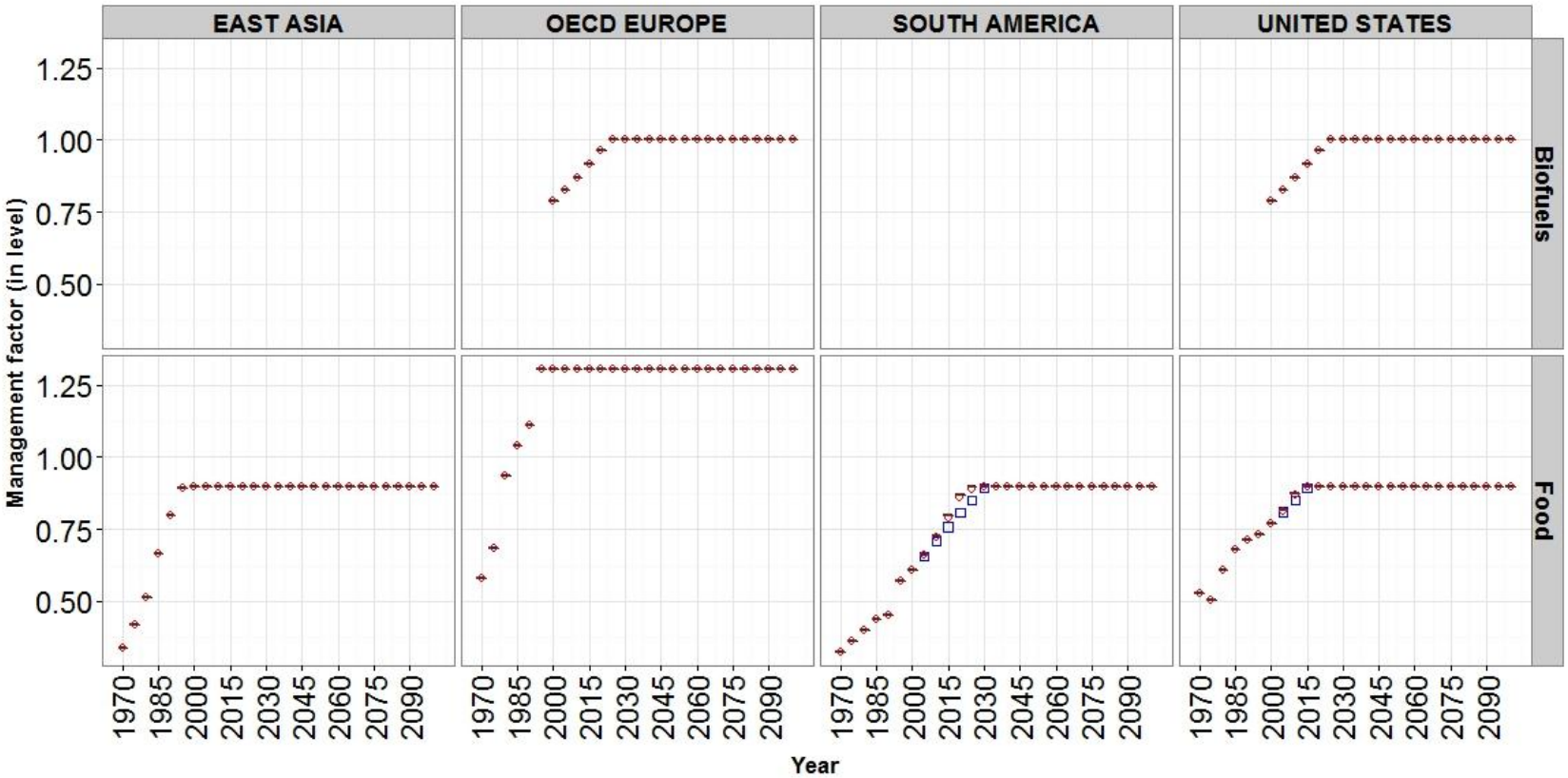

Figure 5.6 Evolution of the Distribution across Scenarios of Management Factors (MF) Data for Maize in the Top Four Producing Regions in the IMAGE Database

Source: Authors' adaptation (data: IMAGE 2.2, 2010)

The yield data in the IMAGE database represents projections of yield estimates, which include the climate change impacts and the potential technology-driven yield enhancement captured by the management factors (MFs). Thus, isolating the climate change impacts on yield is trivial since the latter can be inferred as follows:

$$\text{(Eq. 6)} \qquad Y_t^{CC} = \frac{Y_t^{reported}}{MF_t}$$

where Y_t^{CC} the climate change yield in period t, $Y_t^{reported}$ the reported yield in period t, and MF_t the management factor in period t. For the analysis, we use only the food crop category, which includes 6 crops; namely: maize, oil crops, pulses, rice, roots & tubers, temperate cereals, and tropical cereals.

5.3.3 Harmonization Assumptions and Procedure for IFPRI and IMAGE Data

As previously mentioned, we use the IFPRI and IMAGE databases as our primary sources to develop a new database for climate-induced yield projections. Nonetheless, there exist substantial differences in the dimensions in both databases in terms of regional and crop coverage, and therefore we need a procedure to harmonize the two sets of estimates.

The regional coverage in the IFPRI database encompasses 114 countries/regions and in IMAGE database 17 regional blocs. Harmonizing the regional disaggregation in IFPRI and IMAGE data with the adopted regional structure in the GTAP model is straightforward. For IFPRI, estimates of projected yield impacts are computed for each of

the 113 countries/regions as previously discussed. To obtain estimates at the GTAP region level, we compute a production weighted average of the IFPRI estimates based on the regional matching defined in Table B5.1 (Appendix B). We adopt a similar approach to obtain estimates of projected yields from the IMAGE data based on the regional matching defined in Table B5.2 (Appendix B). As with the IFPRI data, when a GTAP region is matched with more than one region in the IMAGE data, a production-weighted average yield estimate is calculated.

When a GTAP region is not explicitly matched with a region in the IMAGE data, we assume that the yield impact for the GTAP region is the same as the impact for the region in which it belongs within the IMAGE regional aggregation. For example, Morocco, Turkey and Brazil are not modeled separately in the IMAGE data. But data on yield impacts for North Africa, the Middle-East and South America is available. Therefore, we assume that the yield impacts for Morocco, Turkey and Brazil equal the yield impacts in North Africa, the Middle-East and South America respectively given that those countries are part of the regional bloc.

In terms of sector coverage, projections developed through the IFPRI data cover 6 crop categories; namely, rice, wheat, maize, cassava, groundnut, and soybean. For IMAGE, the crop coverage includes 11 crops by distinguishing between food crops and biofuel crops. Only the food crop category is used in the analysis, which includes 6 crops: maize, oil crops, pulses, rice, roots & tubers, temperate cereals, and tropical cereals. Table 5.7 summarizes the matching assumptions between the GTAP crop sectors and the IFPRI and IMAGE crops, which is based on IFPRI's crop matching methodology (IFPRI,

2010).[23] Whenever one GTAP crop is matched with more than one crop category in IFPRI and IMAGE data, a simple average is calculated to represent the final impact associated with the GTAP crop.

Table 5.5 Summary of Crop Matching Between GTAP, IFRPI and IMAGE Crops

GTAP crops	Matching crops in:	
	IFPRI	IMAGE
Paddy rice (pdr)	Rice	Rice
Wheat (wht)	Wheat	Temperate cereals, Tropical cereals
Cereal grains nec (gro)	Wheat, Maize	Temperate cereals, Tropical cereals, Maize
Vegetables, fruit, nuts (VegtFrut)	Rice, Groundnuts	Roots & Tubers, Pulses
Oil seeds (osd)	Soybeans	Oil crops
Sugar cane, sugar beet (c_b)	Maize	Maize
Other crops (OthCrop)	Rice, Wheat, Cassava, Soybeans, Groundnuts, Maize	Rice, Temperare cereals, Tropical cereals, Maize, Oil crops, Roots & Tubers, Pulses

Source: Author's construction (Data source: Data source: GTAP database version 7, IFPRI Food Security CASE maps, 2010 and IMAGE 2.2, 2010)

In terms of projected yield scenarios, the IFPRI database provides a range of future pathways of yield impacts which represent the combination of 3 overall growth scenarios (Baseline, Optimistic, and Pessimistic) x 2 SRES scenarios (A1B and B1) x 2

[23] "Millet, sorghum, sugarcane, and maize all use the C4 pathway and are assumed to follow the DSSAT results for maize in the same geographic regions. The remainder of the crops uses the C3 pathway. The climate effects for the C3 crops not directly modeled in DSSAT follows the average from wheat, rice, soy, and groundnut from the same geographic region, with the following two exceptions. The IMPACT commodities of "other grains" and dryland legumes are directly mapped to the DSSAT results for wheat and groundnuts, respectively (IFPRI, 2010)".

GCM models (MIROC and CSIRO), which capture the impact of climate change. In addition, a third set of yield impacts is calculated using current climate conditions. The latter is considered a “no climate change” scenario, whereby it projects potential yield impacts assuming current climate conditions prevailing under each global growth scenario. Thus, we generate 15 potential pathways of yield impacts from the IFPRI data. The IMAGE database provides 11 pathways of projected yield impacts. Therefore, merging the two databases, we have 26 scenarios of projected yield impacts, of which 23 represent deviation from current climate under climate change and 3 represent current climate prevailing in the future.

Given the high dimensionality characterizing the simulation scenarios, we further condense the data for yield projections in each database given the potential overlap that exists among the scenarios included. Figures A5.1a and A5.1b (Appendix A) summarize the kernel distribution estimation of projected yield impacts for all regions and all crops by GCM in the IFPRI data. Overall, we notice a relatively strong overlap in projected yield impacts under each GCM. Therefore, we first average across GCMs for each crop and each region. Second, we average across growth scenarios. Additionally, we drop the scenarios pertaining to current climate projections as we are interested in future climate impacts. As a result, we reduce the dimension of projected yield impacts in the IFPRI database to 2 scenarios, A1B and B1. We adopt a similar approach for the IMAGE database where we collapse the number of scenarios from 11 to 7. This is achieved by averaging the yield impacts for the scenarios A1B, A1B_Low and A1B_High to a single scenario A1B and B1, B1_Low and B1_High to B1.

The final step in merging the data from IFPRI and IMAGE datasets relates to sorting the issue of SRES overlap. In both databases, observations for projected yield impacts exist for all crops under the A1B and B1 scenarios. Nonetheless, when comparing across crops, the impacts from the IMAGE database are lower compared to IFPRI on average (Table 5.6).

Table 5.6 Average Yield Impact in IFPRI and IMAGE (in % change)

	A1B	B1
IFPRI	-4	-4
IMAGE	-2	0

Source: Author's calculation

Thus, we include the A1B and B1 scenarios from IMAGE data in the final projected yield database as A1BLow and B1Low.

5.3.4 Descriptive Analysis of the New Yield Database

The nature of production systems (irrigated vs. rainfed), location and photosynthetic typology of crops (i.e. C3 vs. C4 plants) are among the main factors that contribute to the heterogeneous climate-induced productivity impacts on yields.[24] Figure 5.7 captures the heterogeneity dimension characterizing climate change impacts globally in our database. Overall, Turkey [13], the Rest of Middle-East [10], Brazil [8], the Rest of

[24] "So-called C3 plants use CO2 less efficiently than C4 plants, so C3 plants such as rice and wheat are more sensitive to higher concentrations of CO2 than C4 plants like maize and sugarcane. However, when nitrogen is limiting, the CO2 fertilization effect is dramatically reduced. So the actual benefits in farmer fields of CO2 fertilization remain uncertain" (Nelson, G.C., et al., 2010).

Latin America [7] and OECD Europe [9] display the largest negative impacts on average agricultural productivity across all crops, respectively -13%, -13%, -7%, -5%, and -8%. The United States [6], Morocco [15], the Rest of North Africa [14], Eastern Europe [11], Former USSR [12] and Southeast Asia [3] experience slight negative impacts, whereas Canada [5], South Asia [4], East Asia [2], Oceania [1] and Sub-Saharan Africa [16] benefit slightly.

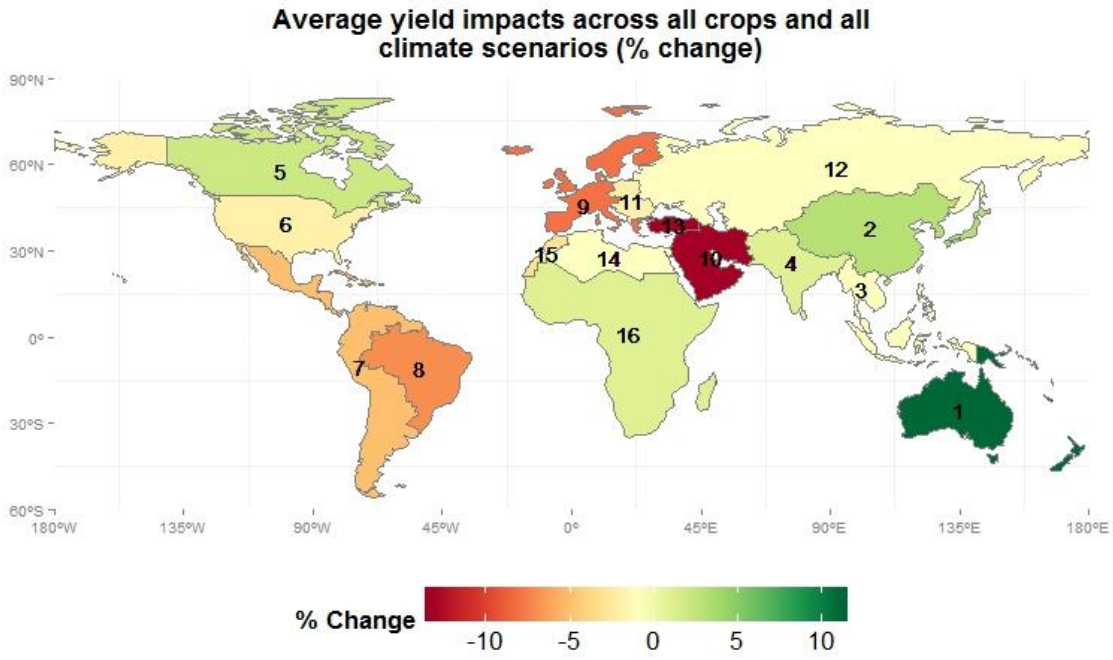

Figure 5.7 Average Distribution of Projected Yield Impacts by Region across Crop Sectors by 2050

Source: Authors' adaptation (Data source: IFPRI Food Security CASE maps, 2010; IMAGE 2.2, 2010)

Focusing on averages can be misleading when analyzing climate change and international trade linkages. Indeed, the distribution of projected yield impacts across

regions and crops, and in combination with the volume of trade flows and their origins, plays a important role in determining the final global impact. For example, impacts on rice yield range from -1% to +6% in East Asia, -6% to +5% in Southeast Asia, -3% to +6% in South Asia and +1% to +10% in the United States (Figure A5.2, Appendix A). These regions respectively represent 21%, 29%, 39%, and 1% of total rice harvested area and 32%, 28%, 31%, and 2% of total rice production globally.

Therefore, we might conclude that climate change impacts on rice yield in the Asian regions are the driving factor that impacts trade flows globally. Nonetheless, the latter is not determined solely by the geographical distribution of biophysical impact on yields in top producing regions, but as well by the geographical distribution of the trade flows, their volumes and origins. In our case, despite the small share of the US rice production globally, it plays a bigger role in international trade compared to East Asia which is the major rice producer. Indeed, US rice exports represent 11% of global rice exports compared to 6% for East Asia. Therefore, accounting for this dimension when modeling the effect of climate change on agriculture globally is paramount to understand the dynamics at play and the resulting impacts on prices and welfare.

5.4 Simulation Results and Discussion

5.4.1 Welfare and Macroeconomic Impact of Climate Change

As previously discussed, climate-induced yield impacts depict large variability across climate scenarios and regions. On average, the world experiences a negative welfare impact with a welfare loss of US$ -31,762 million. Nonetheless, the distribution across climates scenarios suggests a substantial variability in welfare impacts, and ranges

between a minimum of US$ -11,784 million under SRES A1F to a maximum of US$ -54,138 million under SRES A2. This is expected given that productivity losses globally under SRES A2 are larger compared to SRES A1F where average yield losses across crops are -3.7% and -0.2% respectively.

The effects that drive the observed welfare impacts globally most under the climate change only scenario are allocative efficiency and technical efficiency, with the latter providing the bulk of the impact (Table 5.7).[25]

Table 5.7 Decomposition of Welfare Impacts of Climate Change by Effect for the World by 2050 (in 2004 $US million)

	Allocative efficiency	Technical efficiency	Terms of trade	Investment-Savings
A1B	-4,462.35	-26,423.52	2.25	0.67
A1BLow	-4,336.40	-27,953.71	-1.72	-0.30
A1F	-977.94	-10,806.87	-0.06	0.05
A1T	-5,898.39	-39,867.45	-3.61	-0.25
A2	-7,475.46	-46,662.10	-0.75	0.61
B1	-4,120.62	-26,050.43	1.96	0.80
B1Low	-1,279.00	-16,326.30	-1.92	0.07
B2	-4,054.56	-27,503.18	-0.52	0.54
Average	-4,075.59	-27,699.19	-0.55	0.27

Source: Simulation results

Geographical distribution of impacts on welfare and gross domestic product (GDP) suggests a strong correlation with the distribution of projected yield changes across crop

[25] Allocative Efficiency is the change in EV due to the reallocation of economic resources. Technical efficiency is the change in EV due to the change in production technology (i.e. yields in our case)

sectors (Figure A5.3, Appendix A). Climate-induced impacts on welfare and GDP (+ or -) depend on the sign of projected yield impact and its magnitude, where the larger the latter the larger the former. Nonetheless, the final effect depends crucially on which crop sectors are most affected by climate change and their relative shares in agricultural output and exports within each region.

On average, welfare impacts in Oceania, East Asia, South Asia and Sub-Saharan Africa are positive owing to positive average projected yield impacts respectively +3%, +1% and +1%. East Asia registers the largest average welfare gain with US$ +7,926 million and Sub-Saharan Africa the lowest average gain with US$ +754 million. Positive allocative efficiency and technical efficiency effects are the main drivers of the observed results, except for South Asia where allocative efficiency effects are negative. Nonetheless, the latter are largely offset by the technical efficiency effects. The terms of trade and investment-savings effects are too small to alter the final results. For the remaining regions, negative climate-induced productivity shocks induce welfare losses with the largest loss occurring in OECD Europe (US$ -20,908 million) and the lowest in Canada (US$ -83 million). As is the case for the positively impacted regions, allocative efficiency and technical efficiency effects are much larger than the terms of trade and investment-savings effects. The former are negative for most regions; hence, the negative aggregate effect on welfare (Table 5.8).

Table 5.8 Decomposition of Average Welfare Impacts by Effects and by Region under Climate Change Only by 2050 (in 2004 $US million)

GTAP region	Allocative efficiency	Technical efficiency	Terms of Trade	Investment-Savings	Equivalent Variation
Oceania	106	2,086	147	62	2,401
East Asia	415	8,166	-794	139	7,926
Southeast Asia	-78	-788	90	76	-700
South Asia	-190	1,585	200	41	1,636
Canada	-112	-183	213	-2	-83
United States	-548	-3,497	1,462	-543	-3,126
Rest of Latin America	-826	-4,763	1,053	-3	-4,540
Brazil	-307	-3,229	796	171	-2,570
OECD Europe	-1,965	-16,642	-2,321	20	-20,908
Rest of the Middle-East	-173	-4,161	-610	113	-4,832
Eastern Europe	-365	-801	45	-79	-1,200
Former USSR	-121	-2,277	-271	63	-2,607
Turkey	-4	-3,581	207	-51	-3,428
Rest of North Africa	11	231	-363	11	-110
Morocco	78	-427	-33	-5	-387
Sub-Saharan Africa	4	584	179	-14	754

Source: Simulation results

In terms of impacts on gross domestic product (GDP), negative impacts are associated with regions experiencing projected yield declines, and vice-versa. In addition, the sign and magnitude of impacts for most regions are driven by the impacts on the consumption component in GDP, which accounts for more than 55% of total GDP in most regions. In general, regions depicting high climate-induced productivity shocks (+ or -) and where agriculture accounts for relatively a large share of GDP, display the

largest effects on GDP. For instance, the effects on GDP vary from maximum loss of -1.5% for Morocco under SRES A1B to a maximum gain of +1.2% in Sub-Saharan Africa under SRES A1F (Figure A5.3, Appendix A). These results are expected given that crop production accounts for 6.6% and 7.2% of total output in Morocco and Sub-Saharan Africa respectively.

In general, climate-induced yield impacts' implications in terms of welfare and macroeconomic impacts depend on a multitude of factors that jointly determine losers and winners. The distribution of yield impacts and their magnitude across scenarios, and of domestic production and international trade flows, both at the regional and sector levels, are key determinants of the obtained results. Therefore, when investigating the potential of trade liberalization as an adaptation measure in the face of climate change, analyzing the interaction among these factors is crucial to understanding the results.

5.4.2 Trade Liberalization under Climate Change: Welfare and Economy-wide Impacts

In theory, the more international trade is liberalized at the global and sector levels the higher the welfare gains, and the more efficient is smoothing of adverse shocks such as climate-induced productivity shocks. For the world on average, our hypothesis is robustly verified only under the trade liberalization scenario 'CCMULTI', which corresponds to 100% tariff removal for all regions and all sectors under climate change.

Global welfare change under climate change only is negative and reaches US$ -31,775 million on average. With a full multilateral tariff elimination as in scenario 'CCMULTI', the welfare results on average are positive and reach US$ +44,901 million. Therefore, the net effect of trade liberalization amounts to a welfare gain of US$ +76,676

million, which totally mitigates the initial welfare loss due to climate change. Indeed, only under the full multilateral trade liberalization (‘CCMULTI’), the welfare distribution fully changes from negative to positive for the world.

For the rest of the scenarios, which correspond to partial trade liberalization cases, the gains do not deliver in terms of mitigation of the climate-induced impacts as the results remain negative on average. This is verified when investigating the distribution of welfare impacts. Indeed, only partial mitigation of climate change impacts is realized given the unchanged nature in the distribution of welfare results which remained mostly negative. For instance, average net welfare gains for the world reach US$ +13 million, US$ +34 million, US$ +269 million and US$ +551 million respectively under the CCAGLIBEU, CCAGMENA, CCMENA and CCTRLIBEU partial trade liberalization scenarios. Only the agricultural multilateral trade liberalization (‘CCAGMULTI’) exhibits a partial positive shift in the distribution of welfare impacts (Figure 5.8).

Therefore, the results for the world confirm our hypothesis which states that the more trade is liberalized, the higher the gains with total offset of climate change impacts achieved under a multilateral trade liberalization scenario. Hence, as we deviate toward partial trade liberalization, the gains accruing are smaller in comparison with the climate change losses.

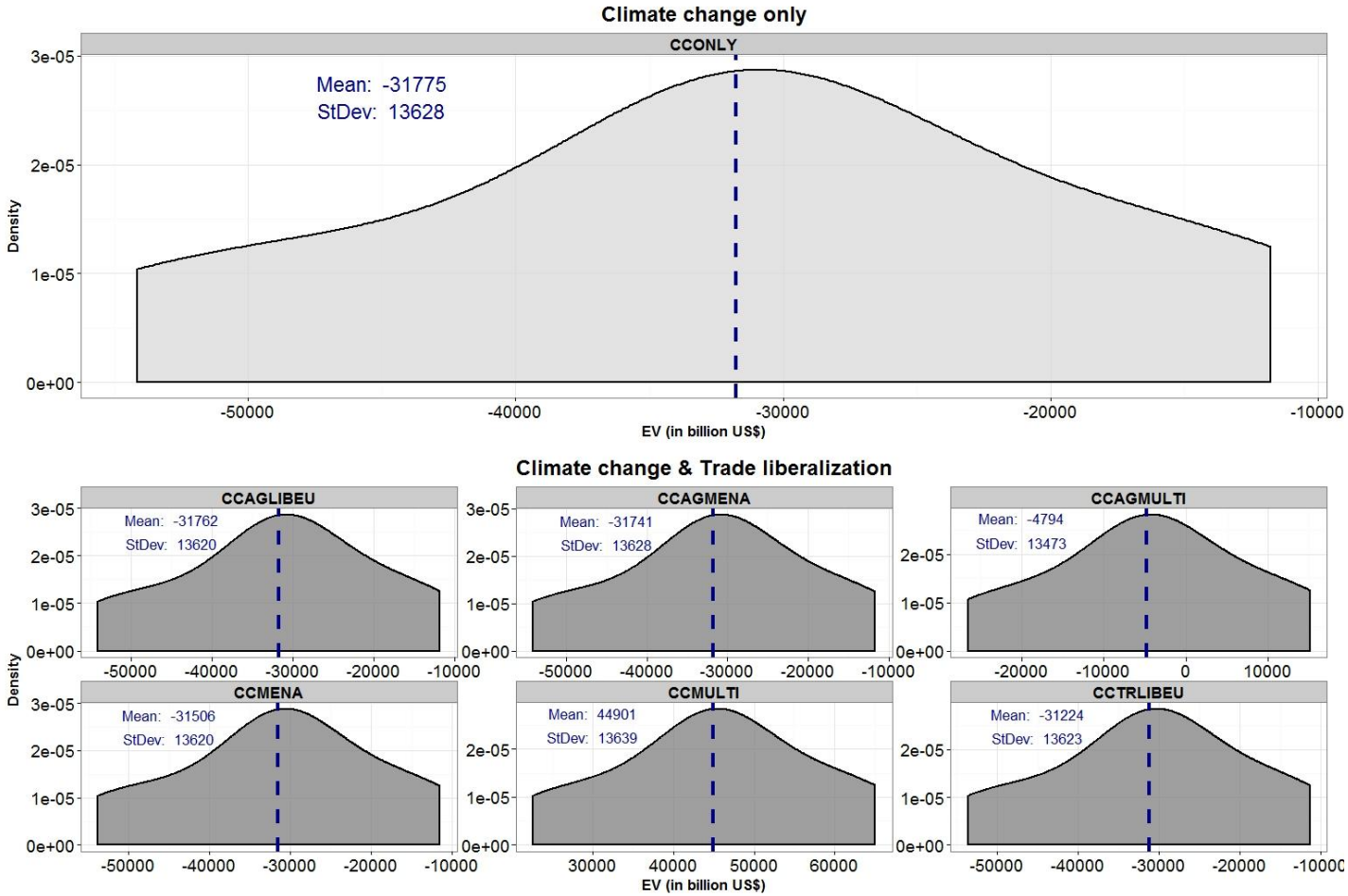

Figure 5.8 Distribution of Welfare Impacts under Climate Change Only, and Climate Change and Trade Liberalization for the World Region by 2050 (in 2004 $US million)

Source: Simulation results

In terms of the decomposition of the welfare impacts for the world, allocative efficiency and technical efficiency effects drive most of the observed results (Table 5.9).

Table 5.9 Decomposition of Average Welfare Impacts for the World Region by Effects by 2050 (in 2004 $US million)

Scenario	Allocative efficiency	Technical efficiency	Terms of trade	Investment-Savings
		Climate change only		
CCONLY	-4,075.59	-27,699.19	-0.55	0.27
		Climate change & Trade liberalization		
CCAGLIBEU	-4,076.47	-27,684.05	-1.61	0.19
CCAGMENA	-4,030.87	-27,709.61	-0.43	0.27
CCAGMULTI	22,334.47	-27,111.75	-16.23	-0.20
CCMENA	-3,718.04	-27,740.84	-42.65	-4.30
CCMULTI	72,854.81	-27,332.46	-671.40	50.42
CCTRLIBEU	-3,524.84	-27,693.09	-5.48	-0.63
		Trade liberalization net		
AGLIBEU	-0.88	15.14	-1.06	-0.08
AGMENA	44.72	-10.42	0.12	0.00
AGMULTI	26,410.06	587.44	-15.68	-0.47
MENA	357.55	-41.65	-42.10	-4.58
MULTI	76,930.39	366.73	-670.85	50.14
TRLIBEU	550.75	6.10	-4.93	-0.90

Source: Simulation results

Compared with the climate change only scenario, there is little change in terms of technical efficiency effects as the latter mainly capture the impacts of climate-induced productivity shocks, which do not change under the different trade liberalization

scenarios. Most of the change due to tariff elimination under the trade liberalization scenarios is captured by the observed change in allocative efficiency effects. The terms of trade and investment-savings effects are not large for all scenarios. Trade liberalization offsets some of the negative climate-induced productivity impacts, but only marginally as suggested by the reduction in the negative contribution of technical efficiency effects.

Under all the partial trade liberalization scenarios (i.e. CCAGMENA, CCAGLIBEU, CCMENA, CCTRLIBEU), allocative efficiency is negative with the largest loss occurring under the CCAGLIBEU trade liberalization scenario (US$ -4,076 million) (Table B5.3, Appendix B). To further highlight the driving forces behind the negative allocative efficiency results, we investigate the decomposition by tax instruments (Table B5.4, Appendix B). Private and intermediate consumption represent the bulk of the impacts globally. Furthermore, considering the regional disaggregation, OECD Europe's results have the highest impacts.

Given that private and intermediate consumption are the primary factors influencing the allocative efficiency results, we investigate the percent change dynamics for domestic and imports sales, decomposed by sectors in OECD Europe for households and firms (Table 5.10).

Table 5.10 Decomposition of Impacts on Domestic and Imports Sales by Commodity in OECD Europe under Climate Change Only and the 'CCAGLIBEU' Trade Liberalization Scenario by 2050 (in % change)

Commodities	Climate change only				Net impact trade liberalization			
	Domestic sales		Import sales		Domestic sales		Import sales	
	Private	Firms	Private	Firms	Private	Firms	Private	Firms
Paddy rice	-13.80	-14.82	24.50	17.65	13.10	14.28	-18.84	-14.53
Wheat	8.37	5.51	30.92	25.50	-7.73	-4.99	-23.04	-19.71
Coarse grains	12.79	13.02	13.79	14.48	-11.34	-11.54	-12.09	-12.63
Vegetables, fruits, and nuts	6.11	7.15	9.00	10.04	-5.85	-6.80	-8.20	-9.11
Oilseeds	2.20	2.60	6.94	7.17	-2.18	-2.58	-6.43	-6.65
Sugar cane, Suger beet	10.99	10.74	24.65	24.30	-9.86	-9.67	-19.68	-19.46
Other crops nes	3.40	4.16	8.69	9.55	-3.29	-4.00	-7.87	-8.60
Meat, livestock, raw milk	0.12	0.50	-0.07	0.40	-0.11	-0.49	0.10	-0.37
Forest, fish & minerals	-0.26	-0.09	-0.26	-0.06	0.27	0.09	0.26	0.05
Vegetable oils and fats	0.49	1.23	-0.40	0.41	-0.51	-1.26	0.44	-0.39
Other processed food	-0.01	0.39	-0.04	0.34	0.01	-0.39	0.06	-0.33
Textile and apparel	-0.20	-0.04	-0.28	-0.12	0.19	0.01	0.31	0.12
Manufactures	-0.23	-0.05	-0.30	-0.12	0.23	0.05	0.31	0.12
Utilities and Construction	-0.25	-0.19	-0.27	-0.19	0.26	0.19	0.28	0.20
Transportation and Services	-0.26	-0.12	-0.29	-0.16	0.26	0.12	0.30	0.17

Source: Simulation results

For most crop and processed food commodities, consumption in values terms increases for both domestic production and imports under climate change; whereas it falls marginally for the non-food sectors. These results can be explained by investigating the

price change dynamics, and its effect on the arbitrage in terms of substitution between domestic output and imports.

At the domestic level, negative productivity shocks induce prices to increase for the food sectors. As a result, demand for domestic output decreases. For the non-food commodities, despite the marginal decrease in prices, demand shrinks but marginally. Given that prices for domestic output increase more compared to imports, an arbitrage occurs whereby demand for imports increases considerably in order to replace lost consumption in domestic output. This is clearly depicted by the magnitude of the percent change in import quantities which outweighs the percent change in demand for domestic output. This dynamic unfolds both for private and intermediate demands under the climate change only scenario. Nonetheless, resorting to imports to replace lost domestic consumption, despite relatively lower import prices, is constrained given that import prices do increase as well. In turn, the allocation of resources across sectors becomes less efficient due to increasing costs as captured by the climate-induced price dynamics in domestic and import markets.

When trade is liberalized under the 'CCAGLIBEU' scenario, import prices decline, but only marginally. Indeed, the deflationary impact of multilateral tariff elimination on import prices does not offset the price increase observed under the climate change only scenario. As a result, import demand slightly expands. Prices for domestic output increase slightly due to increased intermediate demand in exporting sectors, which benefit from favorable terms of trade due to the tariff elimination. For private households, trade liberalization alleviates the cost burden of substituting away from domestic goods through deflationary impacts on import prices, albeit marginal (Table B5.5, Appendix B).

Nonetheless, the gains in efficiency in resource allocation brought about by a reduction in the cost of substitution from domestic goods to imports due to tariff elimination are not large enough to offset the initial loss under climate change only. Arguably, the limited scope of the trade liberalization scenario at the sector and regional level as defined for the 'CCAGLIBEU' scenario does not have a large impact on initial equilibrium conditions. This is clearly depicted by the magnitude of the net impact of tariff elimination, which is substantially smaller compared to the price dynamic unfolding under climate change only.

At the regional level, and depending on the scope of the trade liberalization scenario, we can group the countries/regions based on welfare impacts in three groups (Figure 5.9):

- Group 1: countries/regions that benefit under climate change and gain under trade liberalization scenarios, but not all;
- Group 2: countries/regions that loose under climate change and benefit under trade liberalization scenarios, but not all;
- Group 3: countries/regions that loose under climate change and further loose under trade liberalization scenarios.

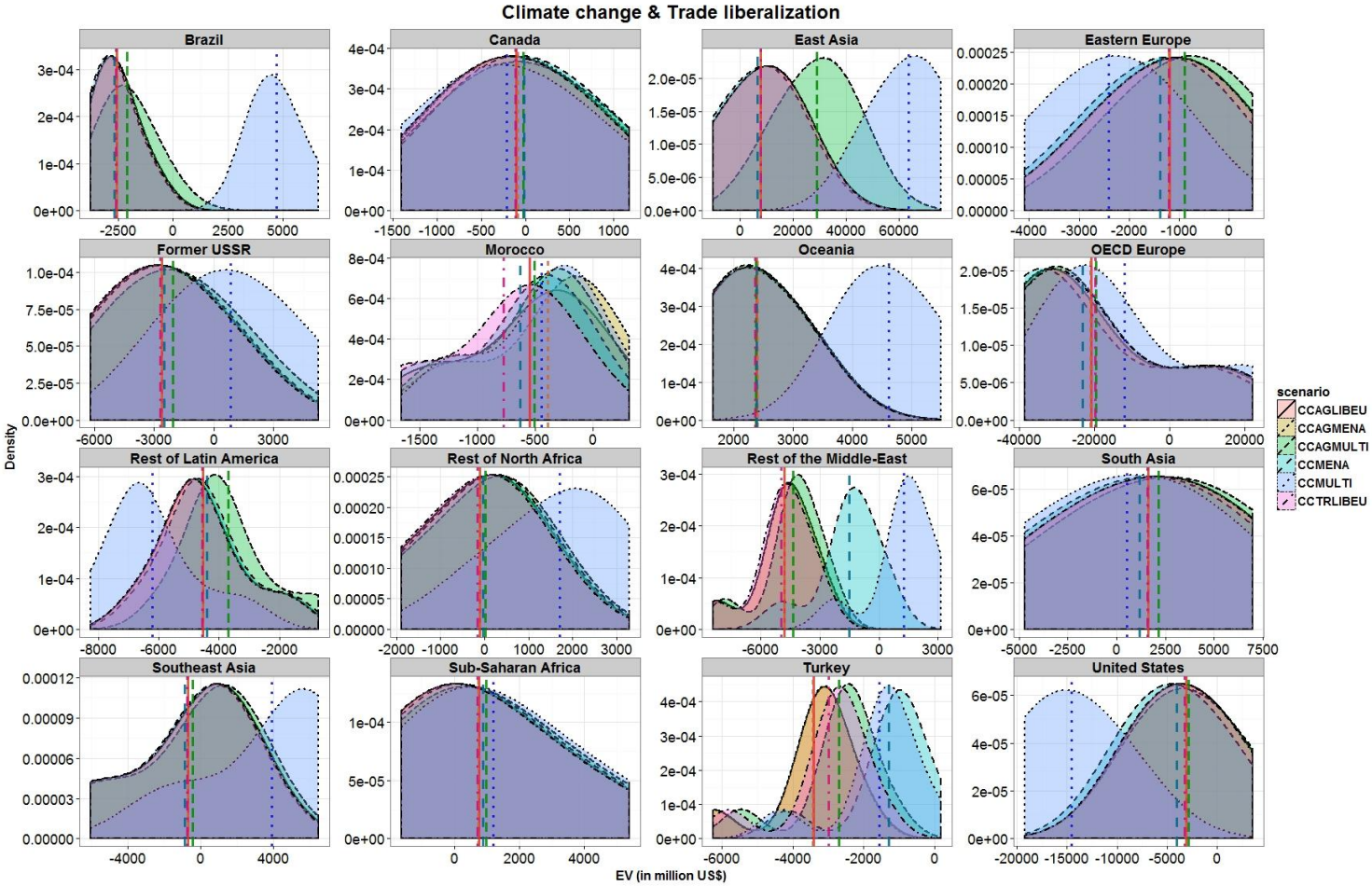

Figure 5.9 Kernel Distribution of Welfare Impacts of Trade Liberalization under Climate Change by Scenario by 2050 (in 2004 $US million)

Source: Simulation results

In Group 1, Oceania, East Asia, South Asia, and Sub-Saharan Africa all benefit under climate change from positive projected yields on average. With trade liberalization, these regions further realize additional welfare gains. Nonetheless, not all regions gain under all scenarios. For instance, Oceania, East Asia and Sub-Saharan Africa realize additional gains under the multilateral trade liberalization ('CCMULTI'), but not South Asia which displays a much lower welfare result compared to the climate change only scenario. In contrast, under the agricultural multilateral trade liberalization ('CCAGMULTI'), Oceania's welfare results are lower compared with the climate change only scenario; whereas East Asia, South Asia and Sub-Saharan Africa all benefit from higher welfare gains. The remaining countries/regions mostly fall within Group 2 which includes Turkey. Morocco is the only country that displays larger welfare losses compared with the climate change only scenario.

For all regions, given the exogenously-induced technical efficiency impacts due to climate change which remain mostly unchanged when introducing tariff elimination, the final welfare impacts are mainly driven by the combined effects of allocative efficiency, terms of trade, and investment-savings.

For regions in Group 1, the contribution of allocative efficiency is positive for all, but only under the full and agricultural multilateral trade liberalization scenarios. For South Asia and Sub-Saharan Africa, allocative efficiency contributes negatively to welfare in two out of the six trade liberalization scenarios respectively.[26] Depending on

[26] In principle, negative allocative efficiency effects are counterintuitive in terms of theoretical expectations which suggest a positive contribution due to tariff elimination. Kabir and Salim (2011) investigated the issue of negative contribution of allocative efficiency to aggregate welfare stemming from regional trade liberalization scenarios.

the scenario, the terms of trade can contribute positively and appreciably to aggregate welfare. For instance, East Asia and Oceania benefit from relatively large terms of trade under the 'CCMULTI' scenario; they contribute negatively in South Asia and Sub-Saharan Africa. A reversal occurs under the 'CCAGMULTI' scenario whereby South Asia and Sub-Saharan Africa benefit, and vice-versa for East Asia. The savings-investment effects contribute positively to aggregate welfare for most regions and under most tariff elimination scenarios.

For countries/regions in Group 2, the allocative efficiency effects in general are positive and relatively large under the multilateral trade liberalization scenarios, except for the United States and Canada under the 'CCAGMULTI' scenario. On the other hand, terms of trade effects are mostly negative under the full multilateral trade liberalization scenario. As we move from a multilateral to a regional scenario in terms of tariff elimination, the terms of trade effect contributes positively for some regions, but not all. For example, under the 'CCMENA' scenario, the United States, Canada, the Rest of the Middle-East and Turkey display positive terms of trade effects; whereas it remains negative for the rest of the regions in the group under the same scenario.

For Morocco in Group 3, the results suggest that only allocative efficiency effects contribute positively to aggregate welfare under the different trade liberalization

---

Their analysis focused on the BIMSTEC FTA, which combines seven geographically contiguous South and Southeast Asian countries: Bangladesh, Bhutan, India, Myanmar, Nepal, Sri Lanka and Thailand. They argue that the negative contribution of allocative efficiency effects can be explained by "the magnitude and interaction of the pre-existing sector subsidies with the quantity change in imports and exports after the removal of import duties within the bloc. The sign of the effect would depend on whether the quantity change in exports that receive domestic subsidies surpasses the effect in quantity change in imports due to the removal of tariff liberalization" (Kabir and Salim, 2011).

scenarios, except under the full FTA in MENA ('CCMENA'). The gains can be large, especially under the broader tariff elimination regimes (e.g. 'CCMULTI'). In addition, the negative climate-induced technical efficiency effects are lower compared to the climate change only scenario, which suggests minor gains. Nonetheless, the latter remain mostly negative and combined with the negative contribution from investment-savings, and the terms of trade effects, the final result is a welfare loss under all trade liberalization scenarios.

5.5 Impacts of Trade Liberalization under Climate Change: A Comparison between Morocco and Turkey

In this section, we will turn our attention to analyzing in more detail the impacts on Morocco. Additionally, we will contrast the results of Morocco with Turkey. The objective is to capture the dynamics of the interaction between climate change and trade liberalization. The choice of Turkey stems from the fact that the two countries share a tendency towards an increasing opening to international markets in recent years, the similarities between their agricultural sectors, and more importantly the template of development that Turkey might offer especially given its recent growth performance.

5.5.1 A Descriptive Analysis of the Macroeconomic Structure in Morocco and Turkey

The objective of this section is to shed light on the structural characteristics of the Moroccan and Turkish economies. We will discuss briefly the structure of production and its allocation across domestic and export markets. We will focus our discussion on patterns of allocation of output across the different demands domestically, and shed light

on key differentials between the two countries. We will also analyze the tax structure in both countries, and especially the trade related policy instruments as they pertain directly to the present analysis. Ultimately, we attempt to understand key features that might explain some of the differentials observed in terms of results of the analysis we performed.

In Morocco and Turkey, the aggregate output at the sectoral level is primarily allocated to domestic markets especially for strategic food commodities (e.g. rice, wheat, coarse grains, etc.). Nonetheless, there exists a differential in terms of exports. Morocco exports more raw commodities compared with Turkey, which are characterized by low value-added. For instance, exports account for 31% and 35% of aggregate output for vegetables & fruits and extraction sectors. On the other hand, Turkey exports more in terms of high value-added commodities such as textile & apparel (58%) and manufactures (31%) (Figures 5.10 and 5.11).

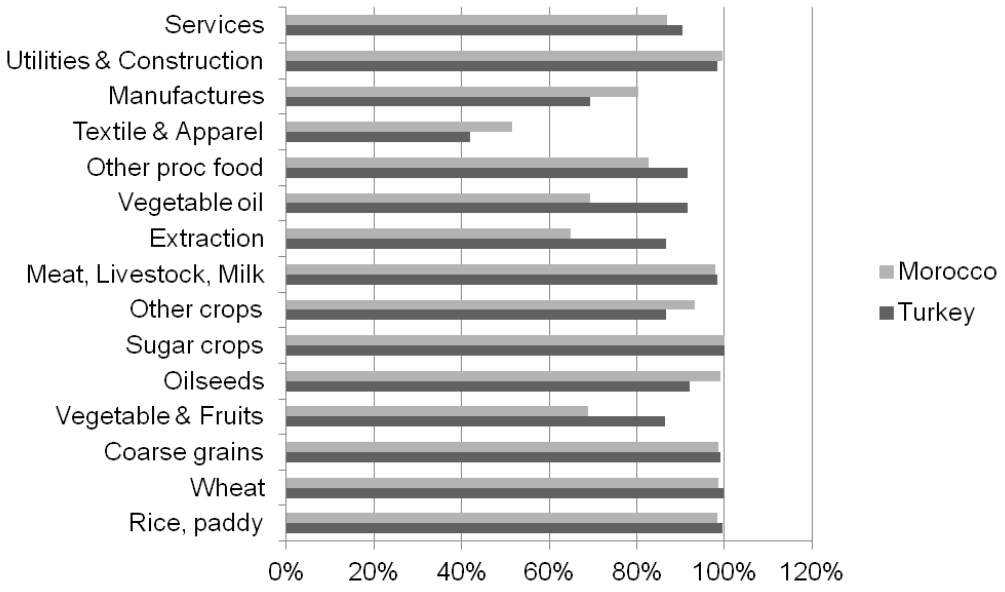

Figure 5.10 Share of Domestic Markets in Aggregate Output by Sector (in %)
Source: Author's adaptation (Data source: GTAP database version 7)

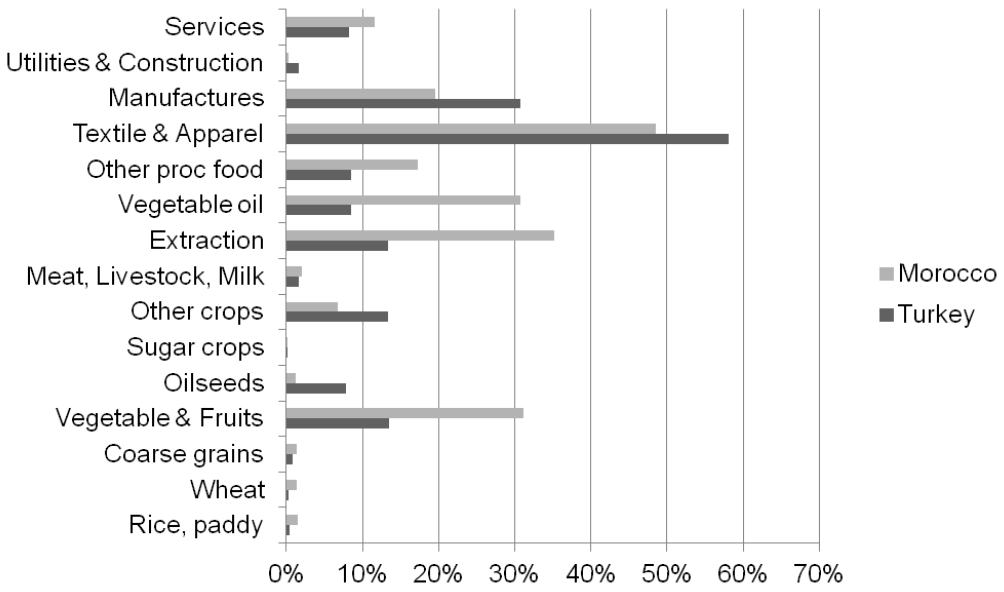

Figure 5.11 Share of Export Markets in Aggregate Output by Sector (in %)
Source: Author's adaptation (Data source: GTAP database version 7)

In what pertains to the allocation of domestic output in both countries, firms' demand represents the bulk of consumption demand for high value-added commodities. Nevertheless, the structure of consumption for food commodities differs significantly in both countries especially for crop commodities. In Turkey, the firms' share in aggregate domestic output exceeds 60% for commodities like rice, wheat, coarse grains, oilseeds, etc.; whereas the reverse is observed for Morocco where private (household) consumption is dominant (Figures 5.12 and 5.13).

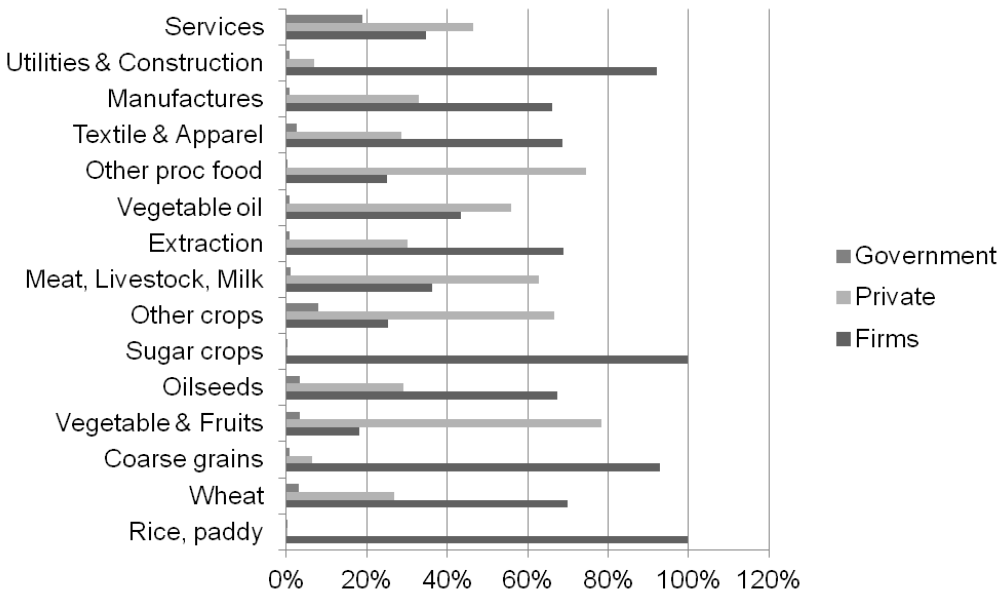

Figure 5.12 Percent Share Distribution of Domestic Output by Sector and by Demand Category in Turkey

Source: Author's adaptation (Data source: GTAP database version 7)

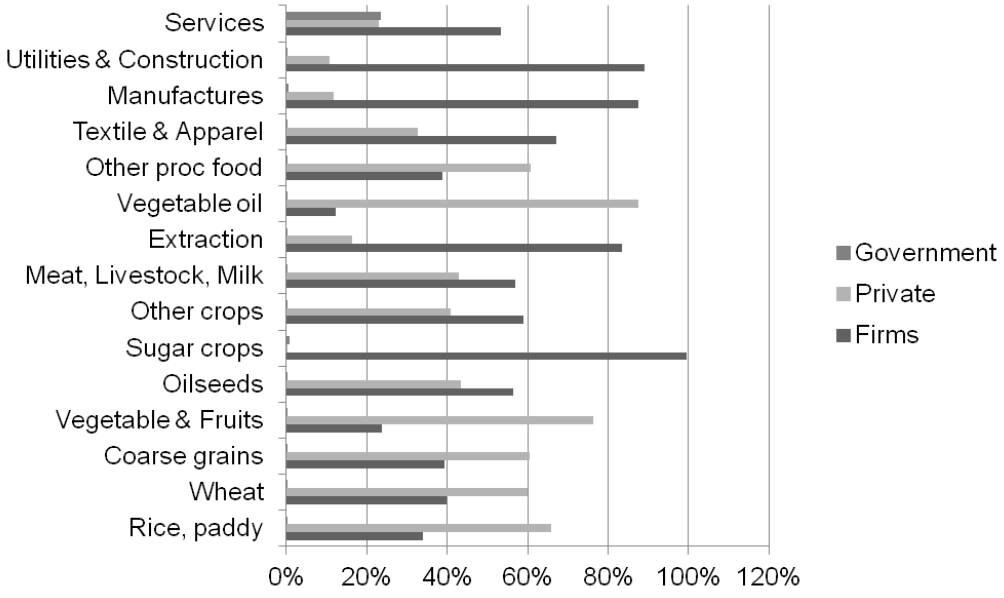

Figure 5.13 Percent Share Distribution of Domestic Output by Sector and by Demand Category in Morocco

Source: Author's adaptation (Data source: GTAP database version 7)

A similar trend is observed for both countries in terms of imports. Imported staple food commodities in Morocco are primarily allocated to household consumption which account for the bulk of the demand. In Turkey, a similar trend is observed for coarse grains and vegetables & fruits, but for the rest of the food commodities firms' demand represents the major source of demand for food imports (Figures 5.14 and 5.15).

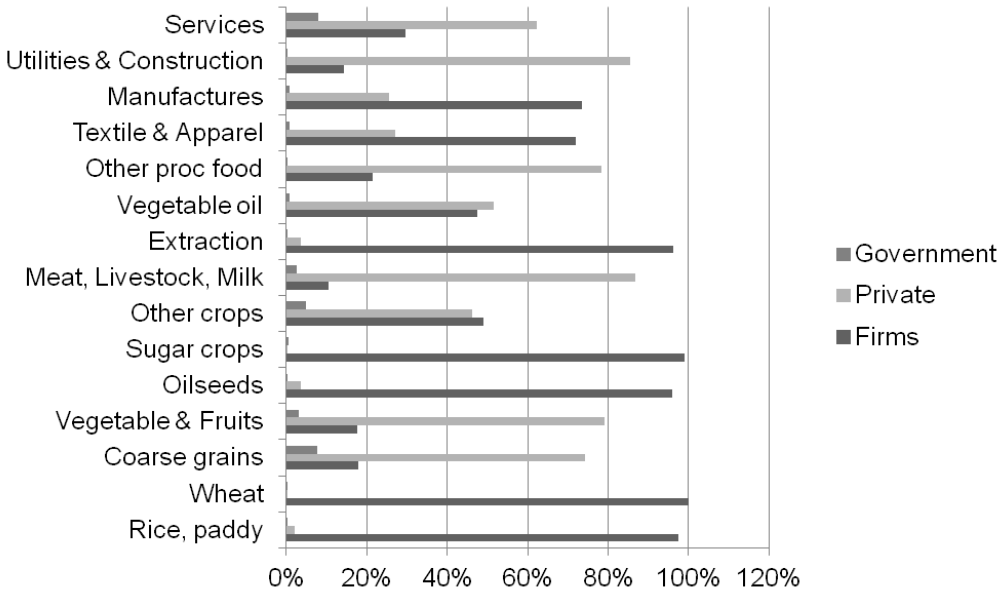

Figure 5.14 Percent Share Distribution of Import Sales by Sector and by Demand Category in Turkey

Source: Author's adaptation (Data source: GTAP database version 7)

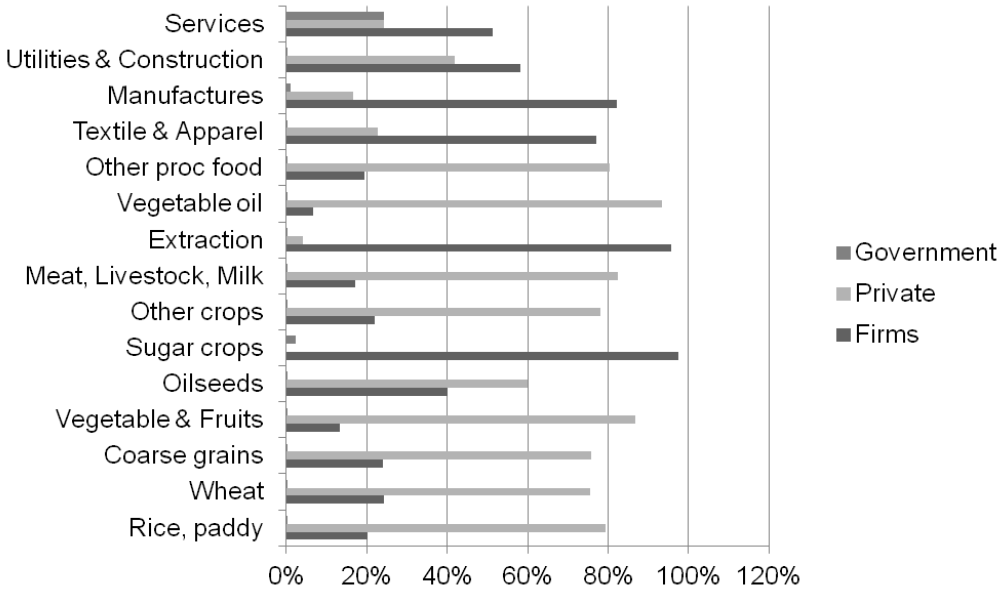

Figure 5.15 Percent Share Distribution of Import Sales by Sector and by Demand Category in Morocco

Source: Author's adaptation (Data source: GTAP database version 7)

5.5.2 Analysis of Aggregate Welfare and Macroeconomic Impacts

As previously argued, Morocco on average does not benefit from trade liberalization ex-post climate change; whereas the opposite is the case for Turkey. In terms of net welfare contribution, Moroccan tariff elimination induces further losses with the lowest occurring under the agricultural FTA in MENA and the highest under the full FTA with OECD Europe and Eastern Europe. In Turkey, trade liberalization has a positive impact on aggregate welfare. There are positive net welfare contributions under all scenarios, with the highest occurring under a full FTA in MENA and the lowest under the agricultural FTA in MENA (Figure 5.16).

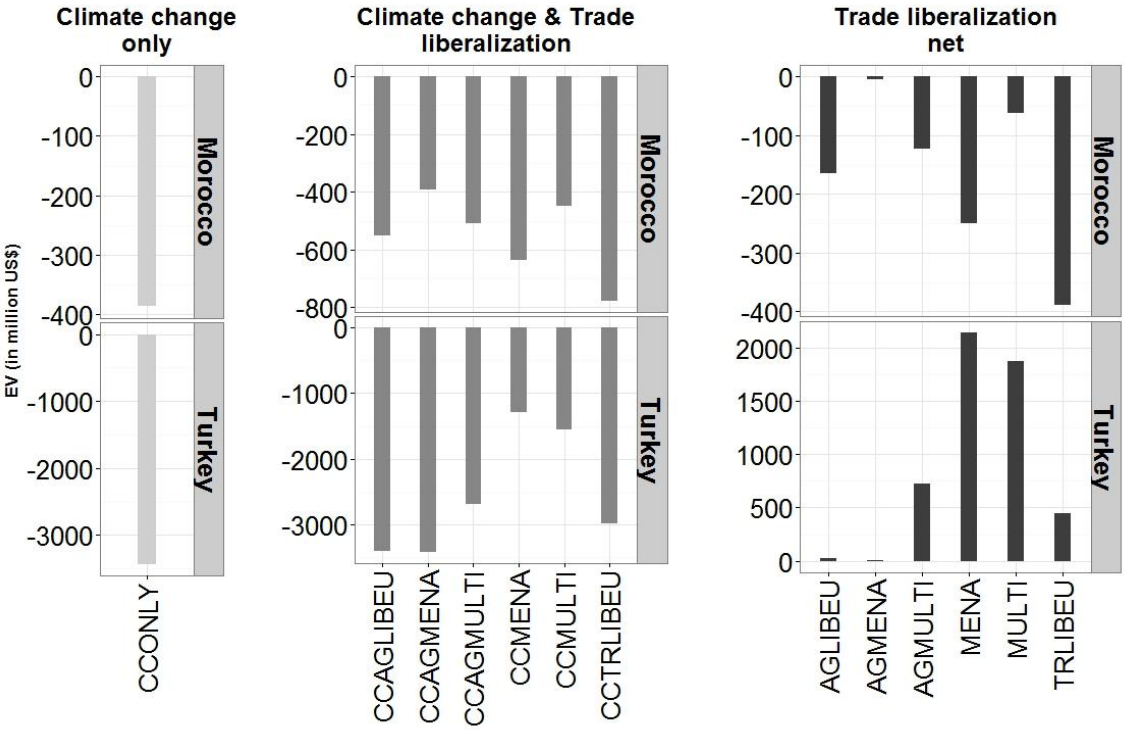

Figure 5.16 Average Welfare Impacts for Morocco and Turkey by Scenario by 2050 (in 2004 $US million)

Source: Simulation results

Impacts on gross domestic product (GDP) are similar to the results for aggregate welfare. For Morocco, the results on average suggest a large negative impact on GDP, especially under the full and agricultural multilateral trade liberalization scenarios. Overall, the net contribution of trade liberalization on GDP is negative under all scenarios, with the highest under the full multilateral trade liberalization (-8%) and the lowest under the agricultural FTA with MENA (-0.3%). In Turkey, the results suggest a mixed picture. On average, impacts on GDP are positive only under trade liberalization scenarios spanning all sectors. For the agricultural trade liberalization scenarios, impacts are marginally negative. The highest GDP gain occurs under the full FTA with MENA where

the latter reaches +4%; whereas the lowest gain is +0.6% under the full multilateral trade liberalization scenario (Figure 5.17).

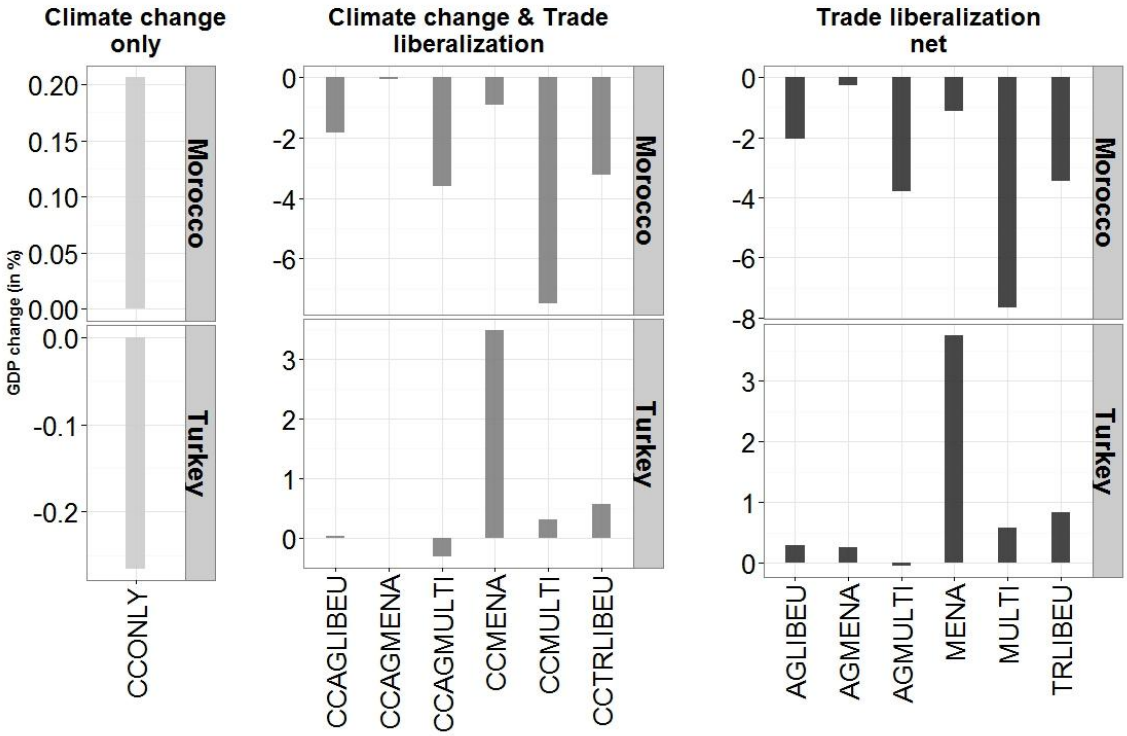

Figure 5.17 Average Gross Domestic Product (GDP) Impacts for Morocco and Turkey by Scenario by 2050 (in 2004 $US million)

Source: Simulation results

Nevertheless, when investigating the distribution across climate scenarios, the results indicate that trade liberalization can yield net welfare gains for Morocco. This occurs mainly under the multilateral trade liberalization scenario for the SRES scenarios A1B and B1 (Table 5.11).

Table 5.11 Net Welfare Impacts of Trade Liberalization in Morocco by Climate and Trade Scenario (in 2004 $US million)

	Trade liberalization scenario					
SRES scenario	AGMENA	AGLIBEU	AGMULTI	MENA	TRLIBEU	MULTI
A1B	-5.4	-184.7	-50.6	-244.2	-385.6	22.9
A1BLow	-5.0	-158.6	-154.0	-249.1	-379.7	-101.4
A1F	-4.7	-181.3	-153.2	-249.4	-404.3	-97.4
A1T	-4.8	-175.7	-155.0	-249.2	-393.6	-99.5
A2	-4.5	-117.7	-132.1	-254.4	-379.1	-80.1
B1	-5.3	-199.9	-55.4	-245.0	-404.1	16.3
B1Low	-4.8	-189.1	-141.2	-249.6	-407.1	-80.0
B2	-4.8	-109.6	-140.5	-255.1	-357.2	-82.7

Source: Simulation results

The results are mainly driven by the combined net gains in allocative efficiency and technical efficiency, which offset the net losses from the terms of trade and investment-savings effects. These gains occur in a context of significant negative impacts on crop yields in Morocco. For instance, average yields across all crops are projected to decline by 13% under both climate scenarios, A1B and B1. On the other hand, average yields are projected to increase especially for the main agricultural trade partners of Morocco such as OECD Europe and the United States (Figure A5.2, Appendix A). This suggests that Morocco can benefit from trade liberalization, but only under potential climate futures where the traditional trading partners of the country benefit.

Given that the major contributing factor to the observed results is the allocative efficiency effect, we further decompose it at the commodity level in Table 5.12. The results show that trade intensive sectors contribute the most to the final result be it on the import side (e.g. wheat, coarse grains, etc.) and/or the export side (e.g. textile and apparel, manufactures, etc.).

Table 5.12 Allocative Efficiency Effect by Commodity for Morocco for the Multilateral Trade Liberalization Scenario 'MULTI' under Climate Scenarios A1B and B1 (2004 $US million)

Commodities	Climate Change Only		Climate Change & Trade Liberalization		Net Trade Liberalization	
	A1B	B1	A1B	B1	A1B	B1
Land	0.00	0.00	0.00	0.00	0.00	0.00
Unskilled labor	0.00	0.00	0.00	0.00	0.00	0.00
Skilled labor	0.00	0.00	0.00	0.00	0.00	0.00
Capital	0.00	0.00	0.00	0.00	0.00	0.00
Natural resources	0.00	0.00	0.00	0.00	0.00	0.00
Paddy rice	0.11	0.11	0.17	0.17	0.06	0.06
Wheat	330.70	305.64	419.16	406.17	88.46	100.53
Coarse grains	33.43	35.49	87.48	88.56	54.04	53.07
Vegetables, fruits, and nuts	3.54	4.09	12.49	12.84	8.95	8.75
Oilseeds	-3.76	-3.43	1.84	2.03	5.60	5.46
Sugar cane, Suger beet	-0.01	-0.01	0.06	0.07	0.08	0.08
Other crops nes	3.61	3.73	5.81	5.83	2.20	2.10
Meat, livestock, raw milk	-3.53	-3.23	331.83	333.26	335.37	336.49
Forest, fish, minerals	3.38	3.36	54.72	54.70	51.34	51.34
Vegetable oils and fats	-0.62	-0.74	6.15	6.06	6.78	6.80
Other processed food	10.05	9.13	64.59	64.25	54.54	55.13
Textile and apparel	0.58	1.23	290.91	291.27	290.34	290.04
Manufactures	-45.62	-43.43	220.77	221.83	266.39	265.27
Utilities and Construction	-0.99	-0.94	4.08	4.12	5.07	5.06
Transportation and Services	-0.14	-0.12	0.40	0.42	0.54	0.54

Source: Simulation results

5.5.3 Decomposition of Welfare and Macroeconomic Impacts

Investigating the decomposition of the welfare impacts, we find that on average the interaction between the allocative efficiency and terms of trade effects is the main determinant of the net welfare position in Morocco and Turkey. For Morocco, trade liberalization induces positive net allocative efficiency effects under all scenarios, except under the full FTA with MENA. On the other hand, investment-savings and terms of trade are generally negative and large for terms of trade. Under most scenarios, the terms of trade losses outweigh the gains in allocative efficiency, except under the full multilateral trade liberalization scenario where net allocative efficiency gains are US$ +1,254 million, and net terms of trade losses are US$ -1,212 million. Nonetheless, the net contribution of investment-savings effects under this scenario is negative and reaches US$ -188 million, thus causing an aggregate welfare loss despite the small net gain in terms of technical efficiency.

For Turkey, on average, the net terms of trade and allocative efficiency effects contribute positively to aggregate welfare. For instance, net gains from allocative efficiency and terms of trade effects under the full multilateral trade liberalization scenario reach US$ +908 million and US$ +906 million. Even in the case where there is a divergence between the two effects, it is usually the case that one or the other is large enough to offset any potential net loss. This occurs for example under the full FTA with MENA where the net gains from terms of trade effects amount to US$ +2,198 million and the net losses from allocative efficiency are US$ -328 million. But generally for Turkey, trade liberalization entails net welfare gains, though not large enough to totally offset the initial loss of welfare under climate change (Figure A5.4, Appendix A).

In terms of net impacts on GDP components, Moroccan consumption and government spending declines under most scenarios, with consumption decreasing more compared to government spending. Aggregate exports and imports display major increases, especially under the full multilateral trade scenario and the full FTA with OECD Europe. Under the non-agricultural trade liberalization scenarios, imports increase more than exports, and vice-versa for the agricultural trade liberalization scenario. For aggregate investment, they decrease under the agricultural trade liberalization scenarios and vice-versa under the non-agricultural trade scenarios. Given the disproportionate share of consumption and government spending in Moroccan GDP, the negative impacts associated with the latter dominate the final effect, which is the negative overall impact on GDP discussed earlier.

In Turkey, the impact of trade liberalization is generally positive for all GDP components. For example, all GDP components increase by more than 3% under the full FTA with MENA. Overall, trade liberalization induces an expansionary surge in terms of aggregate GDP in Turkey, whereas the contrary occurs in Morocco where the economy in general experiences a general contraction (Figure A5.5, Appendix A). This issue is explored further in the next section.

5.5.4 Sectoral Impacts: Trade, Prices, and Production

5.5.4.1 Trade: Imports and Exports

In the aftermath of tariff elimination, the immediate impact is a decline in world prices, thereby affecting the relative price of exports and imports, which in turn affects

the consumption and production patterns domestically. The most important factor determining the results are the import tariff structure in Morocco compared to Turkey, as well as the taxation of imports by firms. Table 5.13 summarizes the average tariff and average tax rate on firms' imports by commodity in Morocco and Turkey as they appear in the GTAP database version 7. The data shows that the level of protection in Morocco is generally significantly higher than for Turkey. This is especially the case for food commodities where for instance Moroccan tariffs are in general twice as high as their Turkish counterpart. Another peculiar difference between Morocco and Turkey is the presence of import subsidies for firms' domestic and import purchases. In Turkey, the latter exist mainly for raw commodities such as crops and food processed products; whereas firms' purchases of high value-added commodities are taxed for both import and domestic purchases. Additionally, we notice the rate of subsidies is higher for import purchases compared to domestic purchases and particularly for raw commodities such as agricultural crops. With respect to high value-added commodities, there is a reverse dynamic with respect to taxation of firms' purchases. Indeed, import purchases are taxed higher compared to domestic purchases. In Morocco, there is little subsidy and/or taxes on firms' purchases.

Hence, the differential in the structure of the fiscal burden in both countries will affect the simulation results and could potentially explain the differences in results we observe between Morocco and Turkey.

Table 5.13 Average Import Tariff and Tax on Firms' Imports by Commodity (% ad valorem rate)

	Import tariffs (% ad valorem rate)			Taxes on firms' imports purchases (% ad valorem rate)			Taxes on firms' domestic purchases (% ad valorem rate)		
	Turkey (1)	Morocco (2)	Ratio (3) = (2)/(1)	Turkey (1)	Morocco (2)	Ratio (3) = (2)/(1)	Turkey (1)	Morocco (2)	Ratio (3) = (2)/(1)
Rice, paddy	8.3	4.2	0.5	-0.9	0.00	0.00	-0.25	0.00	0.00
Wheat	8.8	31.4	3.6	-0.5	0.00	0.00	-0.16	0.00	0.00
Coarse grains	15.1	42.6	2.8	-0.5	0.00	0.00	-0.19	0.00	0.00
Vegetable & Fruits	36.7	38.6	1.1	-0.2	0.00	0.00	-0.25	0.00	0.00
Oilseeds	8.4	19.0	2.3	-1.3	0.00	0.00	-0.14	0.00	0.00
Sugar crops	1.3	2.0	1.6	0.0	0.00	n.a.	-0.78	0.00	0.00
Other crops	21.8	15.7	0.7	-1.5	0.00	0.00	-0.32	0.00	0.00
Meat, Livestock, Milk	16.8	37.5	2.2	-0.3	0.00	0.00	-1.66	0.00	0.00
Extraction	0.7	14.1	19.8	11.2	0.00	0.00	2.24	0.03	0.01
Vegetable oil	13.4	16.3	1.2	0.0	0.00	0.00	-0.01	0.00	0.00
Other proc food	27.7	37.2	1.3	-0.2	0.00	0.00	-0.01	0.00	0.00
Textile & Apparel	5.2	28.2	5.4	0.2	0.00	0.00	-1.60	0.00	0.00
Manufactures	2.3	17.2	7.6	11.7	0.00	0.00	39.63	0.00	0.00
Utilities&Construction	0.0	0.0	n.a.	8.5	0.00	0.00	14.11	0.00	0.00
Services	0.0	0.0	n.a.	0.0	0.02	n.a.	-1.60	0.00	0.00

Source: Author's adaptation (Data source: GTAP database version 7)

For Morocco, the net effect of trade liberalization under climate change on export price and quantity index is different. Under all scenarios, the aggregate export price index decreases considerably, especially under the full multilateral trade liberalization scenario where the decline reaches -6%. As for the change in the quantity index, it is positive, and can be large reaching +39% under the full multilateral scenario. Moroccan imports exhibit a similar surge to exports. Nonetheless, this occurs in a context of increasing import prices (Figure 5.18).

By contrast, Turkey on the export side benefits from increasing prices and quantities as suggested by the net impact on aggregate export price and quantity indices, which are mainly positive under most scenarios. Moreover, Turkish imports are increasing with decreasing prices. And hence, the terms of trade effects are positive for Turkey and negative for Morocco as discussed earlier. These results are robust across scenarios (Figure 5.18).

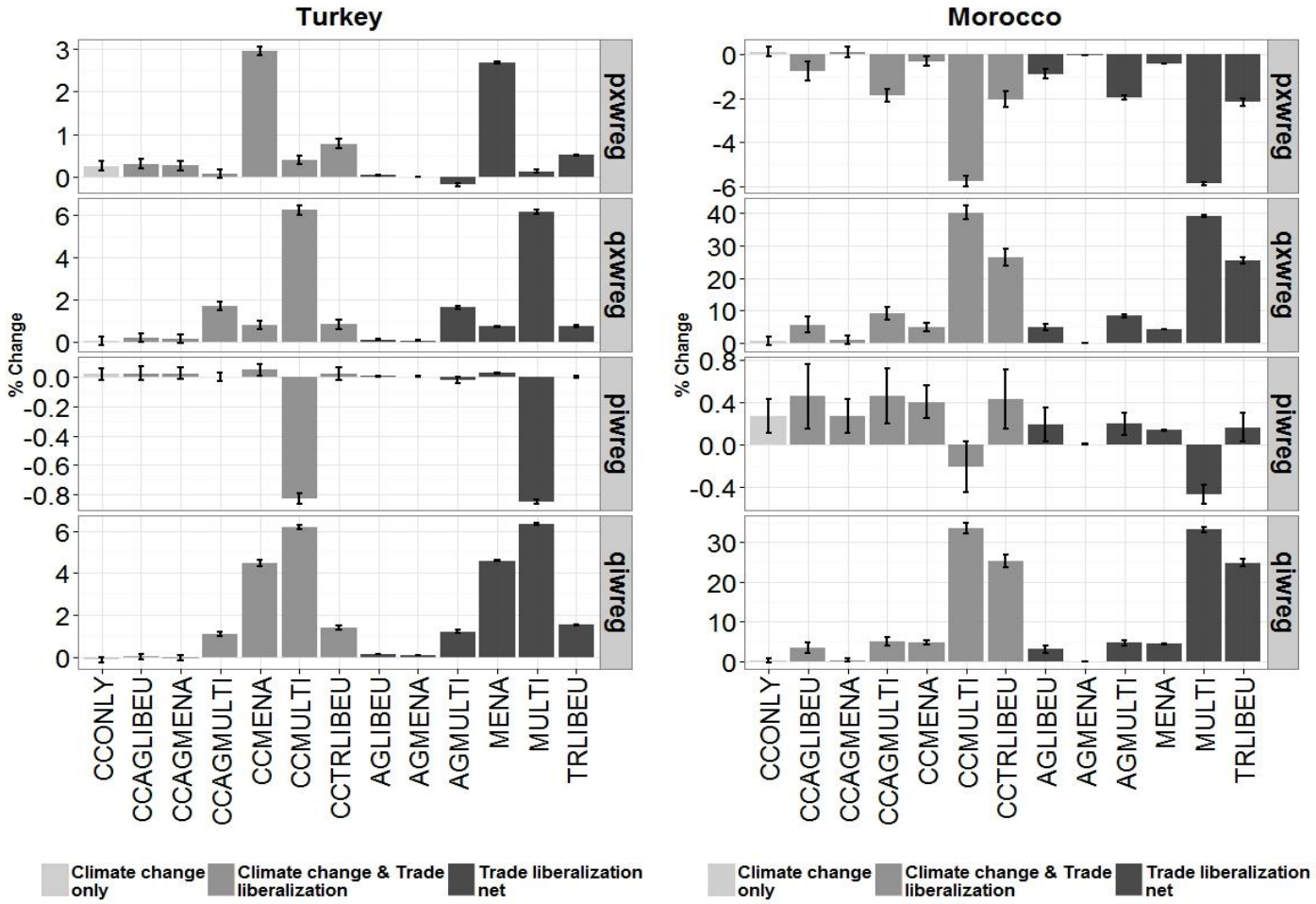

Figure 5.18 Average Percent Change in Exports and Imports Price and Quantity Indices by 2050

Source: Simulation results

For Turkey, import prices for crop commodities tend to increase under most scenarios. The rest of the sectors depict decreasing import prices in general, especially under the full multilateral trade liberalization scenario. Imports quantities on the other hand display substantial increases most notably under the full and agricultural multilateral trade scenarios, and the full FTA with MENA. For instance, net imports for crop commodities on average increase by more than 60% except for coarse grains and oilseeds under the full multilateral trade liberalization scenario (Table B5.6, Appendix B). The export net price impacts induced by trade liberalization are generally positive for most sectors, except under the 'CCAGMULTI' scenario (Table B5.7, Appendix B). In this case, export prices mostly decrease, whereas export quantities increase. Thus, it results in a negative contribution to welfare through the terms of trade effects as discussed earlier. Overall, Turkey seems to benefit from relatively cheap imports, which in turn stimulates domestic production. At the same time, prices on the export side increase, which boosts exports.

For Morocco, import prices increase under most scenarios especially for crop commodities. A small decrease in crop prices occurs under the full and agricultural FTA scenarios with MENA, but remains negligible. The general trend in import quantities suggests substantial increases, most notably for the crop commodities (Table B5.6, Appendix B). In terms of exports, despite increasing volumes, the latter occur in a context of decreasing prices under the 'CCMULTI' and 'CCAGMULTI' scenarios (Table B5.7, Appendix B). The large percent change observed in trade volumes for Morocco is driven by the initial high import tariff structure in place. Therefore, a complete removal of tariffs, as in the 'CCMULTI' scenario, translates into a substantial shock to relative

prices at the sector level, and especially for crops and food commodities. Overall, Morocco does not benefit from its exports despite the substantial increase in exported quantities. This is due to the impacts of trade liberalization on export prices, which cause them to decrease under most cases. In addition, the dependency on imports as suggested by the substantial increase in demand in a context of increasing prices results in an overall negative contribution to welfare from the terms of trade.

5.5.4.2 Domestic Demand and Production

The contractionary effect of climate change on productivity induces price hikes domestically especially for the crop commodities in both Morocco and Turkey. In general, these price hikes in domestic market prices are larger than the price increases of imported commodities. Therefore, there is an increase in final demand for imports which are relatively cheaper than domestic production. In terms of intermediate demand generated by firms, a similar dynamic plays out especially for crop commodities. Generally, firms' demand for imported intermediate inputs increases in both countries at the expense of domestic intermediate inputs, particularly for crop intermediates. Intermediate input prices in the non-agricultural sectors increase only marginally compared with the agricultural sectors, and even decline for certain sectors. As a result, there is a general reallocation of domestic and intermediate inputs from the climatically unconstrained non-agricultural sectors to the crop and food processing sectors. A similar dynamic occurs for final household and government expenditure demand for domestic and imported commodities (Table B5.8, Appendix B).

Eliminating tariffs under all scenarios induces large changes in final and intermediate demands for domestic and imported commodities through price differentials. In Morocco, aggregate output sales by destination display large impacts. The share of domestic markets decline in all sectors especially under the multilateral trade scenario. On the other hand, the share of export markets grows. The largest impacts occur for crop and food processing sectors. The decline in demand for domestic output stems from the decrease in demand from households, government and firms.

As previously argued, tariff elimination induces a substantial price decline for imports, which in turn deflates prices for domestic output. Nonetheless, the disproportionate decrease in import prices compared to domestic prices induces the different agents to substitute away from domestic output to imports, which are relatively cheaper. For instance, the substantial fall in wheat production under the 'MULTI' scenario is a direct result of falling market prices, which are driven by increased import-supply following tariff elimination. Indeed, demand for domestic wheat from private households, government and firms decreases by -54%, -44% and -45% respectively; whereas their demand for imported wheat increases by +23%, +11% and +46%. This comes as no surprise given that import prices for wheat decline by -35% compared with -7% for domestic prices. A similar dynamic unfolds for most of the crop and food processing commodities sectors under the 'MULTI' scenario. These sectors are heavily protected in Morocco, and therefore tariff elimination exposes the less competitive domestic sector to international competition (Tables B5.9-B5.11, Appendix B).

For Turkey, a similar trend is observed for aggregate output sales. The share of domestic markets in output sales declines for most sectors especially under the

multilateral trade scenario. Nonetheless, the magnitude of change is smaller than the Moroccan case. On the other hand, the share of export markets displays a substantial appreciation, higher in comparison with the Moroccan case. The impacts for some sectors can be large. The decline observed in demand for domestic output stems from the decrease in demand from households, government and firms. As previously argued, tariff elimination induces a substantial price decline for imports, which in turn deflates prices for domestic output. But these effects are less pronounced than in Morocco. The effects of trade liberalization on Turkey are mainly through imported intermediate input use. Although effects on sectors may differ, Turkish imports generally increase to supply the increasing intermediate input demand by the export sectors. Use of agricultural inputs increases especially for intermediate use in food, manufacturing, livestock and vegetable oil production as the exports of these commodities increase (Tables B5.9-B5.11, Appendix B).

5.6 Conclusions

Globally, the main conclusions of the analysis suggest that:

- trade liberalization in most cases offsets partially the negative impacts associated with climate change on agriculture;
- total offset of negative welfare impacts associated with climate change occurs only under a multilateral trade liberalization scenario (CCMULTI), which is in line with theoretical expectations from trade theory.

At the regional level, and depending on the scope of the trade liberalization, the results suggest that:

- regions benefitting from positive climate-induced productivity shocks on agriculture benefit the most under trade liberalization;
- regions experiencing negative climate shocks to agricultural yields benefit only marginally from trade liberalization, and under specific tariff elimination scenarios, the net impact is negative.

For Morocco, the analysis suggests that:

- average net welfare contribution of trade liberalization across climate scenarios is negative;
- when considering the distribution of impacts across climate scenarios, Morocco exhibits net welfare gains under the multilateral trade liberalization scenario;
- the gains occur under the climate scenarios A1B and B1, and under which OECD Europe as the main trading partner of Morocco exhibits positive projected yield impacts;
- trade liberalization induces net gains in allocative efficiency, but are on average offset by the substantial negative contribution of the terms of trade and investment-savings effects;
- multilateral trade liberalization under A1B and B1 scenarios induces net technical efficiency gains, which combined with the gains from allocative efficiency, yield net welfare gains;
- exports tend to increase substantially, but in a context of significantly decreasing prices on average; whereas imports show significant increases in a contest of increasing prices, especially for crop and food commodities.

In Turkey:

- trade liberalization induces net welfare gains under all scenarios;
- the magnitude of the gains are not large enough to offset the totality of the initial loss under climate change;
- the combined effect of positive net allocative efficiency and terms of trade effects drive most of the results;.
- exporting sectors in Turkey seem to benefit substantially from free trade given increasing export prices and quantities especially for crop and food commodities (e.g. oilseeds and other crops);
- imports increase substantially, driven primarily by intermediate demand and low import prices;
- for the rest of the sectors, the trend in traded volumes is generally increasing for both exports and imports, due to increasing export prices and declining import prices.

In conclusion, complete trade liberalization significantly reduces the negative effects of climate change globally. However, for all the partial liberalization cases, the results are mixed, with some countries and regions gaining and some losing.

CHAPTER 6. GENERAL CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

6.1 General Conclusion

Climate change is expected to be a major challenge internationally, but also locally in many countries. Anticipating and thwarting its projected negative impacts in Morocco through adaptation is paramount. Climate change is costly and involves trade-offs at the policy-making level that will affect different social stakeholders. In this thesis, we have attempted to capture some of the potential costs and trade-offs. The study attempts to analyze impacts on the different economic agents at the regional and national level in Morocco, as well as linkages with the global dynamics that Morocco would face in the medium to long term. We also explore potential adaptation measures and their effectiveness in the face of uncertainties linked to climate change as encapsulated implicitly in the PMV strategy.

The main findings from Chapter 4 suggest that the implications of the PMV strategy on the Moroccan economy can be significant absent climate change. Indeed, the macroeconomic impacts of the PMV suggests that GDP increases by +2.4%. The largest impacts are observed for consumption, which increases by +3.3%. Similar impacts are observed for the rest of GDP components where they range from +1% to +2.4%. At the sectoral level, agricultural crops value-added exhibits the largest impacts increasing by +16%.

When accounting for climate change only (CC-Only) impacts on agricultural, the results at the macroeconomic level suggest large negative impacts, which cause GDP to fall by -0.5% to -3% across climate scenarios without CO_2 fertilization. Nevertheless, accounting for the productivity enhancement associated with the CO_2 fertilization effect on crop yield, the distribution of the results suggests a positive shift where GDP impacts range from -1.4% to +0.4%.

With respect to GDP components, private consumption exhibits the largest magnitudes in terms of impacts owing to the market price and income dynamics engendered by climate change. Impacts vary from -0.9% to -4.5% across climate scenarios without CO2 fertilization, with lower magnitudes observed when accounting for CO2 fertilization whereby impacts vary from -2.3% to +0.4%. Similar results hold for government expenditures and investment, but relatively lower magnitudes. Impacts on household income is negative under the CC-Only case. On average, incomes declined by -0.5% to -3% across climate scenarios and household types under the without CO2 fertilization case. This is primarily driven by the reduction in returns to primary factors of production, which is caused by the negative impacts on their productivity.

In terms of the PMV potential in mitigating the negative impacts of climate change, the results suggest that it induces very small potential gains. For instance, the net impacts of the PMV on GDP varies from +0.02% to +0.04% across climate scenarios. At level of incomes, the results suggest that the PMV has positive effects on household incomes. Overall, net impacts vary from +0.06% to +0.2%. Nevertheless, the positive effects on incomes does not translate into gains with respect to other measures of household welfare (e.g. real household expenditures, welfare, etc.).

Nevertheless, the ability of the PMV strategy to mitigate the negative effects of climate change are limited at best, if non-existent. This is due to the scope of the PMV simulations limited to the strategic agricultural crop sectors in Morocco, which jointly represent no more than 35% of aggregate agricultural GDP; whereas the rest of the sectors account for 65%. Additionally, the likelihood of meeting the PMV productivity targets is low in light of our benchmark analysis comparing productivity prior and after the adoption of GMO technologies.

In Chapter 5, where we investigated the potential offered by trade liberalization for adaptation in the face of climate change globally. Under climate change only, the welfare impacts globally range from a minimum of US$ -11,784 million to a maximum of US$ -54,138 million. At the regional level, we observe a strong correlation between welfare and GDP impacts on one hand, and the projected yield impacts on the other. When introducing trade liberalization, the results suggest that the wider the regional and sectoral scope of tariff reduction and/or elimination, the larger the gains. Indeed, under a multilateral trade liberalization scenario (CCMULTI), we observe a complete reversal in the distribution of welfare results. The welfare impacts range from US$ +22,609 million to US$ +64,969 million.

At the regional level, the implications of trade liberalization vary depending on the scope of the tariff elimination, but also on the structural characteristics of the economy and the magnitude of the projected climate shocks on the economy mainly through agriculture. For example in Morocco, the net welfare impacts associated with trade liberalization are negative on average. But under the multilateral trade liberalization scenario, Morocco experiences net welfare gains under the SRES A1B and B1, which

respectively reached US$ +23 million and US$ +16 million. Although trade liberalization induces net allocative efficiency gains under most scenarios, the large negative terms of trade effects offsets most of the gains.

In Turkey, trade liberalization induces net welfare gains under all tariff elimination scenarios. The largest net welfare gains occur under the full FTA scenario in the Middle-East and North Africa (CCMENA) where it reaches on average US$ +2,142 million. Nevertheless, the magnitude of the gains is not large enough to offset total initial losses under climate change only. The trade liberalization gains in Turkey are driven by the positive contribution from allocative efficiency and terms of trade effects. Export sectors in Turkey seems to benefit the most given the increase in export prices from international markets; but also due to the decrease in the costs of imported intermediate goods.

In general, trade liberalization induces net welfare gains in most regions. However, it remains true that under most scenarios, the gains are not large enough to offset total initial loss due to climate change. The magnitude of the gains depends on a case-by-case basis on the regional and sectoral scope of the tariff elimination scenario; but also on the structural characteristics of regional economies and their trade dependencies vis-a-vis other regions.

The major take away from both Chapter 4 and 5 is that scope of adaptation policies and/or measure in the face of climate change is a key driver of the results observed. In Chapter 4, the results show that the limited scope of the PMV strategy in terms of its sectoral targets inhibits its overall potential for offsetting impact vis-a-vis the climate change impacts. A similar conclusion is reached from the analysis in Chapter 5

where we demonstrate that the world gains the most when trade liberalization is multilateral. The gains from moving toward partial trade liberalization scenarios are miniscule in the face of climate change impacts.

6.2 Limitations and Future Research

The framework and tools used in this study can be enhanced further by improving the modeling features and updating the underlying data. For example, the two approaches introduced in Chapters 4 and 5 can be integrated to gain more insight. We could derive climate-induced export price distributions for strategic commodities and simulate the potential gains (if any) that the PMV strategy can offer.

Another venue for improvement is to enhance the regional modeling of the Morocco CGE model in Chapter 4. This could be achieved by introducing friction into the interregional flows of commodities across regions following a number of methodologies that have been developed in recent years: Horridge et al. (2005) using the TERM model, the FLQ method introduced by Flegg and Tohmo (2011), or introducing transportation costs as documented in Haddad and Hewings (1998).

Also, in the future, we would hope that better disaggregated data sets would be developed to provide better regional yield shocks by crop. The thrust of this work begins with estimating the impacts of climate change induced yield changes by crop and region. While we constructed the best available data to do this, there is room for substantial improvement in this data.

LIST OF REFERENCES

LIST OF REFERENCES

Abadi Ghadim, A.K. "Water repellency: a whole-farm bio-economic perspective." Journal of Hydrology (200) 231–232, 396–405.

Abeygunawardena, P. Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation. S.l.: African Development Bank, 2003.

Ahmed, Syud Amer, Noah S. Diffenbaugh, Thomas W. Hertel, and William J. Martin. "Agriculture and Trade Opportunities for Tanzania: Past Volatility and Future Climate Change." Review of Development Economics 16, no. 3 (2012): 429-47.

Akesbi, Najib, Benatya, Driss and Oufi, Noureddine. L'agriculture Marocaine À L'épreuve De La Libéralisation. Rabat: Economie Critique, 2008.

Akesbi, Najib. "Agriculture, peche, alimentation et developpement rural durable dans la region mediterraneenne", Rapport annuel - Maroc, CIHEAM, 2005.

Akesbi, Najib. "Evolution et perspectives de l'Agriculture marocaine" [en ligne]. In : Cinquante ans de Développement Humain au Maroc. (Maroc). 50 ans de développement humain au Maroc, perspectives 2025 : rapports thématiques. Rabat : Royaume du Maroc. p. 85-198. (50 ans de Développement Humain au Maroc & Perspectives 2025)

Akesbi, Najib. "La question des prix et des subventions au Maroc face aux mutations de la politique agricole", Options Méditerranéennes: Sér. B / n°11, 1997.

Antle, J. M., and S. M. Capalbo. "Adaptation of Agricultural and Food Systems to Climate Change: An Economic and Policy Perspective." Applied Economic Perspectives and Policy, 2010, 386-416.

Antle, J.M., Capalbo, S.M. "Econometric-process models for integrated assessment of agricultural production systems." American Journal of Agricultural Economics 83, 389–401.

Arnell, Nigel W. "Climate Change and Global Water Resources: SRES Emissions and Socio-economic Scenarios." Global Environmental Change: 31-52.

Babcock B.A., Moreira M., Peng Y. "Biofuel Taxes, Subsidies, and Mandates: Impacts on US and Brazilian Markets." Food and Agricultural Policy Research Institute (FAPRI) at Iowa State University (2013).

Babcock, Bruce A. "Taxpayers, Crop Insurance, and the Drought of 2012." Environmental Working Group, 2014 (Accessed January 31. http://www.ewg.org/research/taxpayers-crop-insurance-and-drought-2012).

Bartolini, F., Bazzani, G.M., Gallerani, V., Raggi, M., Viaggi, D. "The impact of water and agriculture policy scenarios on irrigated farming systems in Italy: an analysis based on farm level multi-attribute linear programming models." Agricultural Systems 93 (2007), 90–114.

Bassett, Thomas J., and Charles Fogelman. "Déjà Vu or Something New? The Adaptation Concept in the Climate Change Literature." Geoforum 48 (2013): 42-53.

Berentsen, P., Giesen, G. "Economic and environmental consequences of different governmental policies to reduce N losses on dairy farms." Netherlands Journal of Agricultural Science 42 (1994), 11–19.

Berrittella, Maria, Andrea Bigano, Roberto Roson, and Richard S.j. Tol. "A General Equilibrium Analysis of Climate Change Impacts on Tourism." Tourism Management 27, no. 5 (2006): 913-24.

Bezabih, Mintewab, Muyeye Chambwera, and Jesper Stage. "Climate Change and Total Factor Productivity in the Tanzanian Economy." Climate Policy: 1289-302.

Birur, Dileep & Hertel, Thomas & Tyner, Wally. "Impact of Biofuel Production on World Agricultural Markets: A Computable General Equilibrium Analysis." GTAP Working Papers 2413, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, 2008.

Blanco M. "Literature Review of Methodologies to Generate Baselines for Agriculture and Land Use.", CAPRI-RD Deliverable D4.1. CAPRI-RD collaborative project, EU 7th Framework Programme (2010).

Bosello, Francesco, Carlo Carraro, and Enrica De Cian. "Climate Policy And The Optimal Balance Between Mitigation, Adaptation And Unavoided Damage." Climate Change Economics 01 (2010): 71.

Bosello, Francesco, Roberto Roson, and Richard S.j. Tol. "Economy-wide Estimates of the Implications of Climate Change: Human Health." Ecological Economics 58 (2006): 579-91.

Bosetti, Valentina and Carraro, Carlo and Duval, Romain and Sgobbi, Alessandra and Tavoni, Massimo, The Role of R&D and Technology Diffusion in Climate Change Mitigation: New Perspectives Using the Witch Model (April 30, 2009). FEEM Working Paper No. 14.2009; CMCC Research Paper No. 63. Available at SSRN: http://ssrn.com/abstract=1397076 or http://dx.doi.org/10.2139/ssrn.1397076

Bosetti, Valentina, Carraro, Carlo, Galeotti, Marzio, Massetti, Emanuele and Tavoni, Massimo. "WITCH - A World Induced Technical Change Hybrid Model." University Ca' Foscari of Venice Economic Research Paper No. 46/06, 2006. Available at SSRN: http://ssrn.com/abstract=948382 or http://dx.doi.org/10.2139/ssrn.948382

Bouderbala, Negib, Chraibi, M. and Pascon, Paul. "La question agraire au Maroc." Publication du Bulletin economique et social du Maroc (BESM): 2 vol. (no. 123-124-125 et 133-134).

Bouderbala, Negib. "la modernisation et la gestion du foncier au Maroc" Options Méditerranéennes: Sér. A / n°29, 1997.

Bouderbala, Negib. "Les Terres Collectives Du Maroc Dans La Première Période Du Protectorat (1912-1930)." Revue Du Monde Musulman Et De La Méditerranée: 143-56.

Bouwman, A.F., Kram, T., Klein Goldewijk, K. "Integrated Modelling of Global Environmental Change: An Overview of IMAGE 2.4." MNP, Bilthoven, The Netherlands, 2006 (http://www.pbl.nl/en/publications/2006/Integratedmodellingofglobalenvironmentalchange.AnoverviewofIMAGE2.4).

Breisinger, C., Zhu, T., Al Riffai, P., Nelson, G., Robertson, R., Funes, J., and Verner, D. "Global and Local Economic Impacts of Climate Change in Syria and Options for Adaptation." IFRPI Discussion Paper 01091, Washington, D.C.: IFPRI, 2011.

Britz, W., and Heckelei, T. "Recent Developments in EU Policies - Challenges for Partial Equilibrium Models." Paper prepared for presentation at the 107th EAAE Seminar "Modeling of Agricultural and Rural Development Policies". Sevilla, Spain, January 29th -February 1st, 2008.

Bruin, Kelly C. De, Rob B. Dellink, and Richard S. J. Tol. "AD-DICE: An Implementation of Adaptation in the DICE Model." Climatic Change 95 (2009): 63-81.

Bürger, G. "Expanded Downscaling for Generating Local Weather Scenarios." Climate Research, no. 7 (1996): 111-28.

Burgess, Robin, and Dave Donaldson. "Can Openness Mitigate the Effects of Weather Shocks? Evidence from India's Famine Era." American Economic Review 100, no. 2 (2010): 449-53.

Burniaux, J-M., G. Nicoletti and J. Oliveira Martins . "GREEN: A Global Model for Quantifying the Costs of Policies to Curb CO2 Emissions", OECD Economic Studies, 19 (1992), (Winter).

Burrell, Alison, Stephan Hubertus Gay, and Aikaterini Kavallari. "The Compatibility of EU Biofuel Policies with Global Sustainability and the WTO." The World Economy 35 (2012): 784-98.

Burton, Ian, Saleemul Huq, Bo Lim, Olga Pilifosova, and Emma Lisa Schipper. "From Impacts Assessment To Adaptation Priorities: The Shaping Of Adaptation Policy." Climate Policy 2 (2002): 145-59.

Calvin, Kate,Wise, Marshall, Page, Kyle, Chini, Louise, 2012. "Spatial land use in the GCAM integrated assessment model." In EMF Workshop on "Climate Change Impacts and Integrated Assessment." Pacific Northwest National Laboratory, Snowmass, Colorado, USA.

Carter, T.R. and Mäkinen, K. 2011. Approaches to climate change impact, adaptation and vulnerability assessment: towards a classification framework to serve decision-making. MEDIATION Technical Report No. 2.1, Finnish Environment Institute (SYKE), Helsinki, Finland, 70 pp.

Challinor, A. J., F. Ewert, S. Arnold, E. Simelton, and E. Fraser. "Crops And Climate Change: Progress, Trends, And Challenges In Simulating Impacts And Informing Adaptation." Journal of Experimental Botany: 2775-789.

Challinor, A. J., J. M. Slingo, T. R. Wheeler, P. Q. Craufurd, and D. I. F. Grimes. "Toward a Combined Seasonal Weather and Crop Productivity Forecasting System: Determination of the Working Spatial Scale." Journal of Applied Meteorology 42 (2003): 175-92.

Challinor, A.j., T.r. Wheeler, P.q. Craufurd, J.m. Slingo, and D.i.f. Grimes. "Design and Optimisation of a Large-area Process-based Model for Annual Crops." Agricultural and Forest Meteorology 124 (2004): 99-120.

Challinor, Andrew J, Elisabeth S Simelton, Evan D G Fraser, Debbie Hemming, and Mathew Collins. "Increased Crop Failure Due to Climate Change: Assessing Adaptation Options Using Models and Socio-economic Data for Wheat in China." Environmental Research Letters 5 (2010): 034012.

Chbouki, Nabil. Spatio-temporal Characteristics of Drought as Inferred from Tree-ring Data in Morocco. University of Arizona., 1992.

Claessens, L., J.m. Antle, J.j. Stoorvogel, R.o. Valdivia, P.k. Thornton, and M. Herrero. "A Method for Evaluating Climate Change Adaptation Strategies for Small-scale Farmers Using Survey, Experimental and Modeled Data." Agricultural Systems 111 (2012): 85-95.

Cline, William R. Global Warming and Agriculture Impact Estimates by Country. Washington, DC: Center for Global Development :, 2007.

Conseil Général du Développement Agricole (CGDA), 2004.

Conseil Général du Développement Agricole (CGDA) (2009). "Atlas de l'Agriculture Marocaine". Ministère de l'Agriculture et de la Pêche Maritime (MAPM) (http://www.agriculture.gov.ma/pages/publications/atlas-de-lagriculture-marocaine)

Deryng, D., W. J. Sacks, C. C. Barford, and N. Ramankutty. "Simulating the Effects of Climate and Agricultural Management Practices on Global Crop Yield." Global Biogeochemical Cycles 25 (2011).

Disaster Risk Reduction a Development Concern : A Scoping Study on Links between Disaster Risk Reduction, Poverty and Development. London: DFID, 2005.

Doukkali, Rachid. "Evolution des performances du secteur agricole : résultats d'une expérience." In : Cinquante ans de Développement Humain au Maroc (Maroc). 50 ans de développement humain au Maroc, perspectives 2025 : rapports thématiques. Maroc : Cinquante ans de Développement Humain au Maroc. p. 199-233. (50 ans de Développement Humain au Maroc & Perspectives 2025).

Doukkali, Rachid. "Water institutional reforms in Morocco", Water Policy 7 (2005): 71-88.

Dudu, H. and Cakmak, E. H. "An integrated analysis of economywide effects of climate change." UNU-WIDER Working paper 2014/106, Helsinki, Finland, 2014 http://www.wider.unu.edu/publications/working-papers/2014/en_GB/wp2014-106/

Dumortier J., Hayes D.J., Carriquiry M., Dong F., Du X., Elobeid A., Fabiosa J.F., Mulik K. "Modeling the effects of pasture expansion on emissions from land-use change." Center for Agricultural and Rural Development, Working Paper (2010).

Elobeid A., Carriquiry M., Fabiosa J.F., Mulik K., Hayes D.J., Babcock B.A., Dumortier J., Rosas F. "Greenhouse Gas and Nitrogen Fertilizer Scenarios for US Agriculture and Global Biofuels." (2011).

Erjavec E., Salputra G. "Could the radical changes of direct payments policy destroy agricultural markets in the EU new Member States?" Ekonomika poljoprivrede 58 (2011):45-65.

FAPRI (2012). "FAPRI-ISU 2012 World Agricultural Outlook." (http://www.fapri.iastate.edu/outlook/2012/)

Farrow, Andrew, Didace Musoni, Simon Cook, and Robin Buruchara. "Assessing The Risk Of Root Rots In Common Beans In East Africa Using Simulated, Estimated And Observed Daily Rainfall Data." Experimental Agriculture 47 (Special Issue 02) (2011): 357-73.

Feenstra, Jan F. Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies. Version 2.0. ed. Nairobi, Kenya?: United Nations Environment Programme, 1998.

Fernández F.J., Blanco M., Ceglar A., M'Barek R., Ciaian P., Srivastava A.K., Lecerf R., Ramos F., Niemeyer S., Van-Doorslaer B. (2013). "Still a challenge - interaction of biophysical and economic models for crop production and market analysis." Working

Paper nº 3, ULYSSES project, EU 7th Framework Programme, Project 312182 KBBE.2012.1.4-05, http://www.fp7-ulysses.eu/ , 96 pp.

Fischer, G., M. Shah, and H. Van Velthuizen. "Climate Change and Agricultural Vulnerability." IIASA Special Report Commissioned by the UN for The World Summit on Sustainable Development, Johannesburg 2002, International Institute For Applied Systems Analysis, Laxenburg, Austria, pp.160.

Fischer, G., M. Shah, F. N. Tubiello, and H. Van Velhuizen. "Socio-economic And Climate Change Impacts On Agriculture: An Integrated Assessment, 1990-2080." Philosophical Transactions of the Royal Society B: Biological Sciences: 2067-083.

Flichman, G., Donatelli, M., Louhichi, K., Romstad, E, Heckelei, T., Auclair, D., Garvey, E., van Ittersum, M., Janssen, S., Elbersen, B. "Quantitative models of SEAMLESS-IF and procedures for up-and downscaling." SEAMLESS report no. 17, November 2006.

Friggens, Megan M., and Colo Collins. Review and Recommendations for Climate Change Vulnerability Assessment Approaches with Examples from the Southwest. Fort Collins, CO: United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2013.

Gal, P.-Y. Le, P. Dugué, G. Faure, and S. Novak. "How Does Research Address the Design of Innovative Agricultural Production Systems at the Farm Level? A Review." Agricultural Systems 104 (2011): 714-28.

Gerald C. Nelson, Mark W. Rosegrant, Amanda Palazzo, Ian Gray, Christina Ingersoll, Richard Robertson, Simla Tokgoz, Tingju Zhu, Timothy B. Sulser, Claudia Ringler, Siwa Msangi, and Liangzhi You. "Food security, farming, and climate change to 2050 : scenarios, results, policy options." International Food Policy Research Institute (IFPRI), Washington, D.C.: IFPRI, 2010.

Giorgi, Filippo. "Simulation of Regional Climate Using a Limited Area Model Nested in a General Circulation Model." Journal of Climate, 1990, 941-63.

Golub, A. A., B. B. Henderson, T. W. Hertel, P. J. Gerber, S. K. Rose, and B. Sohngen. "Global Climate Policy Impacts on Livestock, Land Use, Livelihoods, and Food Security." Proceedings of the National Academy of Sciences, 2013, 20894-0899.

Golub, A., Henderson, B., Hertel, T., Rose, S., Avetisyan, M., and Sohngen, B. "Effects of the GHG Mitigation Policies on Livestock Sectors." GTAP Working Paper No. 62, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, 2010.

Golub, Alla, Thomas Hertel, Huey-Lin Lee, Steven Rose, and Brent Sohngen. "The Opportunity Cost of Land Use and the Global Potential for Greenhouse Gas Mitigation in Agriculture and Forestry." Resource and Energy Economics 31 (2009): 299-319.

Happe, K., Kellermann, K., and Balmann, A. "Agent-based Analysis of Agricultural Policies: an Illustration of the Agricultural Policy Simulator AgriPoliS, its Adaptation and Behavior." Ecology and Society 11(1), 2006: 49.

Harberger, Arnold C. "The Incidence of the Corporation Income Tax." Journal of Political Economy, 1962, 215.

Haut Commissariat au Plan (HCP). "Enquête Nationale sur la Consommation et les Dépenses des Ménages 2000/2001", http://www.hcp.ma/Enquete-nationale-sur-la-consommation-et-les-depenses-des-menages_a95.html - Last accessed 21/04/2015.

Havlík P., Herrero M., Mosnier A., Obersteiner M., Schmid E., Fuss S., Schneider U.A. (2011a) "Production system based global livestock sector modeling: Good news for the future", 2011 International Congress, August 30-September 2, 2011, Zurich, Switzerland, European Association of Agricultural Economists.

Havlik, P., H. Valin, A. Mosnier, M. Obersteiner, J. S. Baker, M. Herrero, M. C. Rufino, and E. Schmid. "Crop Productivity and the Global Livestock Sector: Implications for Land Use Change and Greenhouse Gas Emissions." American Journal of Agricultural Economics, 2013, 442-48.

Havlík, Petr, Uwe A. Schneider, Erwin Schmid, Hannes Böttcher, Steffen Fritz, Rastislav Skalský, Kentaro Aoki, Stéphane De Cara, Georg Kindermann, Florian Kraxner, Sylvain Leduc, Ian McCallum, Aline Mosnier, Timm Sauer, and Michael Obersteiner. "Global Land-use Implications Of First And Second Generation Biofuel Targets." Energy Policy 39 (2011b): 5690-702.

Hazilla, Michael & Kopp, Raymond J. "Social Cost of Environmental Quality Regulations: A General Equilibrium Analysis," Journal of Political Economy, University of Chicago Press, vol. 98(4): 1990, pages 853-73, August.

Hertel, T., Verma, M., Ivanic, M., and Rios, A. "GTAP-POV: A Framework for Assessing the National Poverty Impacts of Global Economic and Environmental Policies." GTAP Technical Paper No. 31, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, 2011.

Hertel, T.W., Lobell, D.B., "Agricultural adaptation to climate change in rich and poor countries: Current modeling practice and potential for empirical contributions", Energy Economic, 2014, http://dx.doi.org/10.1016/j.eneco.2014.04.014.

Hertel, Thomas and Lobell, David B. "Agricultural adaptation to climate change in rich and poor countries: Current modeling practice and potential for empirical contributions." Energy Economics (2014),

Hertel, Thomas W., Marshall B. Burke, and David B. Lobell. "The Poverty Implications of Climate-induced Crop Yield Changes by 2030." Global Environmental Change, 2010, 577-85.

Hertel, Thomas, Lee, Huey-Lin, Rose, Steven and Sohngen, Brent. "Modeling Land-use Related Greenhouse Gas Sources and Sinks and their Mitigation Potential." GTAP Working Papers 2605, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, 2008.

Hussein, Zekarias, Thomas Hertel, and Alla Golub. "Climate Change Mitigation Policies and Poverty in Developing Countries." Environmental Research Letters 8 (2013): 035009.

IPCC First Assessment Report. Geneva: Intergovernmental Panel on Climate Change, 1990.

IPCC Fourth Assessment Report Climate Change 2007. Geneva: Intergovernmental Panel on Climate Change, 2007.

IPCC Fourth Assessment Report Climate Change 2007. Geneva: Intergovernmental Panel on Climate Change, 2007.

IPCC Second Assessment: Climate Change 1995: A Report of the Intergovernmental Panel on Climate Change. Geneva: World Meteorological Organization, 1996.

IPCC Third Assessment: Climate Change 2001. Geneva: WMO, 2001.

Janssen, Sander, and Martin K. Van Ittersum. "Assessing Farm Innovations and Responses to Policies: A Review of Bio-economic Farm Models." Agricultural Systems 94 (2007): 622-36.

Jansson, T. (2007). "Econometric specification of constrained optimization models." PhD thesis, Bonn, Institute for Food and Resource Economics.

Jarvis, Andy, Charlotte Lau, Simon Cook, Eva Wollenberg, James Hansen, Osana Bonilla, and Andy Challinor. "An Integrated Adaptation And Mitigation Framework For Developing Agricultural Research: Synergies And Trade-Offs." Experimental Agriculture 47, no. 2 (2011): 185-203.

Johansen, L. "A multi-sectoral study of economic growth", Amsterdam: North-Holland Publishing Company, 1960.

Keil, A., N. Teufel, D. Gunawan, and C. Leemhuis. "Vulnerability of Smallholder Farmers to ENSO-related Drought in Indonesia." Climate Research 38 (2009): 155-69.

Kim, J-W., J-T. Chang, N. L. Baker, D. S. Wilks, and W. L. Gates. "The Statistical Problem of Climate Inversion: Determination of the Relationship between Local and Large-Scale Climate." Monthly Weather Review, no. 112 (1984): 2069-077.

Klein, R.J.T. "Adaptation to Climate Variability and Change: What is Optimal and Appropriate?" in Giupponi, C., M. Schechter (eds.) Climate Change and the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation, Edward Elgar: Cheltenham, 2003.

Kuik, O., Reynes, F., Delobel, F., and Bernardi, M. "FAO-MOSAICC: The FAO Modeling System for Agricultural Impacts of Climate Change to Support Decision-Making in Adaptation" Presented at the 14th Annual Conference on Global Economic Analysis, Venice, Italy 2011.

Kurukulasuriya, P. "Will African Agriculture Survive Climate Change?" The World Bank Economic Review, 2006, 367-88.

Li, S., Challinor A.J., and Wheeler T.R. "Development of a Large Area Wheat Crop Model for Studying Climate Change Impacts in China." Journal of Agricultural Science 145 (2007): 635-50.

Lin, Tun. Climate Change and Agricultural Interregional Trade Flows in the People's Republic of China. Manila: Asian Development Bank, 2011.

Lobell, D. B., W. Schlenker, and J. Costa-Roberts. "Climate Trends And Global Crop Production Since 1980." Science 333 (2011): 616-20.

Lobell, David B. "Climate change adaptation in crop production: Beware of illusions." Global Food Security 3 (2014): 72-76.

Martin, E., B. Timbal, and E. Brun. "Downscaling of General Circulation Model Outputs: Simulation of the Snow Climatology of the French Alps and Sensitivity to Climate Change." Climate Dynamics, no. 13 (1997): 45-56.

Mavromatis, T., and P.d Jones. "Comparison of Climate Change Scenario Construction Methodologies for Impact Assessment Studies." Agricultural and Forest Meteorology 91 (1998): 51-67.

Mcgill, Robert, John W. Tukey, and Wayne A. Larsen. "Variations of Box Plots." *The American Statistician* 32, no. 1 (1978): 12.

McCown, R.L., Carberry, P.S., Hochman, Z., Dalgliesh, N.P., Foale, M.A. "Reinventing model-based decision support with Australian dryland farmers." 1. Changing intervention concepts during 17 years of action-research. Crop & Pasture Science 60 (2009), 1017–1030.

McSweeney, C., New, M. & Lizcano, G. 2010. UNDP Climate Change Country Profiles: Morocco. Available: http://country-profiles.geog.ox.ac.uk/[Accessed 10 May 2013].

McSweeney, C., New, M., Lizcano, G. & Lu, X. 2010. The UNDP Climate Change Country Profiles Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries. *Bulletin of the American Meteorological Society*, 91, 157-166.

Mcsweeney, C., G. Lizcano, M. New, and X. Lu. "The UNDP Climate Change Country Profiles." Bulletin of the American Meteorological Society, 2010, 157-66.

Mearns, L. "Analysis of Daily Variability of Precipitation in a Nested Regional Climate Model: Comparison with Observations and Doubled CO2 Results." Global and Planetary Change, no. 10 (1995): 55-78.

Mearns, L. O., Rosenweig, C. and Goldberg, R. "Mean and Variance Change in Climate Scenarios: Methods, Agricultural Applications, and Measures of Uncertainty." Climatic Change 35 (1997): 367-96.

Mearns, Linda O. Issues in the Impacts of Climate Variability and Change on Agriculture Applications to the Southeastern United States. Dordrecht ; Boston: Kluwer Academic Publishers, 2003.

Mendelsohn, R., A. Dinar, and A. Dalfelt. "Climate Change Impacts on African Agriculture.", Preliminary analysis prepared for the World Bank, Washington, D.C.: World Bank, 2000b.

Mendelsohn, R., Nordhaus, W. D. and Shaw, D. "The Impact of Global Warming on Agriculture." American Economic Review, September 1994, 84(4), pp. 753- 71.

Mendelsohn, Robert, Ariel Dinar, and Larry Williams. "The Distributional Impact Of Climate Change On Rich And Poor Countries." Environment and Development Economics 11 (2006): 159.

Ministère de l'Agriculture et de la Pêche maritime (MAPM) – Agence pour le Développement Agricole (ADA), *Plan Maroc Vert*, conférence de M. Hajjaji, DG de l'ADA, Rabat, Janvier, 2009.

Möller T., Grethe H. "Climate Change and Agriculture in 2050: Assessing Prospects for European Cereal and Oilseed Markets." Agricultural and Applied Economics Association (AAEA) Annual Meeting, July 25-27, 2010.

Möller T., Grethe H., Waha K., Müller C. "Modeling Climate Change Impacts on European Agriculture: Does the Choice of Climate Models matter?" XIIIth EAAE Congress "Change and Uncertainty", Zurich, Switzerland (2011).

Moorhead, A. "Climate, Agriculture and Food Security: A Strategy for Change." Alliance of the CGIAR Centers, 2009.

Morton, J., and C. Sear. "Challenges for Drought Management in West Asia and North Africa." Paper presented to Ministerial Meeting on Opportunities for Sustainable Investment in the Rainfed Areas of West Asia and North Africa, Rabat, Morocco and forthcoming as chapter of book published by IFAD, 2001.

Nekhay O., Gay S.H., Fellmann T. "A Free Trade between Ukraine and the European Union: Challenges and Opportunities for Agricultural Markets." 2011 International Congress, August 30-September 2, 2011, Zurich, Switzerland, European Association of Agricultural Economists (2011).

Nordhaus, William D. A Question of Balance: Weighing the Options on Global Warming Policies. New Haven: Yale University Press, 2008.

OECD/FAO. (2013) OECD-FAO Agricultural Outlook 2013-2022. OECD Publishing and FAO.

Olmstead, A. L., and P. W. Rhode. "Adapting North American Wheat Production to Climatic Challenges, 1839-2009." Proceedings of the National Academy of Sciences 108, no. 2 (2011): 480-85.

Osborne, Tom, Gillian Rose, and Tim Wheeler. "Variation in the Global-scale Impacts of Climate Change on Crop Productivity Due to Climate Model Uncertainty and Adaptation." Agricultural and Forest Meteorology 170 (2013): 183-94.

Ouassou, A., T. Ameziane, A. Ziyad, and M. Belghiti. "Chapter 19. Application of the Drought Management Guidelines in Morocco." Options Méditerranéennes, Series B, No. 58, 2007.

Palosuoa, T., Kersebaumb, K. C., Angulo, C., Hlavinka, P., Moriondo, M., Olesenf, J. E., Patil, R. H., Ruget, F., Rumbaur, C., Takac, J., Trnka, M., Bindi, M., Barıs, C., Ewert, F., Ferrise, R., Mirschelb, W., Levent, S., Siskak, B., Rotter, R. "Simulation of winter wheat yield and its variability in different climates of Europe: A comparison of eight crop growth models." European Journal of Agronomy 35 (2011): 103-114.

Paltsev, Sergey, Reilly, John M., Jacoby, Henry D., Eckaus, Richard S., McFarland, James R., Sarofim, Marcus C., Asadoorian, Malcolm O., Babiker, Mustafa H.M. "The MIT emissions prediction and policy analysis (EPPA) model: version 4." Technical Report, 2005. MIT Joint Program on the Science and Policy of Global Change (http://dspace.mit.edu/handle/1721.1/29790).

Parry, M. L. Climate Change 2007 Impacts, Adaptation and Vulnerability : Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge [England: Cambridge University Press, 2007.

Parry, M., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer. "Effects Of Climate Change On Global Food Production Under SRES Emissions And Socio-economic Scenarios." Global Environmental Change: 53-67.

Parry, M., C. Rosenzweig, and M. Livermore. "Climate Change, Global Food Supply And Risk Of Hunger." Philosophical Transactions of the Royal Society B: Biological Sciences: 2125-138.

Parry, Martin. "Global Impacts of Climate Change under the SRES Scenarios." Global Environmental Change: 1.

Pielke, R. A., G. A. Dalu, J. S. Snook, T. J. Lee, and T. G. F. Kittel. "Nonlinear Influence of Mesoscale Land Use on Weather and Climate." Journal of Climate, 1991, 1053-069.

Popp, Alexander, Dietrich, Jan Philipp, Lotze-Campen, Hermann, Klein, David, Bauer, Nico, Krause, Michael, Beringer, Tim, Gerten, Dieter, Edenhofer, Ottmar. "The economic potential of bioenergy for climate changemitigation with special attention given to implications for the land system." Environ. Res. Lett. 6 (3), 2011. http://dx.doi.org/10.1088/1748-9326/6/3/034017.

Proceedings of the Expert Meeting on How to Feed the World in 2050 24-26 June 2009, FAO Headquarters, Rome. Rome: FAO, 2009.

Quintero, M., S. Wunder, and R.d. Estrada. "For Services Rendered? Modeling Hydrology and Livelihoods in Andean Payments for Environmental Services Schemes." Forest Ecology and Management 258 (2009): 1871-880.

Reducing Disaster Risk: A Challenge for Development. New York: United Nations Development Programme, Bureau for Crisis Prevention and Recovery, 2004.

Robbins, Paul. Political Ecology: A Critical Introduction. Malden, MA: Blackwell Pub., 2004.

Robert Mendelsohn. "The Impact of Climate Change on Agriculture in Asia." Journal of Interactive Agriculture 13(4) (2014): 660-665.

Robinson, Sherman, Hans Van Meijl, Dirk Willenbockel, Hugo Valin, Shinichiro Fujimori, Toshihiko Masui, Ron Sands, Marshall Wise, Katherine Calvin, Petr Havlik, Daniel Mason D'croz, Andrzej Tabeau, Aikaterini Kavallari, Christoph Schmitz, Jan Philipp Dietrich, and Martin Von Lampe. "Comparing Supply-side Specifications in Models of Global Agriculture and the Food System." Agricultural Economics 45 (2014): 21-35.

S. Asseng, F. Ewert, C. Rosenzweig, Salputra, Guna. The Agri-food Sector in Russia Current Situation and Market Outlook until 2025. Luxembourg: Publications Office, 2013.

Schipper, E. Lisa F. "Conceptual History Of Adaptation In The UNFCCC Process." Review of European Community and International Environmental Law 16, no. 1 (2006a): 82-92.

Schlenker, W., and M. J. Roberts. "Nonlinear Temperature Effects Indicate Severe Damages To U.S. Crop Yields Under Climate Change." Proceedings of the National Academy of Sciences, 2009, 15594-5598.

Schlenker, Wolfram, and David B Lobell. "Robust Negative Impacts of Climate Change on African Agriculture." Environmental Research Letters 5 (2010): 014010.

Schlenker, Wolfram, W Michael Hanemann, and Anthony C Fisher. "Will U.S. Agriculture Really Benefit from Global Warming? Accounting for Irrigation in the Hedonic Approach." American Economic Review 95 (2005): 395-406.

Schwanitz, Valeria Jana. "Evaluating Integrated Assessment Models of Global Climate Change." Environmental Modelling & Software 50 (2013): 120-31.

Semenov, M A, and E M Barrow. "Use of Stochastic Weather Generator in the Development of Climate Change Scenarios." Climatic Change, no. 35 (1997): 397-414.

Seo, S. Niggol, and Robert Mendelsohn. "An Analysis of Crop Choice: Adapting to Climate Change in South American Farms." Ecological Economics 67 (2008): 109-16.

Shetty, S. "Water, Food Security and Agricultural Policy in the Middle East and North Africa Region." Washington, D.C.: World Bank working paper, 2006.

Shrestha S., Ciaian P., Himics M., Van Doorslaer B. "Regional Impacts of Climate Change on EU Agriculture." International Association of Agricultural Economists (IAAE) Conference, August 18-24, 2012, Foz do Iguacu, Brazil.

Soussana, J. F., A. I. Graux, and F. N. Tubiello. "Improving The Use Of Modelling For Projections Of Climate Change Impacts On Crops And Pastures." Journal of Experimental Botany 61, no. 8 (2010): 2217-228.

Southworth, J., Ra Pfeifer, M. Habeck, Jc Randolph, Oc Doering, and Dg Rao. "Sensitivity of Winter Wheat Yields in the Midwestern United States to Future Changes in Climate, Climate Variability, and CO2 Fertilization." Climate Research, no. 22 (2002): 73-86.

Stockton, C. W. "Current Research Progress toward Understanding Drought." In Proceedings, Drought, Water Management and Food Production, Agadir, Morocco, 1988: pp. 21-35.

Stour, L., and A. Agoumi. "Sécheresse Climatique Au Maroc Durant Les Dernières Décennies." Hydroécologie Appliquée, no. Tome 16 (2008): 215-32.

Swearingen, Will D. "Drought Hazard in Morocco." Geographical Review: 401.

Swearingen, Will D. "In Pursuit of the Granary of Rome: France's Wheat Policy in Morocco, 1915–1931."International Journal of Middle East Studies: 347-63.

Swearingen, Will D. Moroccan Mirages: Agrarian Dreams and Deceptions, 1912-1986. Princeton, N.J.: Princeton University Press, 1987.

Swearingen, Will D., and Abdellatif Bencherifa. The North African Environment at Risk. Boulder, Colo.: Westview Press, 1996.

Tableau de bord social. Rabat, Morocco: Ministère de l'Economie et des Finances, Direction des Etudes et des Prévisions Financières (DEPF), 2013.

Taheripour, Farzad and Tyner, Wallace E. "Welfare Assessment of the Renewable Fuel Standard: Economic Efficiency, Rebound Effect, and Policy Interaction in a General Equilibrium Framework". Presented at the 15th Annual Conference on Global Economic Analysis, "New Challenges for Global Trade and Sustainable Development", Geneva, Switzerland June 27-29, 2012.

Taheripour, Farzad, Thomas W. Hertel, and Wallace E. Tyner. "Implications of Biofuels Mandates for the Global Livestock Industry: A Computable General Equilibrium Analysis." Agricultural Economics 42 (2011): 325-42.

Thissen, M., 1998, “Two decades of CGE modeling; Lessons from models for Egypt”, SOM Research Report 99C02, University of Groningen, [accessed 20 April 2007] http://som.eldoc.ub.rug.nl/FILES/reports/1995-1999/themeC/1999/99C02/99c02.pdf

Thomas, D. T., J. Finlayson, A. D. Moore, and M. J. Robertson. "Profitability of Grazing Crop Stubbles May Be Overestimated by Using the Metabolisable Energy Intake from the Stubble." Animal Production Science 50 (2010): 699.

Thornton, P.k, and M. Herrero. "Integrated Crop–livestock Simulation Models for Scenario Analysis and Impact Assessment." Agricultural Systems 70 (2001): 581-602.

Thurlow, J., Zhu, T., Diao, X. "The Impact of Climate Variability and Change on Economic Growth and Poverty in Zambia." IFRPI Discussion Paper 00890, Washington, D.C.: IFPRI, 2011.

Tubiello, Francesco N., and Günther Fischer. "Reducing Climate Change Impacts on Agriculture: Global and Regional Effects of Mitigation, 2000–2080." Technological Forecasting and Social Change: 1030-056.

van Leeuwen M., Salamon P., Fellmann T., Koç A., Bölük G., Tabeau A., Esposti R., Bonfiglio A., Lobianco A., Hanrahan K. "Potential impacts on agricultural commodity markets of an EU enlargement to Turkey." European Commission, Joint Research Centre, Institute for Prospective Technological Studies, JRC (2011).

van Wijk MT, Rufino MC, Enahoro D, Parsons D, Silvestri S, Valdivia RO, Herrero M. "A review on farm household modelling with a focus on climate change adaptation and mitigation." Working Paper No. 20 (2012). CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

Ward, Patrick S. "An Economic Perspective on Risk and Vulnerability". (PhD diss., Purdue University, 2011), 103-106.

Water and Climate Change: Understanding the Risks and Making Climate-Smart Investment Decisions. Washington, D.C.: World Bank, 2009.

Water and Climate Change: Understanding the Risks and Making Climate-Smart Investment Decisions. Washington, D.C.: World Bank, 2009.

Weersink, A., Jeffrey, S., Pannell, D. "Farm-level modeling for bigger issues." Review of Agricultural Economics 24, 123–140.

White, Dale, Michael Richman, and Brent Yarnal. "Climate Regionalization and Rotation of Principal Components." International Journal of Climatology, no. 11 (1991): 1-25.

White, Jeffrey W., Gerrit Hoogenboom, Bruce A. Kimball, and Gerard W. Wall. "Methodologies for Simulating Impacts of Climate Change on Crop Production." Field Crops Research, 2011, 357-68.

Wigley, T. M. L., P. D. Jones, K. R. Briffa, and G. Smith. "Obtaining Sub-Grid-Scale Information From Coarse-Resolution General Circulation Model Output." Journal of Geophysical Research, no. 95 (1990): 1943-953.

Williams, Ann, and Will D. Swearingen. "Moroccan Mirages: Agrarian Dreams and Deceptions."International Affairs (Royal Institute of International Affairs 1944-): 365.

World Development Report 2010: Development and Climate Change. Washington, D.C.: World Bank, 2009.

Birka Wicke, Floor Van Der Hilst, Vassilis Daioglou, Martin Banse, Tim Beringer, Sarah Gerssen-Gondelach, Sanne Heijnen, Derek Karssenberg, David Laborde, Melvin Lippe, Hans Van Meijl, André Nassar, Jeff Powell, Anne Gerdien Prins, Steve N. K. Rose, Edward M. W. Smeets, Elke Stehfest, Wallace E . Tyner, Judith A. Verstegen, Hugo Valin, Detlef P. Van Vuuren, Sonia Yeh and André P.C. Faaij "Model collaboration for the improved assessment of biomass supply, demand, and impacts." GCB Bioenergy (2014), doi: 10.1111/gcbb.12176

Yarnal, Brent. Synoptic Climatology in Environmental Analysis: A Primer. London: Belhaven Press, 1993.

Zalud, Z., and M. Dubrovsky. "Modelling Climate Change Impacts on Maize Growth and Development in the Czech Republic." Theoretical and Applied Climatology, no. 72 (2002): 85-102.

Zingore S, González-Estrada E, Delve RJ, Herrero M, Dimes JP, Giller KE. "An integrated evaluation of strategies for enhancing productivity and profitability of resource constrained smallholder farms in Zimbabwe." Agricultural Systems 101 (2009): 57–68

APPENDICES

Appendix A Figures

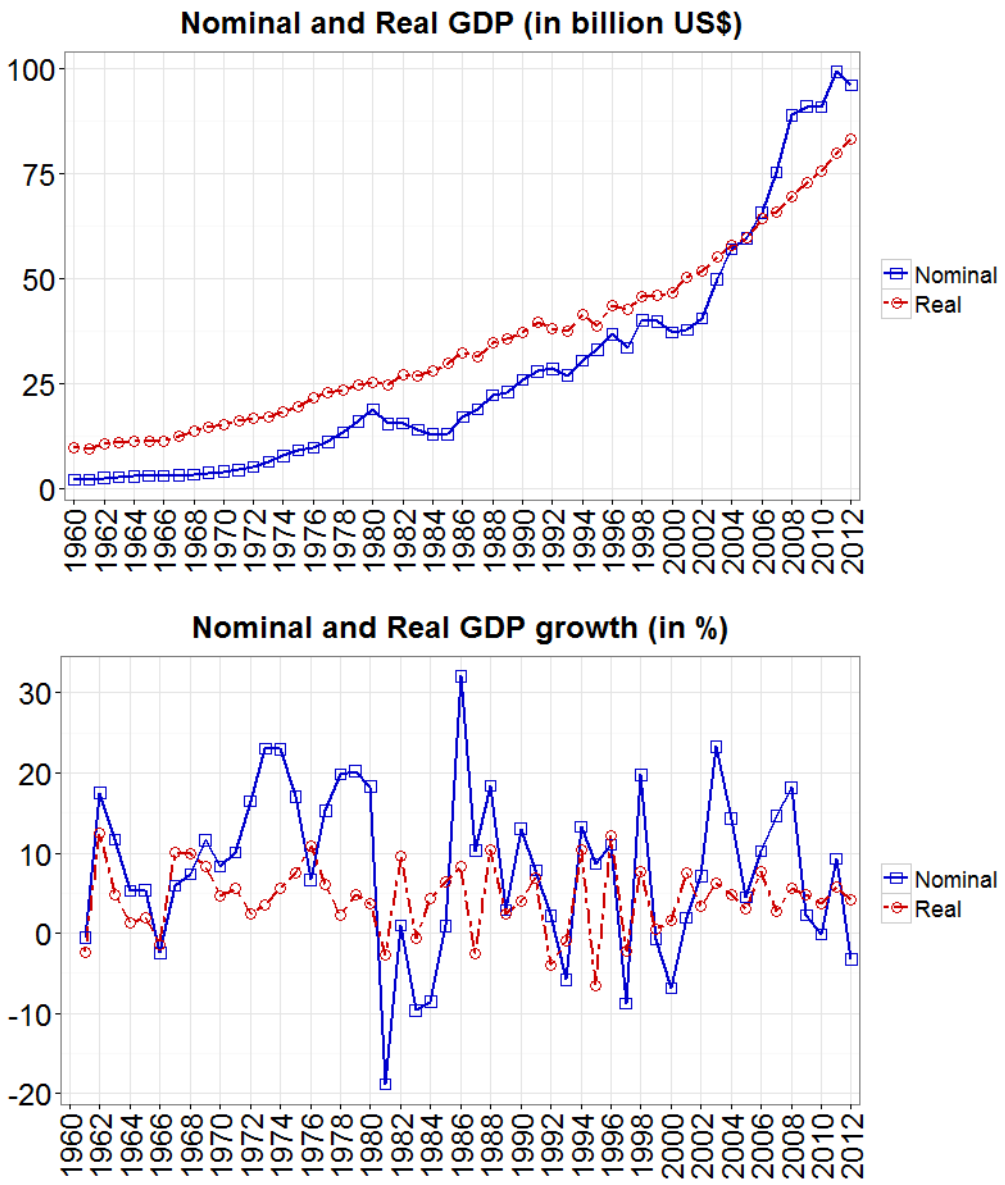

Figure A6.1: Evolution of Real and Nominal GDP and GDP Growth Rates in Morocco
Source: Author's adaptation (Data source: WDI 2013)

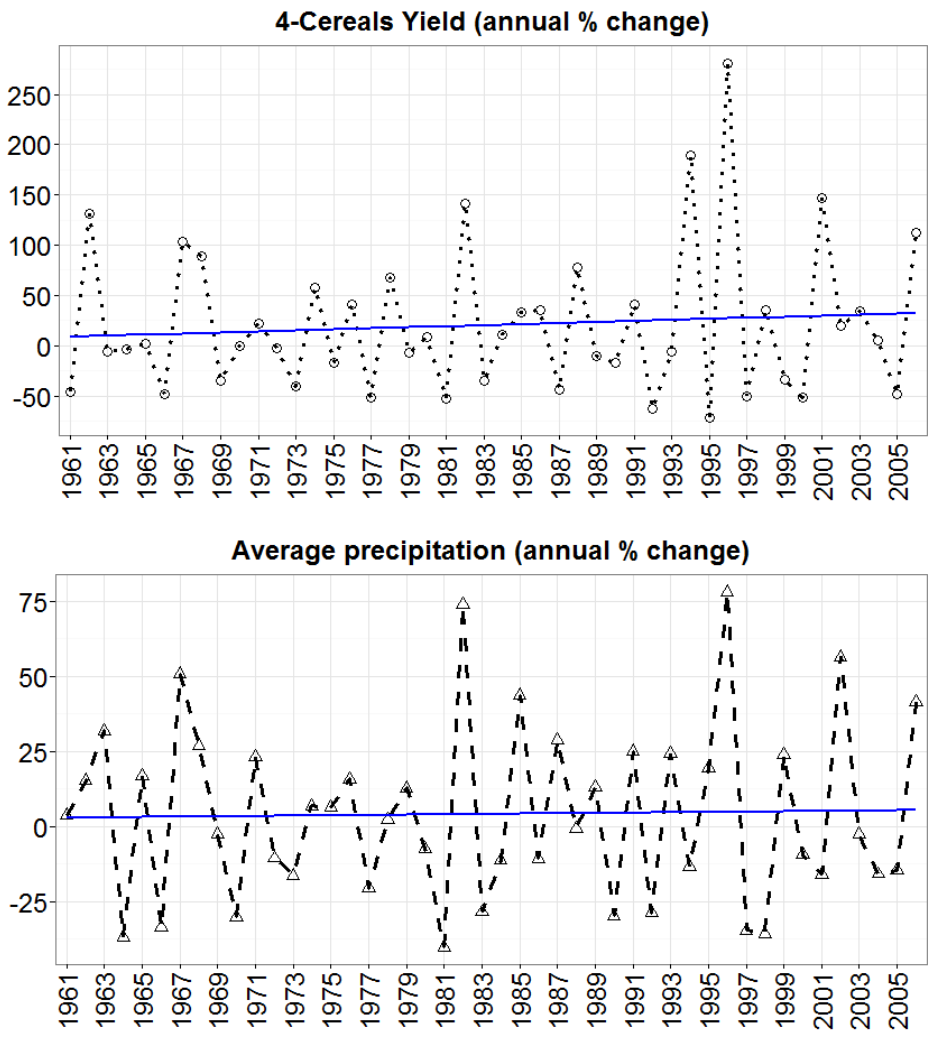

Figure A6.2 Evolution of Annual Percent Change in Average Precipitation (in mm) and Average Cereals Yields (in Qx/Ha) in Morocco

Source: Author's construction

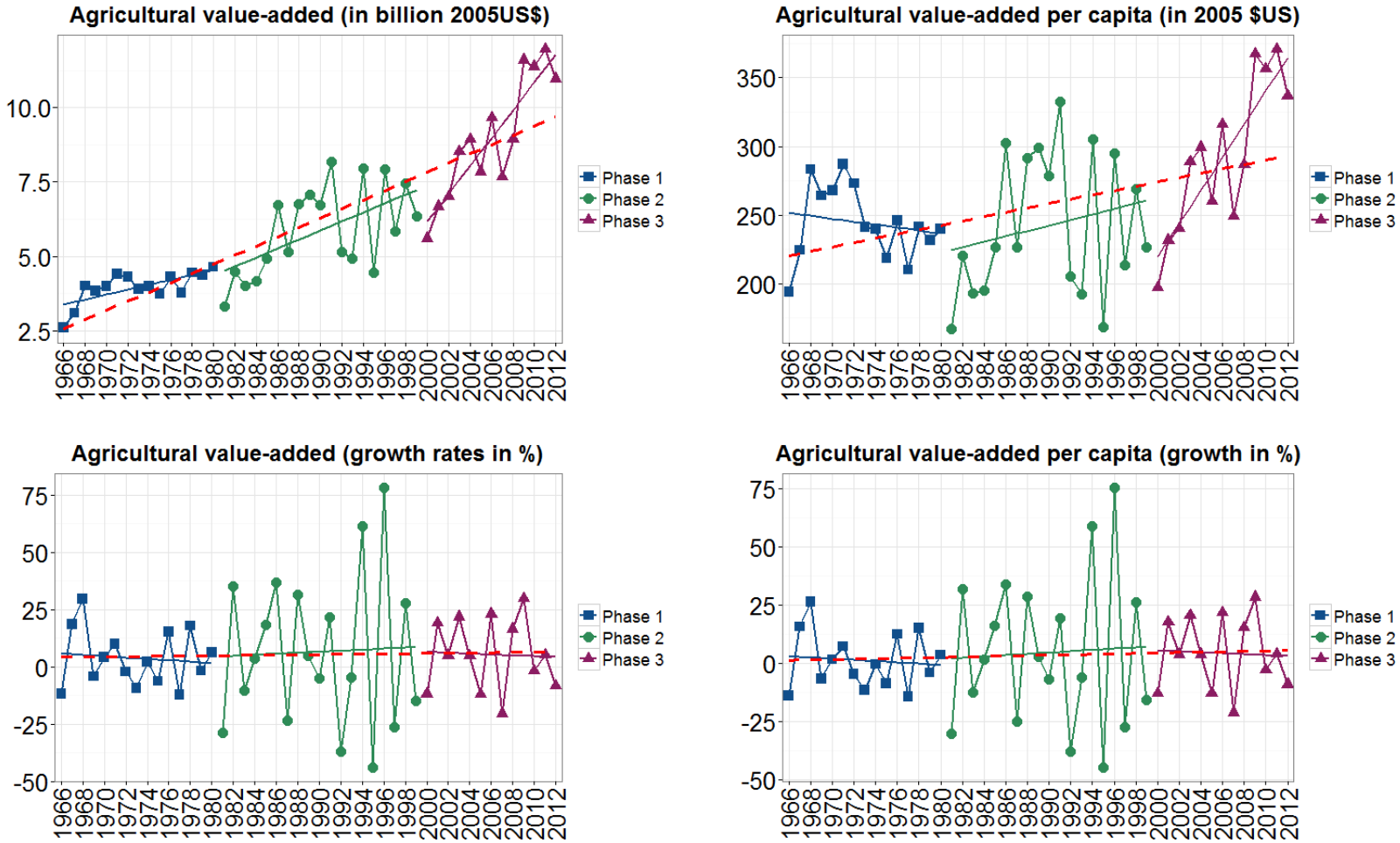

Figure A2.3: Evolution of Aggregate and Per Capita Agricultural Value-added and Agricultural Value-added Growth Rates in Morocco

Source: Author's adaptation (Data source: WDI 2013)

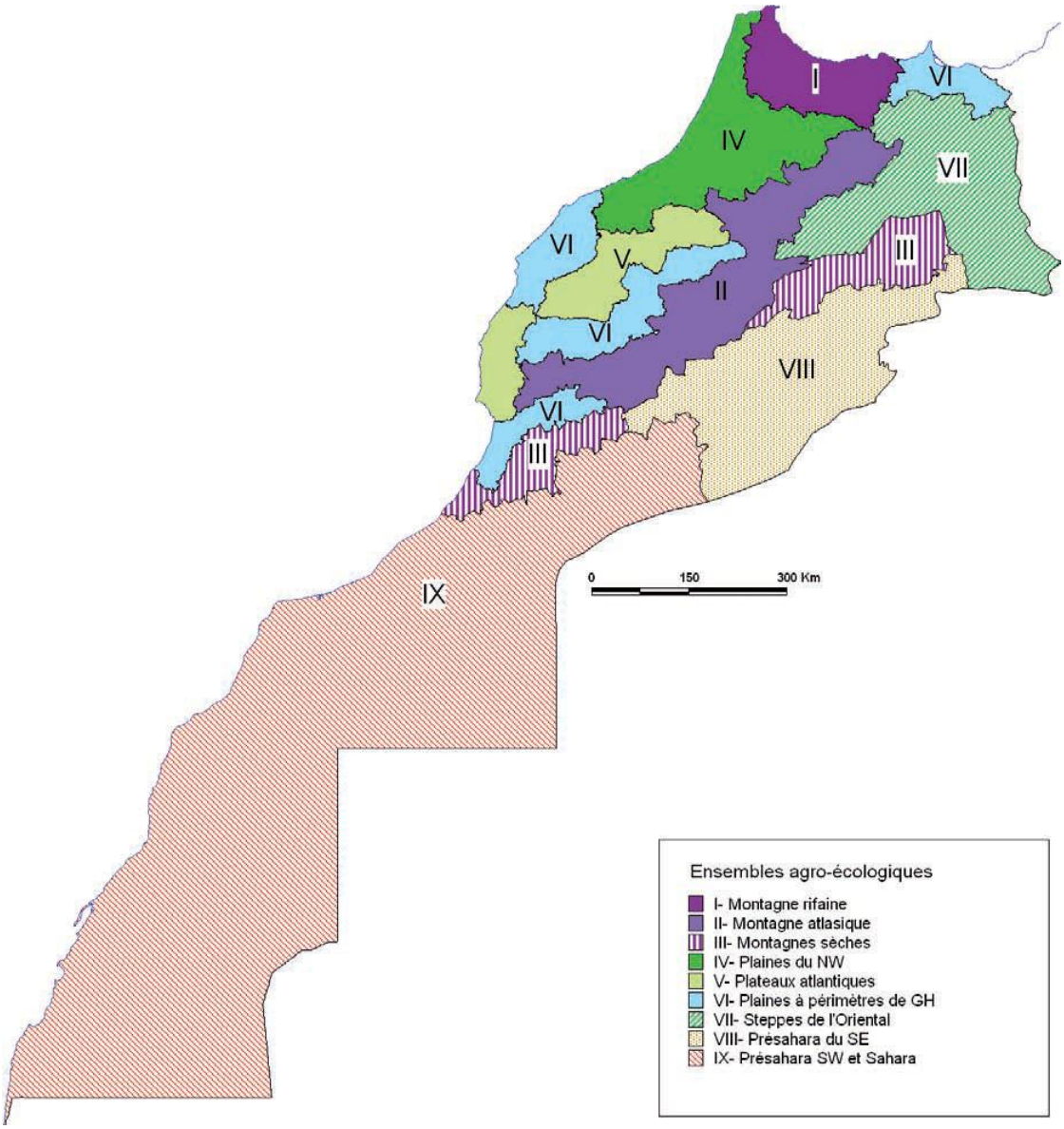

Figure A2.4: Agro-Ecological Zones (AEZ) in Morocco
(Source: CGDA 2009)

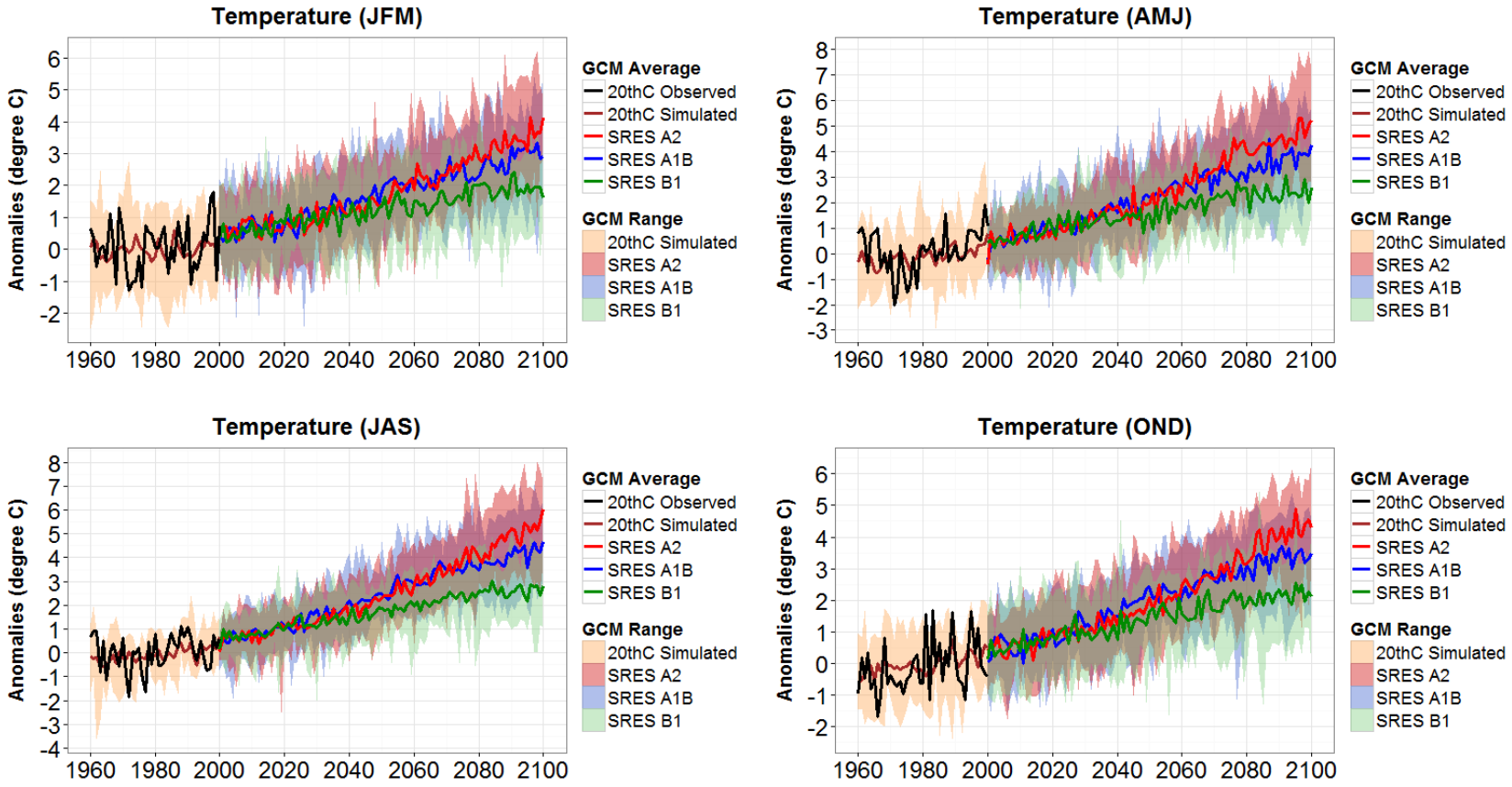

Figure A2.5a: Evolution of Observed and Simulated Projected Average Seasonal Temperatures by SRES Scenario for Morocco

Source: Author's adaptation (Data source: UNDP Climate Change Country Profiles: Morocco)
Note : Indicated values are anomalies with respect to the mean 1970-1999

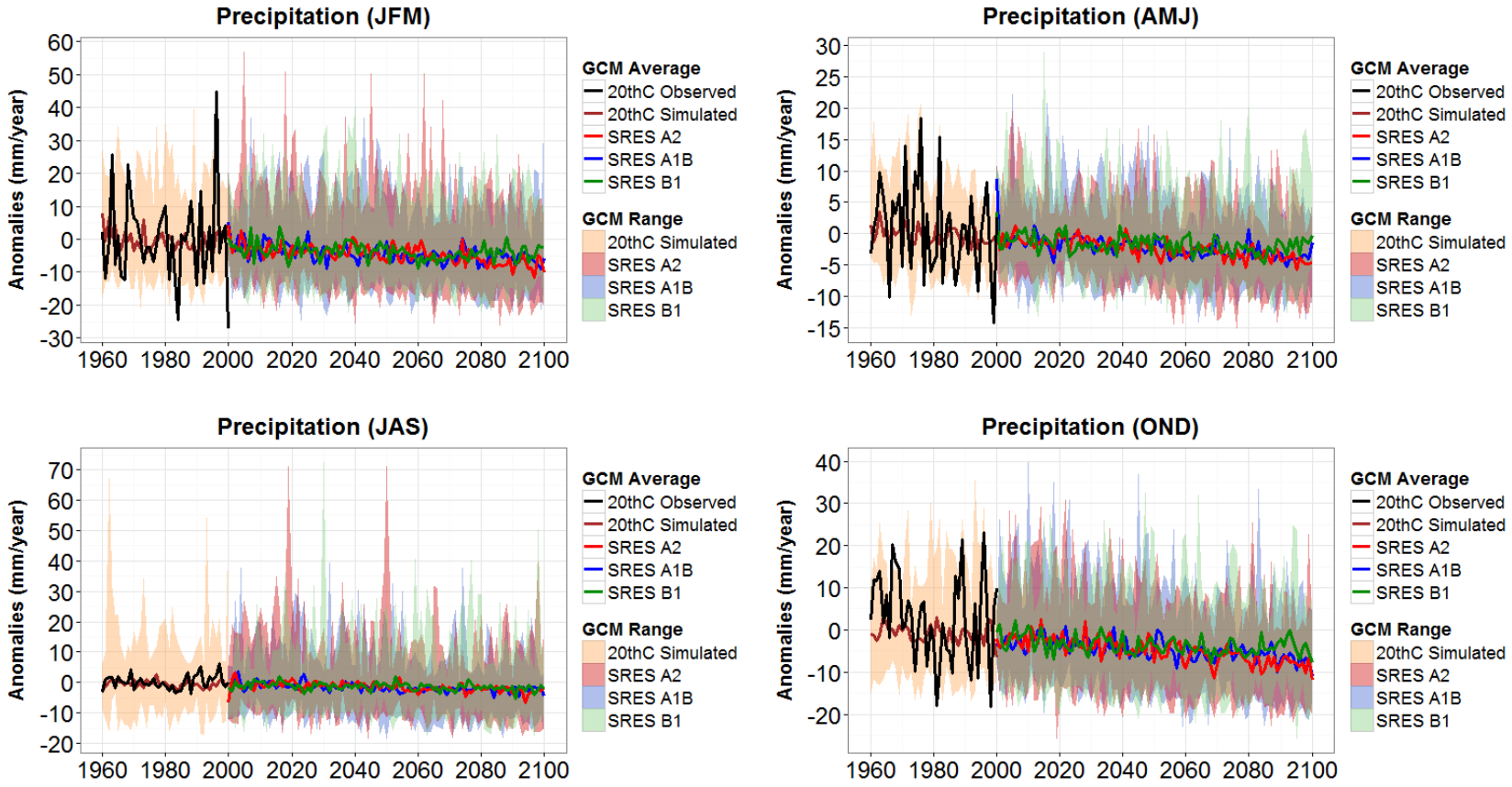

Figure A2.5b: Evolution of Observed and Simulated Projected Average Seasonal Precipitation by SRES Scenario for Morocco

Source: Author's adaptation (Data source: UNDP Climate Change Country Profiles: Morocco)
Note : Indicated values are anomalies with respect to the mean 1970-1999

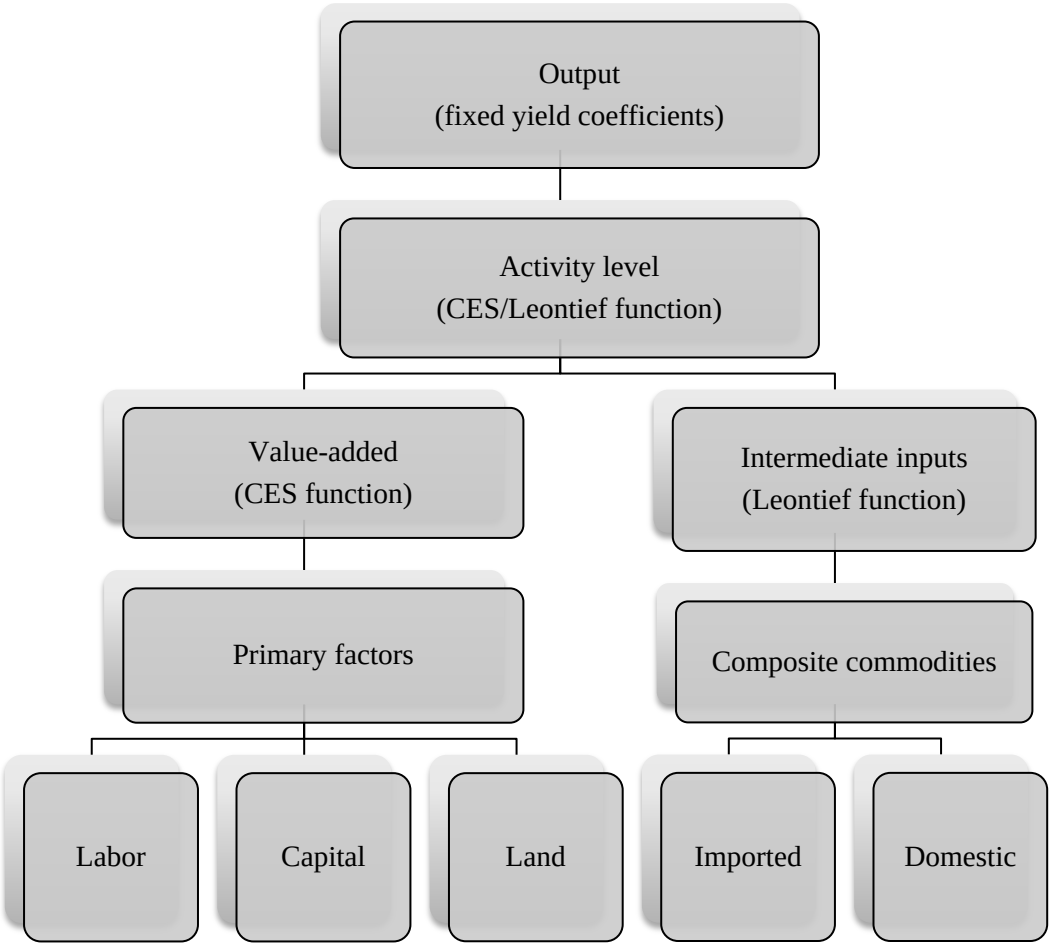

Figure A4.1: Production Technology

Source: Authors' adaptation based on Lofgren et al. (2002)

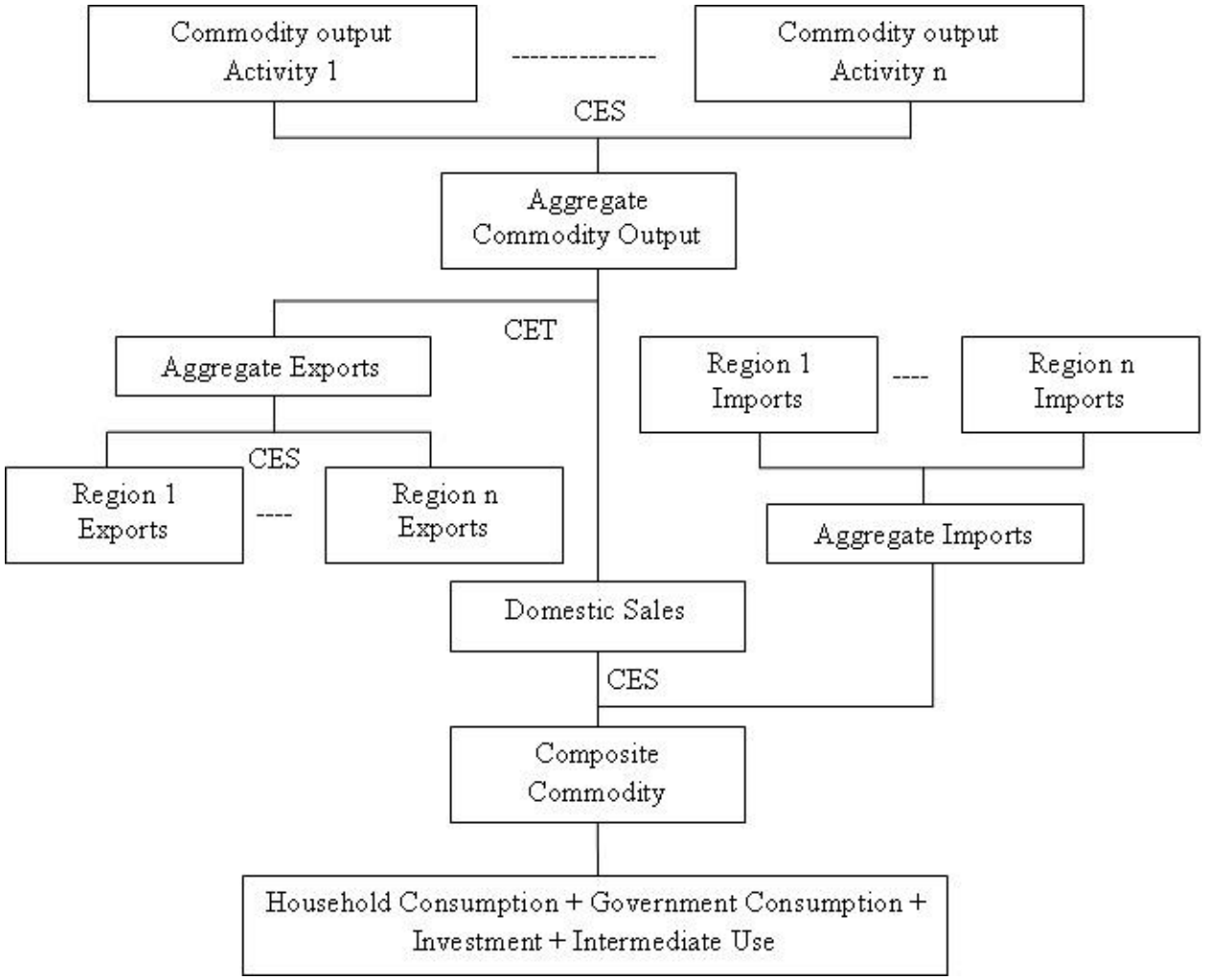

Figure A4.2: Flow of Commodity Market
Source: Author's adaptation from Lofgren et al. (2002)

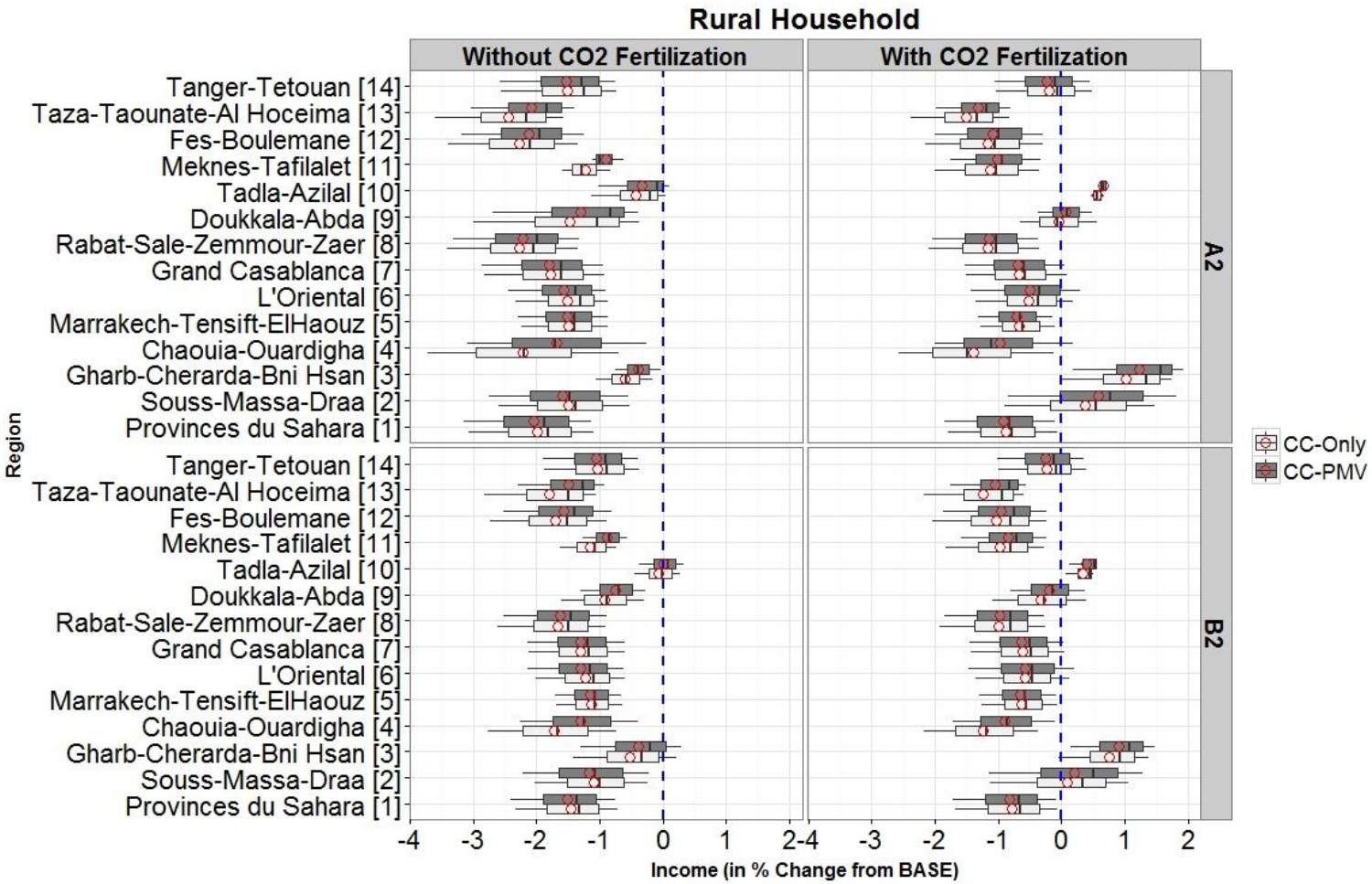

Figure A4.3a: Distribution of Climate Change Impacts on Rural Household Income - Without and With the PMV Strategy by 2050 (in % change from BASE)
Source: Simulation results

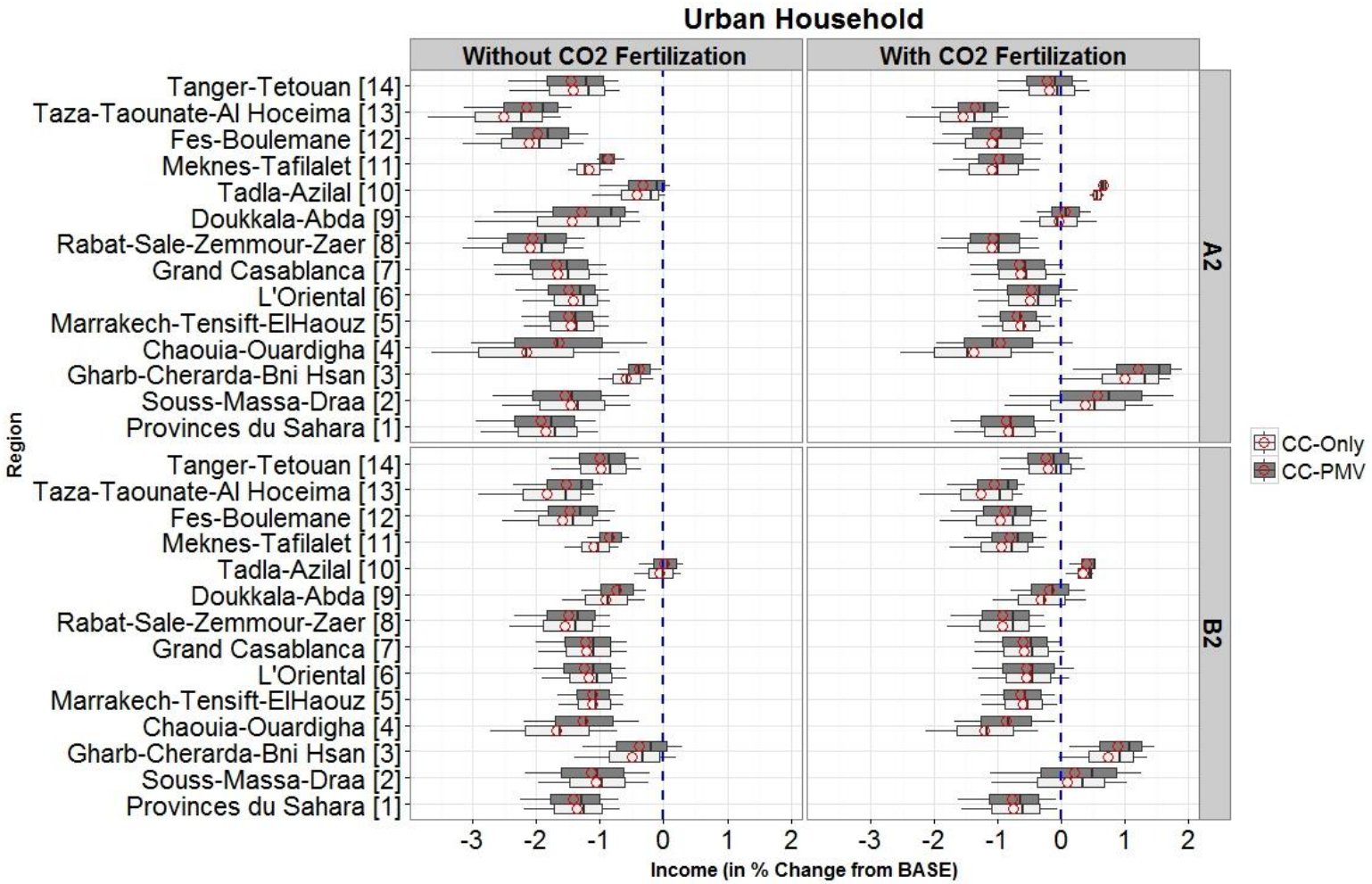

Figure A4.3b: Distribution of Climate Change Impacts on Urban Household Income - Without and With the PMV Strategy by 2050 (in % change from BASE)
Source: Simulation results

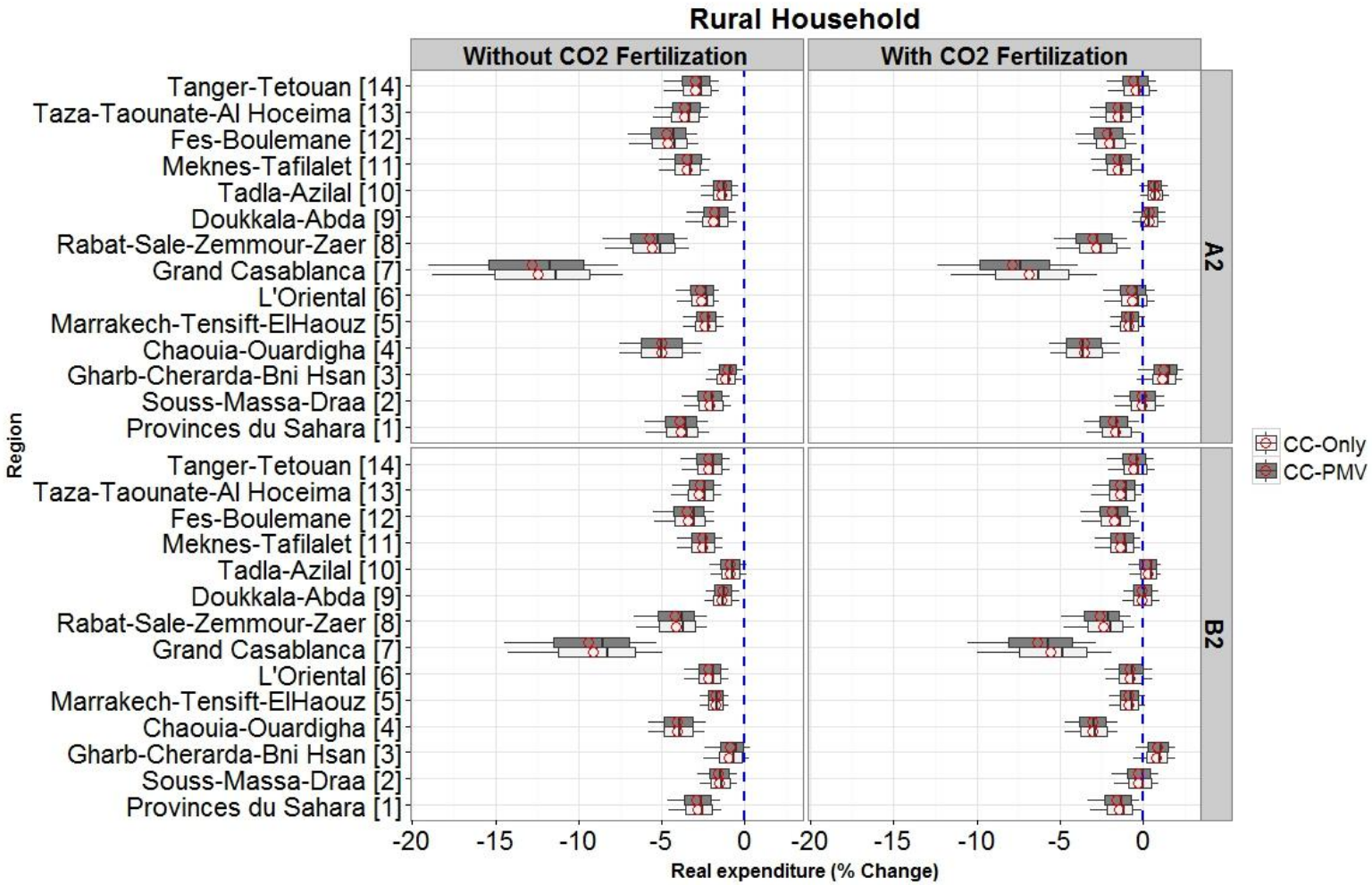

Figure A4.4a: Distribution of Climate Change Impacts on Rural Household Real Expenditures - Without and With the PMV Strategy by 2050 (in % change from BASE)
Source: Simulation results

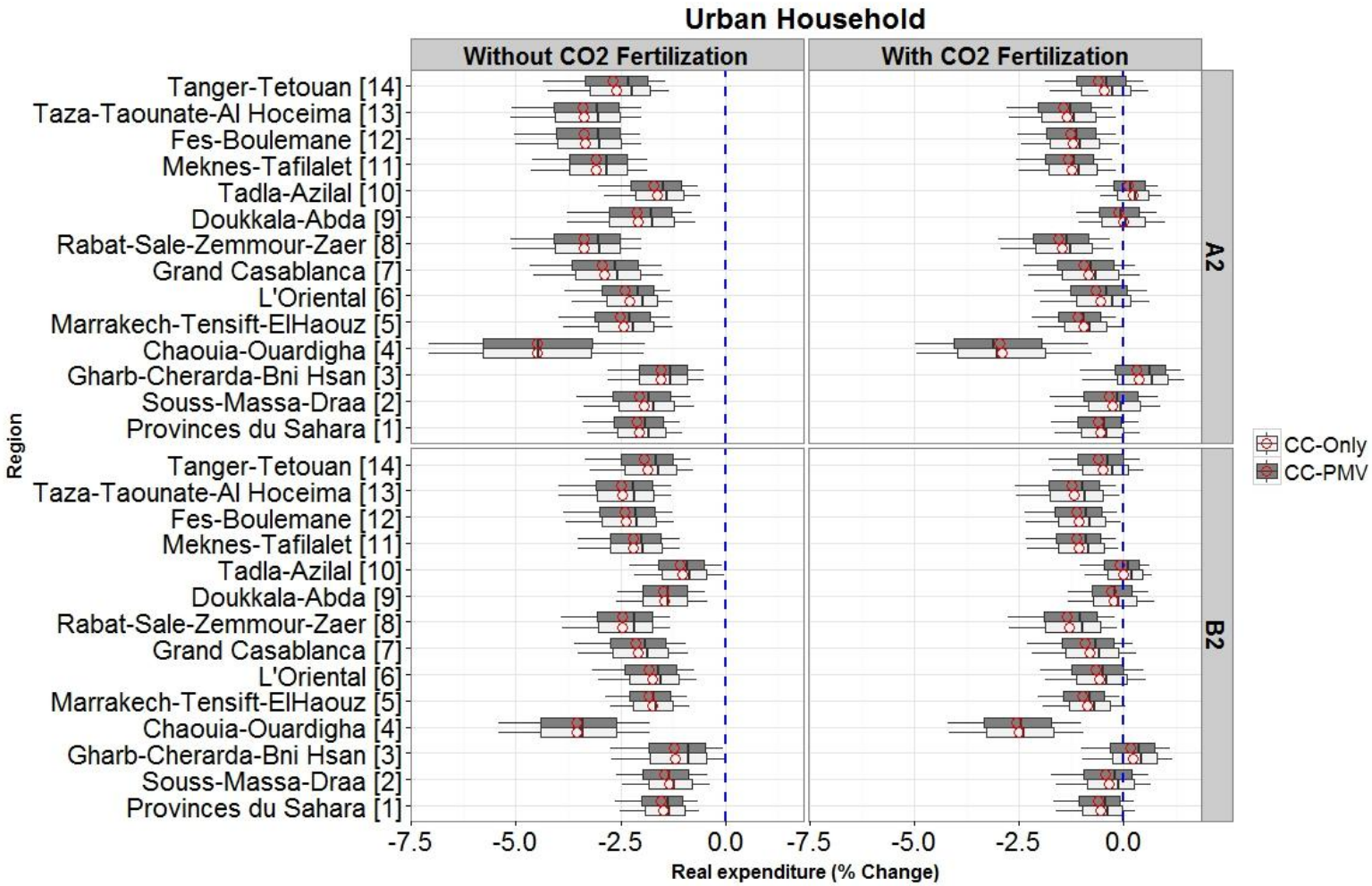

Figure A4.4b: Distribution of Climate Change Impacts on Urban Household Real Expenditures - Without and With the PMV Strategy by 2050 (in % change from BASE)
Source: Simulation results

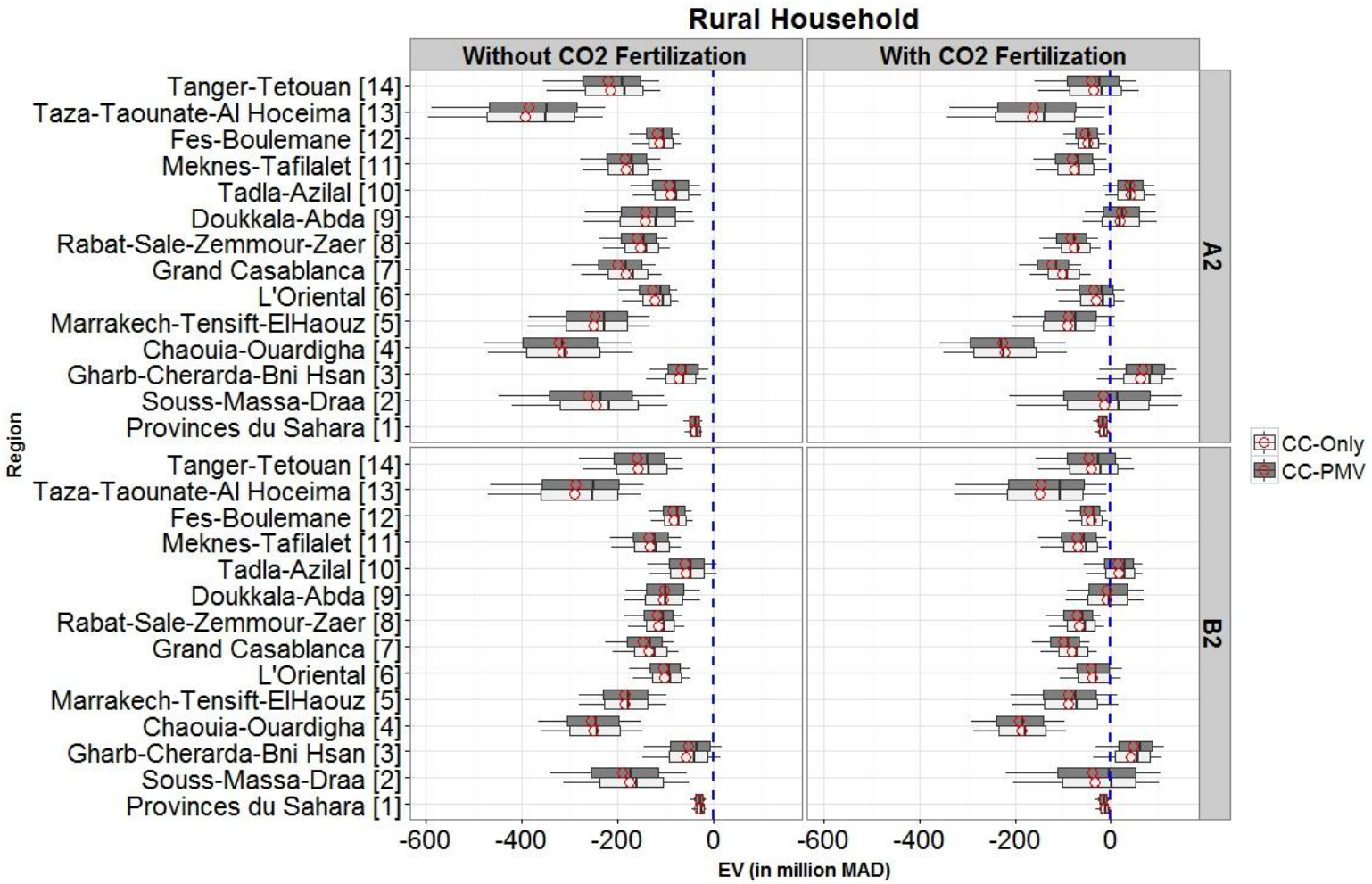

Figure A4.5a: Distribution of Climate Change Impacts on Rural Household Welfare - Without and With the PMV Strategy by 2050 (in million MAD)
Source: Simulation results

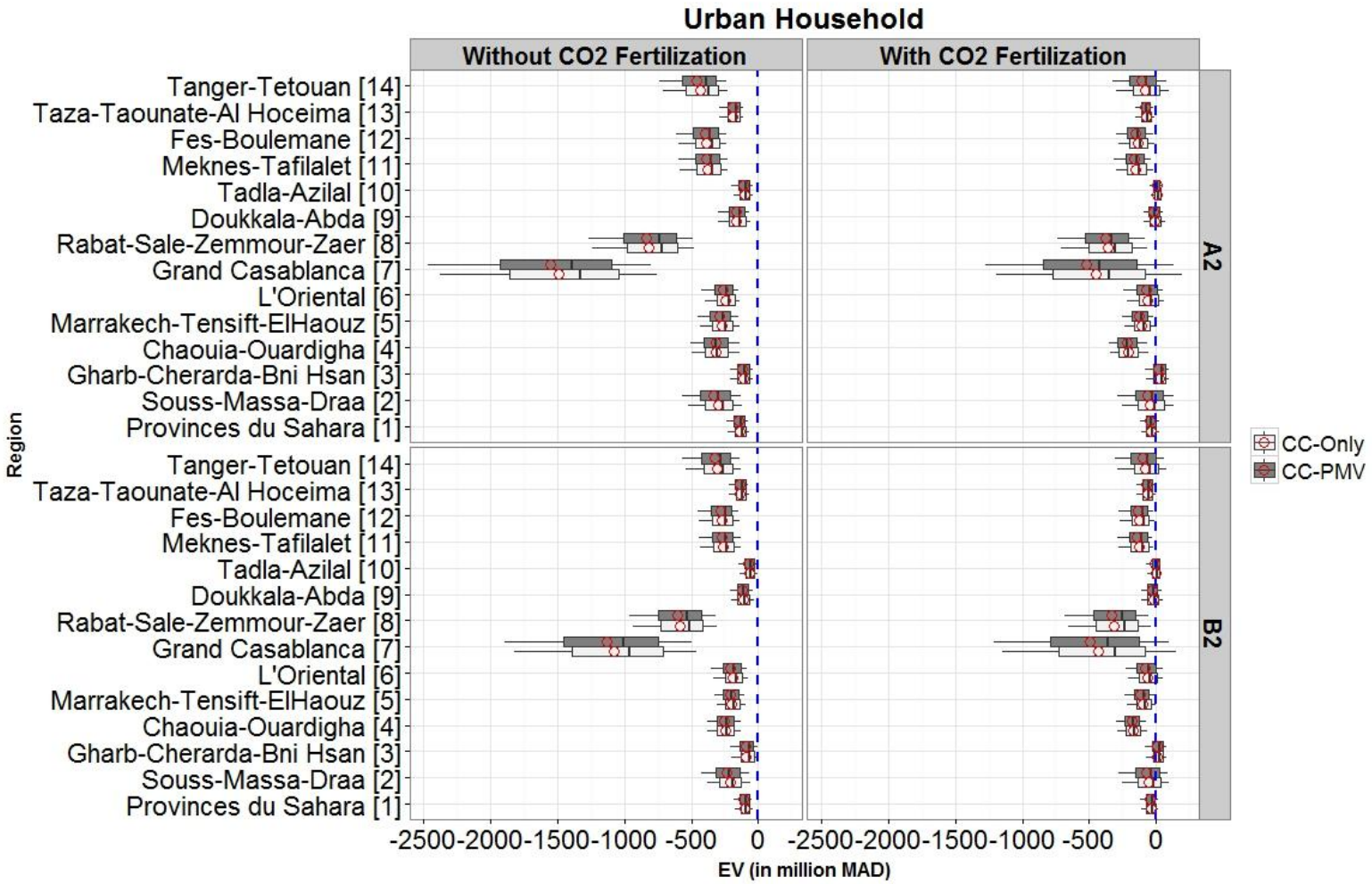

Figure A4.5b: Distribution of Climate Change Impacts on Urban Household Welfare - Without and With the PMV Strategy by 2050 (in million MAD)
Source: Simulation results

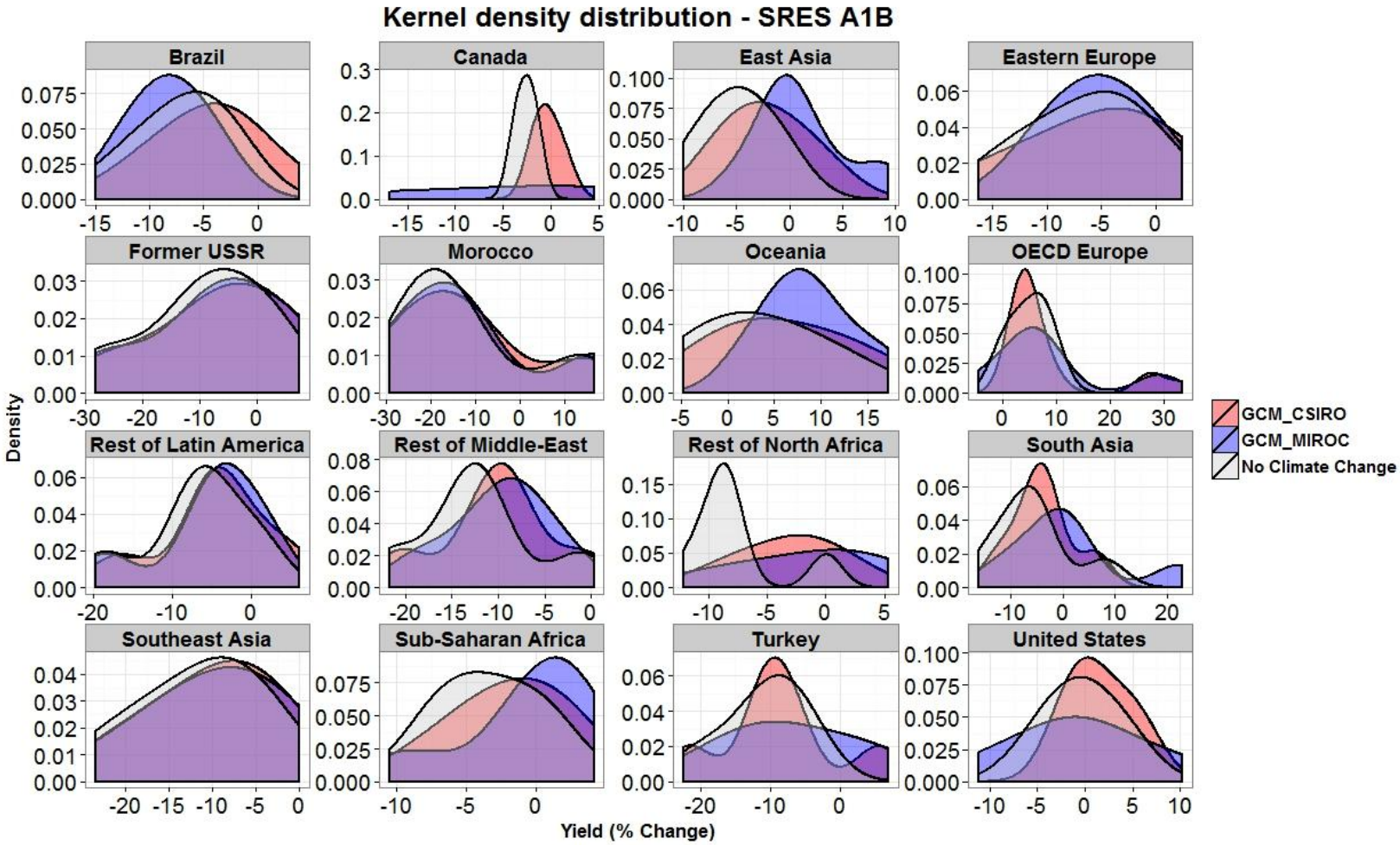

Figure A5.1a: Kernel Density Distribution across Growth Scenarios of Projected Yield Impacts by GCM for All Regions in IFPRI Data under SRES A1B

Source: Authors' adaptation (data: IFPRI Food Security CASE maps, 2010)

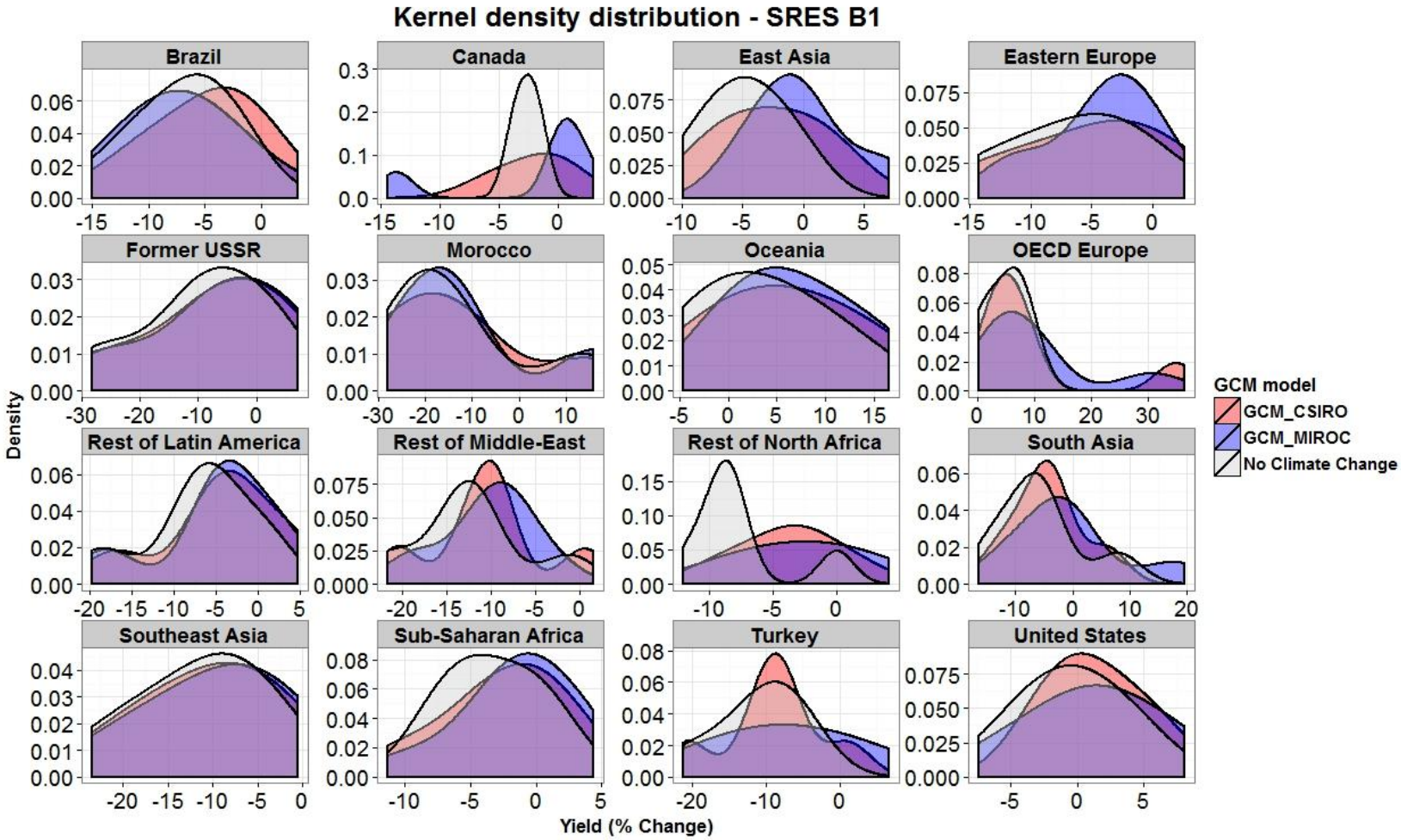

Figure A5.1b: Kernel Density Distribution across Growth Scenarios of Projected Yield Impacts by GCM for All Regions in IFPRI Data under SRES B1 by 2050

Source: Authors' adaptation (data: IFPRI Food Security CASE maps, 2010)

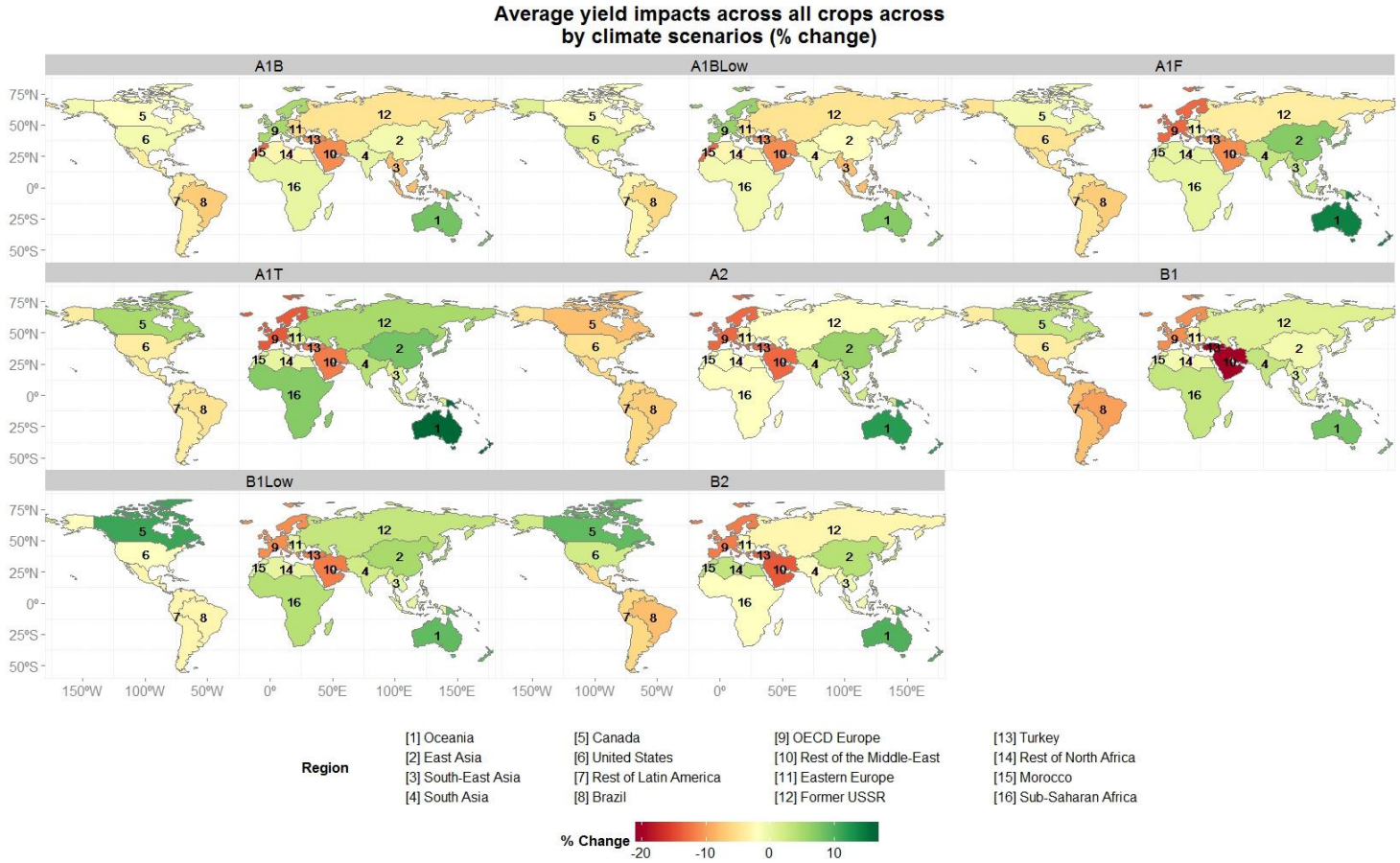

Figure A5.2: Distribution of Projected Yield Impacts across Climate Scenarios by Crop and by Region
Source: Authors' adaptation (data: IFPRI Food Security CASE maps, 2010; IMAGE 2.2, 2010

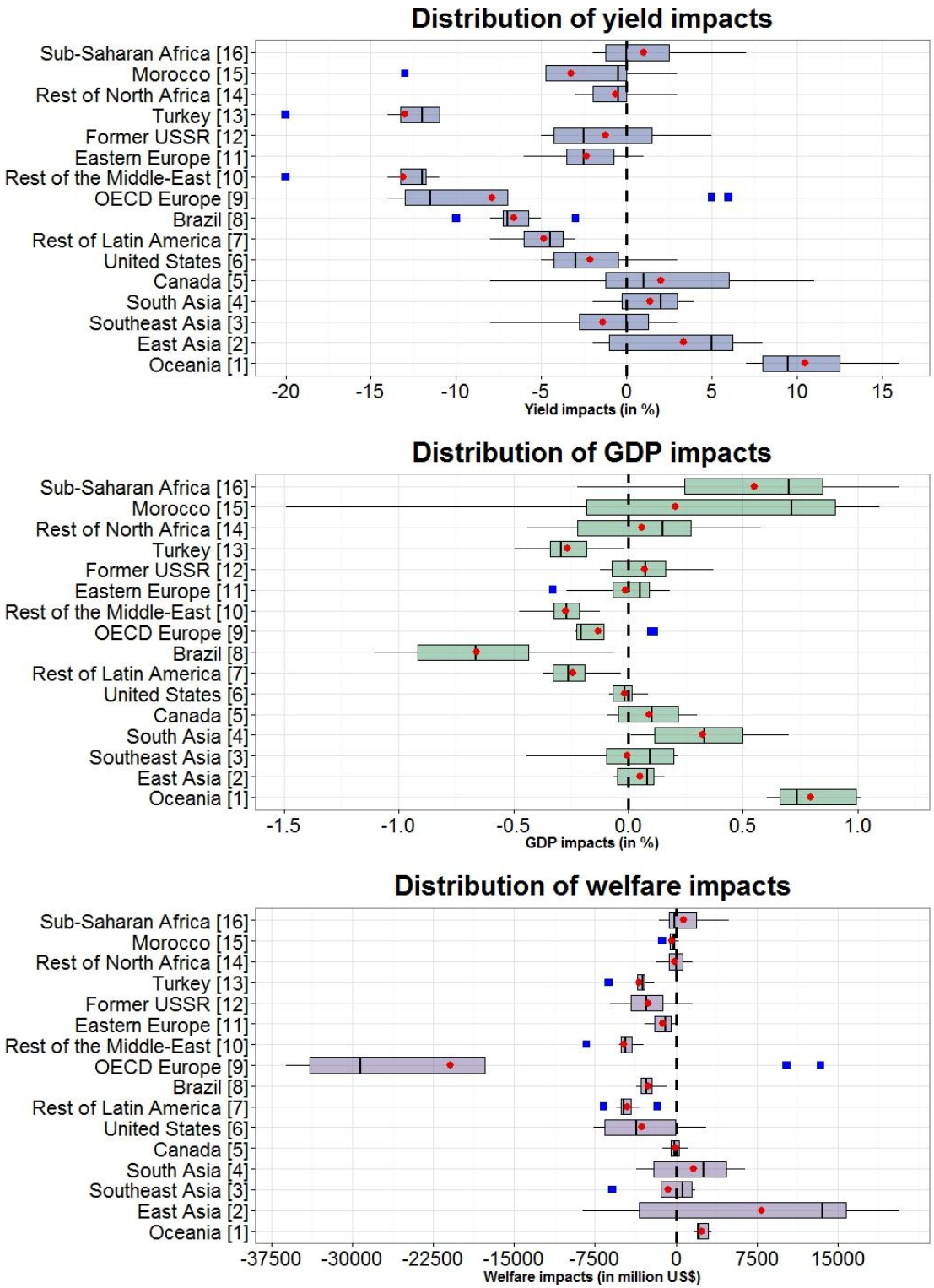

Figure A5.3: Regional Distribution of Climate-induced Projected Yield, and Impacts on Welfare and Gross Domestic Product (GDP) by 2050
Source: Simulation results

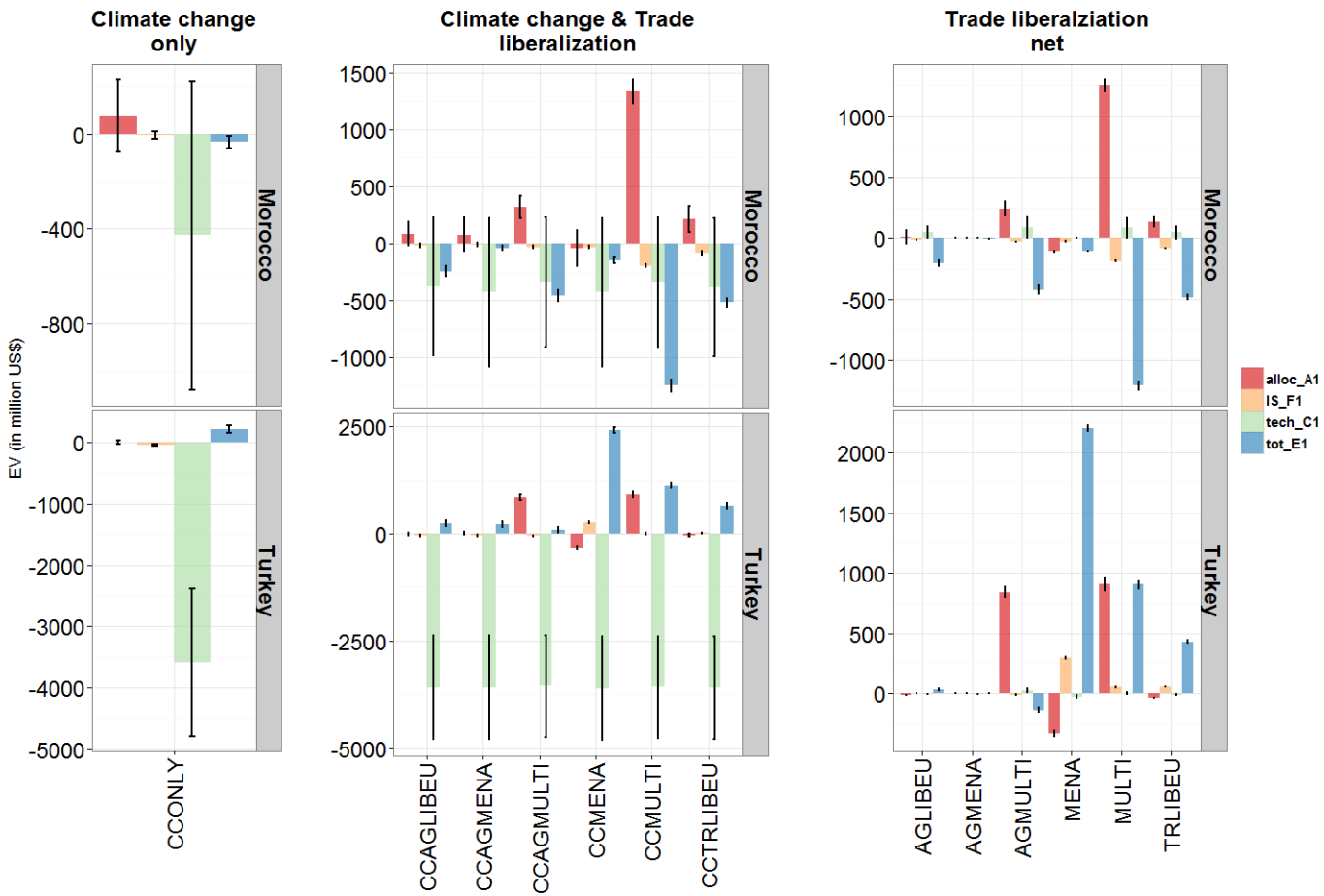

Figure A5.4: Decomposition of Aggregate Average Welfare Impacts by Effect in Morocco and Turkey by 2050
Source: Simulation results

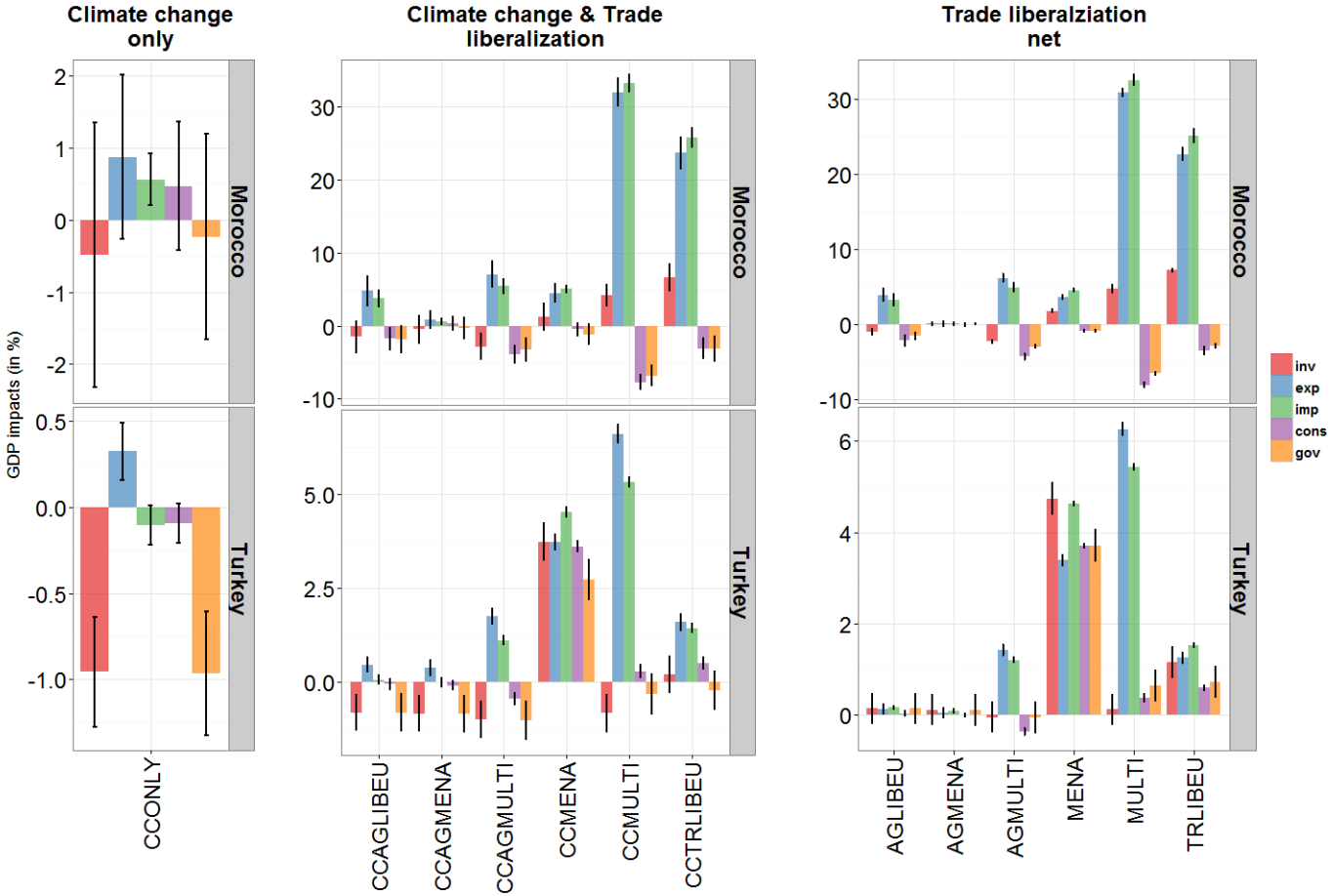

Figure A5.5: Decomposition of Gross Domestic Product (GDP) Average Impacts by Category in Morocco and Turkey by 2050
Source: Simulations results

Appendix B Tables

Table B4.1: Nomenclature of Activity Accounts in the Morocco's Social Accounting Matrix

Sectors/Activities	Description	Sectors/Activities	Description
Agriculture crops (x26)		xmeat-a	Other meat production
hdwht-a	Hard wheat	Pasture (x2)	
sfwht-a	Soft wheat	fl-a	Fallow land
barly-a	Barley	ps-a	Pasture land
xgrns-a	Other grains	Byproducts (x2)	
gnleg-a	Grain legumes	sp-a	Agricultural byproducts
sgrbt-a	Sugar beets	spfdp-a	Byproducts of agro-food industries
sgrcn-a	Sugar cane	Forestry (x1)	
xcshc-a	Other industrial crops incl oil seeds	forst-a	Forestry
tomat-a	Tomatoes	Fishery (x1)	
potat-a	Potatoes	fshry-a	Fishery
onion-a	Onions	Food processing (x10)	
melon-a	Melons	dairy-a	Dairy
wtmln-a	Watermelons	sgrrw-a	Raw sugar
xvegt-a	Other vegetables	sgrrf-a	Refined sugar
xvgin-a	Other industrial vegetables	milhw-a	Hard wheat mill
alfaf-a	Alfafa	milsw-a	Soft wheat mill
forag-a	Forage crops	oilrw-a	Raw oil
olive-a	Olives	oilrf-a	Refined oil
agrms-a	Clementines and small citrus	olvwh-a	Whole olives
xagrm-a	Other citrus	olvol-a	Olive oil
grape-a	Grapes	xfdpr-a	Other food processing
almnd-a	Almonds	Industry and manufacturing (x4)	
apple-a	Apples	chmcl-a	Chemical industries
dates-a	Dates	refol-a	Refined petroleum

Table B4.1: Nomenclature of Activity Accounts in the Morocco's Social Accounting Matrix (continued)

Sectors/Activities	Description	Sectors/Activities	Description
xfrut-a	Other fruit	wtrel-a	Water and electricity utilities
xcrop-a	Other crops nes	xinds-a	Other industries
Livestocks (x4)		Services (x2)	
bovin-a	Bovine meat	srvpr-a	Private services
ovine-a	Sheep and other red meats	srvpb-a	Public services
avine-a	Poultry		

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.2: Nomenclature of Commodity Accounts in the Morocco's Social Accounting Matrix

Commodities	Description	Commodities	Description
Agriculture, crops (x26)		eggrw-c	Eggs
hdwht-c	Hard wheat	xmeat-c	Other animal products
sfwht-c	Soft wheat	Pasture (x2)	
barly-c	Barley	fl-c	Fallow land
xgrns-c	Other grains	ps-c	Pasture land
gnleg-c	Grain legumes	Byproducts (x2)	
sgrbt-c	Sugar beets	sp-c	Agricultural byproducts
sgrcn-c	Sugar cane	spfdp-c	Byproducts of agro-food industries
xcshc-c	Other industrial crops incl oil seeds	Forestry (x1)	
tomat-c	Tomatoes	forst-c	Forestry
potat-c	Potatoes	Fishery (x1)	
onion-c	Onions	fshry-c	Fishery
melon-c	Melons	Food processing (x10)	
wtmln-c	Watermelons	dairy-c	Dairy
xvegt-c	Other vegetables	sgrrw-c	Raw sugar
xvgin-c	Other industrial vegetables	sgrrf-c	Refined sugar
alfa-c	Alfafa	milhw-c	Hard wheat mill
forag-c	Forage crops	milsw-c	Soft wheat mill
olive-c	Olives	oilrw-c	Raw oil
agrms-c	Clementines and small citrus	oilrf-c	Refined oil
xagrm-c	Other citrus	olvwh-c	Whole olives
grape-c	Grapes	olvol-c	Olive oil
almnd-c	Almonds	xfdpr-c	Other food processing
apple-c	Apples	Industry and manufacturing (x4)	
dates-c	Dates	chmcl-c	Chemical industries
xfrut-c	Other fruit	refol-c	Refined petroleum
xcrop-c	Other crops nes	wtrel-c	Water and electricity utilities

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.2: Nomenclature of Commodity Accounts in the Morocco's Social Accounting Matrix (continued)

Commodities	Description	Commodities	Description
Livestocks (x5)		xinds-c	Other industries
meatr-c	Red meats	Services (x2)	
meatw-c	White meats	srvpr-c	Private services
mlkrw-c	Raw milk	srvpb-c	Public services

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.3: Nomenclature of Institutional Accounts in the Morocco's Social Accounting Matrix

Institution	Description	Institution	Description
vaadd	Value added	rhdc1	Rural households first decile
txsub	Taxes and subsidies	rhdc2	Rural households second decile
govnt	Government	rhdc3	Rural households third decile
uhdc1	Urban households first decile	rhdc4	Rural households fourth decile
uhdc2	Urban households second decile	rhdc5	Rural households fifth decile
uhdc3	Urban households third decile	invst	Investment savings account
uhdc4	Urban households fourth decile	rowld	Rest of the world
uhdc5	Urban households fifth decile		

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.4: Updated Nomenclature of Activity Accounts for the 2003 Morocco's Social Accounting Matrix

Sectors/Activities	Description	Sectors/Activities	Description
Agriculture, crops (x11)		Fishery (x1)	
hdwht-a	Hard wheat	fshry-a	Fishery
sfwht-a	Soft wheat	Food processing (x7)	
barly-a	Barley	dairy-a	Dairy
tomat-a	Tomatoes	milhw-a	Hard wheat mill
xvegts-a	Other vegetables	milsw-a	Soft wheat mill
xvgin-a	Other industrial vegetables	oilpr-a	Processed oil
forags-a	Forage crops	olvwh-a	Whole olives
olive-a	Olives	olvol-a	Olive oil
agrms-a	Citrus	xfdpr-a	Other food processing
xfruts-a	Other fruit	Industry and manufacturing (x4)	
xcrops-a	Other crops nes	chmcl-a	Chemical industries
Livestocks (x4)		refol-a	Refined petroleum
bovin-a	Cattle etc.	wtrel-a	Water and electricity utilities
ovine-a	Sheep	xinds-a	Other industries
avine-a	Poultry	Services (x2)	
xmeat-a	Other animal products	srvpr-a	Private services
Forestry (x1)		srvpb-a	Public services
forst-a	Forestry		

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.5: Updated Nomenclature of Commodity Accounts for the 2003 Morocco's Social Accounting Matrix

Commodity account	Description	Commodity account	Description
Agriculture, crops (x11)		Fishery (x1)	
hdwht-c	Hard wheat	fshry-c	Fishery
sfwht-c	Soft wheat	Food processing (x7)	
barly-c	Barley	dairy-c	Dairy
tomat-c	Tomatoes	milhw-c	Hard wheat mill
xvegts-c	Other vegetables	milsw-c	Soft wheat mill
xvgin-c	Other industrial vegetables	oilpr-c	Processed oil
forags-c	Forage crops	olvwh-c	Whole olives
olive-c	Olives	olvol-c	Olive oil
agrms-c	Citrus	xfdpr-c	Other food processing
xfruts-c	Other fruit	Industry and manufacturing (x4)	
xcrops-c	Other crops nes	chmcl-c	Chemical industries
Livestocks (x4)		refol-c	Refined petroleum
meatrbov-c	Cattle etc	wtrel-c	Water and electricity utilities
meatrov-c	Sheep	xinds-c	Other industries
meatw-c	Poultry	Services (x2)	
xmeat-c	Other animal products	srvpr-c	Private services
Forestry (x1)		srvpb-c	Public services
forst-c	Forestry		

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.6: Updated Nomenclature of Institutional Accounts for the 2003 Morocco's Social Accounting Matrix

Institution	Description	Institution	Description
Value-added accounts		comtax	Commodity tax
flab	Labour	imptax	Tariff
fcap	Capital	instax	Institutional tax
flandfl	Fallow land	factax	Factor Taxes
flandps	Pasture land	Government account	
flandir	Irriagted land	gov	Government
flandrf	Rainfed land	Savings-Investment	
Households account		s-i	saving-investment
uh	Urban household	Rest of the world	
rh	Rural household	row	rest of the world
Tax accounts			
actax	Activity tax		

Source: Authors' adaptation based on data from Doukkali's SAM (2003)

Table B4.7: Data Sources for Regionalization Shares of the Morocco 2003 SAM Accounts

Sectors/Activities	Description	Sources for regional shares
Agriculture, crops (x11)		
hdwht-a	Hard wheat	For all crop productions, disaggregation at the administrative regional level was done based on the production statistics in the PV of Agriculture for the agricultural campaign 2002-2003
sfwht-a	Soft wheat	
barly-a	Barley	
tomat-a	Tomatoes	
xvegts-a	Other vegetables	
xvgin-a	Other industrial vegetables	
forags-a	Forage crops	
olive-a	Olives	
agrms-a	Citrus	
xfruts-a	Other fruit	
xcrops-a	Other crops nes	
Livestocks (x4)		
bovin-a	Cattle etc.	For ‘bovin-a’ and ‘ovine-a’ activities, the regionalization was based on data on livestock headcount of cattle and sheep for 2004 (source: HCP, 2005, ‘Le Maroc des regions ‘); For ‘avine-a’ activities, we regionalized the data based on regional statistics of poultry meat production for 2005; For ‘xmeat-a’, we have adopted a regionalization based on the average regional shares for cattle and sheep for 2004 given no availability of data
ovine-a	Sheep	
avine-a	Poultry	
xmeat-a	Other animal products	
Forestry (x1)		
forst-a	Forestry	We used regional data on forest cover as provided in the “Atlas de l’Agriculture 2008”. The data pertains to the General Agricultural Survey of 1996.

Source: Author's construction

Table B4.7: Data sources for Regionalization Shares of the Morocco 2003 SAM Accounts (continued)

Sectors/Activities	Description	Sources for regional shares
Fishery (x1)		
fshry-a	Fishery	We used statistics of value of catchment at the regional level. The data was obtained from the Statistical Report of the Office National des Peches, 2003.
Food processing (x8)		
dairy-a	Dairy	We used data on milk production available at the regional level (ADA, 2005).
milhw-a	Hard wheat mill	For ‘milhw-a’ and ‘milsw-a’, we used data at the regional level pertaining to processing capacity of hard wheat and soft wheat (ONICL, 2010).
milsw-a	Soft wheat mill	
oilpr-a	Processed oil	We used data pertaining to food processing industry’s production level in 2003 (in millions Dhs) at the regional level to approximate regionalization shares (HCP, 2010).
olvwh-a	Whole olives	We use the same shares as for olive crops based on the assumption that processing units are located within the perimeters producing sugar beet and sugar cane.
olvol-a	Olive oil	
xfdpr-a	Other food processing	We used data pertaining to food processing industry’s production level in 2003 (in millions Dhs) at the regional level to approximate regionalization shares (HCP, 2010).

Source: Author's construction

Table B4.7: Data Sources for Regionalization Shares of the Morocco 2003 SAM Accounts (continued)

Sectors/Activities	Description	Sources for regional shares
Industry and manufacturing (x4)		
chmcl-a	Chemical industries	Data on regional production (in million Dhs) for 2003 was obtained from the PDF file 'Maroc des Regions2005'.
refol-a	Refined petroleum	For the Petroleum activity, Morocco has two refineries which supply the entirety of its refining capacity and for which data was obtained from the PDF file 'Maroc des Regions2005'
wtrel-a	Water and electricity utilities	The regionalization of ‘wtrel-a’ was based on regional production statistics of municipal water (in m3) and net electricity production (in million KWh) for 2003 (HCP, 2010).
xinds-a	Other industries	The regionalization shares for ‘xinds-a’ approximated by regional data of production level (in million Dhs) for textile and leather industries, mechanical and metal industries, and electronic industries 2003 (HCP, 2010).
Services (x2)		
srvpr-a	Private services	For the service sectors, regionalization was based on regional employment data in the sector for 2003
srvpb-a	Public services	

Source: Author's construction

Table B4.8: Regional Government Expenditures

Regions	Government expenditure (in MAD)			Government expenditure (in %share)		
	Hardware and other expenditures	Investment	Total	Hardware and other expenditures	Investment	Total
Oued Ed-Dahab-Lagouira/Laâyoune-Boujdour-Sakia El Hamra/Guelmim-Es-Semara	209,387,920	573,638,039	783,025,959	3.2%	5.4%	4.6%
Souss-Massa-Draâ	527,608,934	1,003,421,345	1,531,030,279	8.1%	9.5%	9.0%
Gharb-Chrarda-Beni Hsen	236,196,871	565,168,054	801,364,925	3.6%	5.4%	4.7%
Chaouia-Ourdigha	261,425,098	294,868,165	556,293,263	4.0%	2.8%	3.3%
Marrakech-Tensift-Al Haouz	693,561,283	1,299,201,169	1,992,762,452	10.7%	12.3%	11.7%
Oriental	392,233,403	788,608,019	1,180,841,422	6.0%	7.5%	6.9%
Grand Casablanca	824,573,643	438,380,715	1,262,954,358	12.7%	4.2%	7.4%
Rabat-Salé-Zemmour-Zaër	1,158,218,163	950,942,561	2,109,160,724	17.8%	9.0%	12.4%
Doukala-Abda	259,538,476	709,962,303	969,500,779	4.0%	6.7%	5.7%
Tadla-Azilal	247,688,904	321,333,842	569,022,746	3.8%	3.0%	3.3%
Meknès-Tafilalet	426,165,037	913,759,927	1,339,924,964	6.6%	8.7%	7.9%
Fès-Boulmane	607,317,063	617,345,469	1,224,662,532	9.3%	5.8%	7.2%
Taza-Al Hoceima-Taounate	260,200,560	400,314,721	660,515,281	4.0%	3.8%	3.9%
Tanger-Tetouan	393,249,401	1,679,266,686	2,072,516,087	6.1%	15.9%	12.2%
Total	6,497,364,756	10,556,211,015	17,053,575,771	100.0%	100.0%	100.0%

Source: Author's adaptation (Data source: Ministry of Economy and Finance (MEF), 2010)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Provinces du Sahara [1]	Cereals sector (incl. seeds)		1		421	421
	Citrus sector					
	Olive oil sector (incl. olives)	1		10		10
	Vegetables and Fruits sector	12		1,541		1,541
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	1	4	1	408	409
	Crop sectors total	**14**	**5**	**1,552**	**829**	**2,381**
	Dairy sector		8		431	431
	Red meat sector	4	7	670	1,504	2,174
	White meat sector (incl. eggs)	11	1	262	22	284
	Other livestock (incl. apiculture, cuniculture, etc.)		1		48	48
	Livestock sectors total	**15**	**17**	**932**	**2,005**	**2,937**
	Transversal actions total					**7**
	Aggreagte total	**29**	**22**	**2,484**	**2,834**	**5,325**
Souss-Massa-Draa [2]	Cereals sector (incl. seeds)	1		101		101
	Citrus sector	4		1,302		1,302
	Olive oil sector (incl. olives)		12		264	264
	Vegetables and Fruits sector	3	8	2,206	259	2,465
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	1	19	27	888	915
	Crop sectors total	**9**	**39**	**3,636**	**1,411**	**5,047**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Souss-Massa-Draa [2]	Dairy sector	2	5	797	32	829
	Red meat sector	9	4	376	64	440
	White meat sector (incl. eggs)	4	2	46	5	51
	Other livestock (incl. apiculture, cuniculture, etc.)		6		30	30
	Livestock sectors total	**15**	**17**	**1,219**	**131**	**1,350**
	Transversal actions total					
	Aggreagte total	**24**	**56**	**4,855**	**1,542**	**6,397**
Gharb-Cherarda-Bni Hsan [3]	Cereals sector (incl. seeds)	11		1,270		1,270
	Citrus sector	15		2,884		2,884
	Olive oil sector (incl. olives)		4		705	705
	Vegetables and Fruits sector	40		4,203		4,203
	Sugar crops	1		3,053		3,053
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	2		1,478		1,478
	Crop sectors total	**69**	**4**	**12,888**	**705**	**13,593**
	Dairy sector	22		4,434		4,434
	Red meat sector		11		99	99
	White meat sector (incl. eggs)		4		18	18
	Other livestock (incl. apiculture, cuniculture, etc.)		3		9	9
	Livestock sectors total	**22**	**18**	**4,434**	**126**	**4,560**
	Transversal actions total					
	Aggreagte total	**91**	**22**	**17,322**	**831**	**18,153**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Chaouia-Ouardigha [4]	Cereals sector (incl. seeds)	38	15	587	507	1,094
	Citrus sector					
	Olive oil sector (incl. olives)	14	14	1,032	556	1,588
	Vegetables and Fruits sector	3	5	196	110	306
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)					
	Crop sectors total	**55**	**34**	**1,815**	**1,173**	**2,988**
	Dairy sector	8	1	282	185	467
	Red meat sector	164	27	332	475	807
	White meat sector (incl. eggs)	3	2	2,099	19	2,118
	Other livestock (incl. apiculture, cuniculture, etc.)		1		37	37
	Livestock sectors total	**175**	**31**	**2,713**	**716**	**3,429**
	Transversal actions total					**2,374**
	Aggreagte total	**230**	**65**	**4,528**	**1,889**	**8,791**
Marrakech-Tensift-El Haouz [5]	Cereals sector (incl. seeds)	15		278		278
	Citrus sector	4		410		410
	Olive oil sector (incl. olives)	47	29	4,293	1,823	6,116
	Vegetables and Fruits sector					
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	1	8	42	210	252
	Crop sectors total	**67**	**37**	**5,023**	**2,033**	**7,056**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Marrakech-Tensift-El Haouz [5]	Dairy sector	11		959		959
	Red meat sector	4	22	218	177	395
	White meat sector (incl. eggs)					
	Other livestock (incl. apiculture, cuniculture, etc.)					
	Livestock sectors total	**15**	**22**	**1,177**	**177**	**1,354**
	Transversal actions total					
	Aggreagte total	**82**	**59**	**6,200**	**2,210**	**8,410**
L'Oriental [6]	Cereals sector (incl. seeds)	2		316		316
	Citrus sector	15		2,015		2,015
	Olive oil sector (incl. olives)	6	10	846	655	1,501
	Vegetables and Fruits sector	5		691		691
	Sugar crops	1		349		349
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	3	7	140	281	421
	Crop sectors total	**32**	**17**	**4,357**	**936**	**5,293**
	Dairy sector	4		160		160
	Red meat sector	3	1	422	14	436
	White meat sector (incl. eggs)	1		155		155
	Other livestock (incl. apiculture, cuniculture, etc.)	1	1	8	6	14
	Livestock sectors total	**9**	**2**	**745**	**20**	**765**
	Transversal actions total					**3,064**
	Aggreagte total	**41**	**19**	**5,102**	**956**	**9,122**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Grand Casablanca [7]	Cereals sector (incl. seeds)	1	1	13	14	27
	Citrus sector					
	Olive oil sector (incl. olives)					
	Vegetables and Fruits sector					
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	6	3	314	32	346
	Crop sectors total	**7**	**4**	**327**	**46**	**373**
	Dairy sector	2		55		55
	Red meat sector	3	1	122	91	213
	White meat sector (incl. eggs)	8	6	1,280	6	1,286
	Other livestock (incl. apiculture, cuniculture, etc.)		4		6	6
	Livestock sectors total	**13**	**11**	**1,457**	**103**	**1,560**
	Transversal actions total					**125**
	Aggreagte total	**20**	**15**	**1,784**	**149**	**2,058**
Rabat-Sale-Zemmour-Zaer [8]	Cereals sector (incl. seeds)	20	13	1,040	344	1,384
	Citrus sector	2		162		162
	Olive oil sector (incl. olives)		10		337	337
	Vegetables and Fruits sector	8		456		456
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	4	6	456	41	497
	Crop sectors total	**34**	**29**	**2,114**	**722**	**2,836**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Rabat-Sale-Zemmour-Zaer [8]	Dairy sector	7		239		239
	Red meat sector	15	6	328	56	384
	White meat sector (incl. eggs)	2	2	242	9	251
	Other livestock (incl. apiculture, cuniculture, etc.)		2		89	89
	Livestock sectors total	**24**	**10**	**809**	**154**	**963**
	Transversal actions total					**1,494**
	Aggreagte total	**58**	**39**	**2,923**	**876**	**5,293**
Doukkala-Abda [9]	Cereals sector (incl. seeds)	39		2,011		2,011
	Citrus sector					
	Olive oil sector (incl. olives)	1	1	26	126	152
	Vegetables and Fruits sector	12	1	3,097	32	3,129
	Sugar crops	1		1,697		1,697
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	5	5	114	180	294
	Crop sectors total	**58**	**7**	**6,945**	**338**	**7,283**
	Dairy sector	6		2,630		2,630
	Red meat sector	16	3	198	64	262
	White meat sector (incl. eggs)	2	2	306	6	312
	Other livestock (incl. apiculture, cuniculture, etc.)	1	1	21	9	30
	Livestock sectors total	**25**	**6**	**3,155**	**79**	**3,234**
	Transversal actions total					
	Aggreagte total	**83**	**13**	**10,100**	**417**	**10,517**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Tadla-Azilal [10]	Cereals sector (incl. seeds)	4	1	123	10	133
	Citrus sector	10		1,334		1,334
	Olive oil sector (incl. olives)	10	10	561	336	897
	Vegetables and Fruits sector	2		39		39
	Sugar crops	1		937		937
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	3	10	59	208	266
	Crop sectors total	**30**	**21**	**3,054**	**553**	**3,607**
	Dairy sector	5		1,838		1,838
	Red meat sector	2	10	64	20	84
	White meat sector (incl. eggs)	1		10		10
	Other livestock (incl. apiculture, cuniculture, etc.)		1		10	10
	Livestock sectors total	**8**	**11**	**1,911**	**30**	**1,942**
	Transversal actions total					**6,381**
	Aggreagte total	**38**	**32**	**4,965**	**584**	**11,930**
Meknes-Tafilalet [11]	Cereals sector (incl. seeds)	21	25	606	413	1,020
	Citrus sector					
	Olive oil sector (incl. olives)	27	13	1,857	539	2,396
	Vegetables and Fruits sector	21	7	2,177	843	3,019
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	16	12	2,344	317	2,661
	Crop sectors total	**85**	**57**	**6,984**	**2,112**	**9,096**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Meknes-Tafilalet [11]	Dairy sector	7	3	564	441	1,005
	Red meat sector	4	3	335	5	339
	White meat sector (incl. eggs)	6	3	393	7	399
	Other livestock (incl. apiculture, cuniculture, etc.)	1	1	331	13	344
	Livestock sectors total	**18**	**10**	**1,622**	**466**	**2,088**
	Transversal actions total					
	Aggreagte total	**103**	**67**	**8,606**	**2,577**	**11,183**
Fes-Boulemane [12]	Cereals sector (incl. seeds)	11	1	1,815	1,507	3,322
	Citrus sector					
	Olive oil sector (incl. olives)	22	2	600	366	966
	Vegetables and Fruits sector	3	3	61	210	271
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	7	4	3,675	17	3,692
	Crop sectors total	**43**	**10**	**6,151**	**2,100**	**8,251**
	Dairy sector	6		102		102
	Red meat sector	31	1	161	53	214
	White meat sector (incl. eggs)	5	11	730	22	752
	Other livestock (incl. apiculture, cuniculture, etc.)		1		12	12
	Livestock sectors total	**42**	**13**	**993**	**87**	**1,080**
	Transversal actions total					**1,335**
	Aggreagte total	**85**	**23**	**7,144**	**2,187**	**10,666**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Taza-Taounate-Al Hoceima [13]	Cereals sector (incl. seeds)	21		1,058		1,058
	Citrus sector	2		312		312
	Olive oil sector (incl. olives)	4	22	340	1,186	1,526
	Vegetables and Fruits sector					
	Sugar crops					
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	1	15	6	611	617
	Crop sectors total	**28**	**37**	**1,716**	**1,797**	**3,513**
	Dairy sector	4	1	289	3	292
	Red meat sector	1	2	53	127	180
	White meat sector (incl. eggs)					
	Other livestock (incl. apiculture, cuniculture, etc.)	1	1	9	7	16
	Livestock sectors total	**6**	**4**	**351**	**137**	**488**
	Transversal actions total					**1,179**
	Aggreagte total	**34**	**41**	**2,067**	**1,934**	**5,180**
Tanger-Tetouan [14]	Cereals sector (incl. seeds)					
	Citrus sector	2		561		561
	Olive oil sector (incl. olives)	13	42	62	916	978
	Vegetables and Fruits sector	7		705		705
	Sugar crops	1		142		142
	Other crops (e.g. Argan, Dattes, Safran, Cactus, etc.)	2	18	229	63	292
	Crop sectors total	**25**	**60**	**1,699**	**979**	**2,678**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.9: Summary Analysis of Projected Investments of the PMV at the Regional Level in Morocco by 2020 (continued)

Regions	Sectors	No. of projects		Investment costs (in million MAD)		Total cost (in million MAD)
		Pillar I	Pillar II	Pillar I	Pillar II	
Tanger-Tetouan [14]	Dairy sector	3	5	406	112	518
	Red meat sector	11	3	76	71	147
	White meat sector (incl. eggs)	3	1	210	7	217
	Other livestock (incl. apiculture, cuniculture, etc.)	1	3	4	98	101
	Livestock sectors total	**18**	**12**	**696**	**287**	**983**
	Transversal actions total					**4,517**
	Aggreagte total	**43**	**72**	**2,395**	**1,266**	**8,178**

Source: Author's compilation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.10: Summary Analysis of Projected Impacts of the PMV at the Regional Level for Area, Production and Yield by 2020

Region	Sector	Current			PMV targets			%Change		
		SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)
Souss-Massa-Draa [2]	Vegetable & Fruits	25,500	1,460,000	57.25	25,500	2,141,000	83.96	0.0%	46.6%	46.6%
	Citrus	33,000	630,000	19.09	34,000	864,000	25.41	3.0%	37.1%	33.1%
	Olives	27,000	23,000	0.85	31,700	43,000	1.36	17.4%	87.0%	59.2%
Gharb-Cherarda-Bni Hsan [3]	Cereals	326,000	712,000	2.18	199,000	790,000	3.97	-39.0%	11.0%	81.8%
	Citrus	16,200	340,000	20.99	39,300	1,377,500	35.05	142.6%	305.1%	67.0%
	Sugar crops	26,400	1,240,000	46.97	47,000	3,164,400	67.33	78.0%	155.2%	43.3%
	Olives	46,700	51,000	1.09	86,700	217,060	2.50	85.7%	325.6%	129.2%
Chaouia-Ouardigha [4]	Cereals	681,700	760,000	1.11	569,300	1,074,000	1.89	-16.5%	41.3%	69.2%
	Vegetable & Fruits	6,500	188,000	28.92	8,500	483,000	56.82	30.8%	156.9%	96.5%
	Olives	18,925	38,000	2.01	60,275	324,000	5.38	218.5%	752.6%	167.7%
Marrakech-Tensift-Al Haouz [5]	Cereals	800,000	636,000	0.80	712,000	860,000	1.21	-11.0%	35.2%	51.9%
	Citrus	5,400	105,000	19.44	9,120	231,000	25.33	68.9%	120.0%	30.3%
	Olives	123,100	246,000	2.00	172,100	861,000	5.00	39.8%	250.0%	150.3%

Source: Author's calculation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.10: Summary Analysis of Projected Impacts of the PMV at the Regional Level for Area, Production and Yield by 2020 (continued)

Region	Sector	Current			PMV targets			%Change		
		SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)
L'Oriental [6]	Citrus	14,450	200,000	13.84	19,400	527,500	27.19	34.3%	163.8%	96.5%
	Olives	59,300	80,000	1.35	119,000	202,000	1.70	100.7%	152.5%	25.8%
	Vegetable & Fruits (potatoes)	15,840	200,000	12.63	15,900	305,800	19.23	0.4%	52.9%	52.3%
	Sugar crops	4,400	244,000	55.45	5,000	351,500	70.30	13.6%	44.1%	26.8%
Grand Casablanca [7]	Cereals	41,400	56,000	1.35	20,700	52,000	2.51	-50.0%	-7.1%	85.7%
	Vegetable & Fruits	3,120	75,000	24.04	3,500	170,000	48.57	12.2%	126.7%	102.1%
Rabat-Sale-Zemmour-Zaer [8]	Cereals	274,600	275,000	1.00	233,600	664,000	2.84	-14.9%	141.5%	183.8%
	Vegetable & Fruits	13,100	74,000	5.65	16,700	260,000	15.57	27.5%	251.4%	175.6%
	Olives	20,000	18,000	0.90	61,000	110,000	1.80	205.0%	511.1%	100.4%
Doukkala-Abda [9]	Cereals	349,300	580,000	1.66	228,900	1,035,000	4.52	-34.5%	78.4%	172.3%
	Vegetable & Fruits	18,000	447,000	24.83	23,200	1,122,000	48.36	28.9%	151.0%	94.7%
	Sugar crops	20,600	1,120,500	54.39	20,000	1,500,500	75.03	-2.9%	33.9%	37.9%

Source: Author's calculation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.10: Summary Analysis of Projected Impacts of the PMV at the Regional Level for Area, Production and Yield by 2020 (continued)

Region	Sector	Current			PMV targets			%Change		
		SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)
Tadla-Azilal [10]	Cereals	81,500	301,380	3.70	67,300	342,740	5.09	-17.4%	13.7%	37.7%
	Citrus	12,000	210,000	17.50	16,200	424,132	26.18	35.0%	102.0%	49.6%
	Olives	49,600	101,200	2.04	80,000	400,000	5.00	61.3%	295.3%	145.1%
Meknes-Tafilalet [11]	Vegetable & Fruits (potatoes)	12,400	328,600	26.50	13,750	500,500	36.40	10.9%	52.3%	37.4%
	Vegetable & Fruits (onions)	7,000	261,500	37.36	7,700	477,500	62.01	10.0%	82.6%	66.0%
	Olives	52,600	75,861	1.44	86,400	413,221	4.78	64.3%	444.7%	231.6%
	Cereals	391,250	518,000	1.32	329,600	911,000	2.76	-15.8%	75.9%	108.8%
Fes-Boulemane [12]	Vegetable & Fruits	12,800	243,000	18.98	20,000	1,600,000	80.00	56.3%	558.4%	321.4%
	Olives	56,000	67,000	1.20	120,000	540,000	4.50	114.3%	706.0%	276.1%
	Cereals	173,600	230,000	1.32	105,000	309,000	2.94	-39.5%	34.3%	122.1%
Taza-Taounate-Al Hoceime [13]	Citrus	2,000	20,000	10.00	5,000	150,000	30.00	150.0%	650.0%	200.0%
	Olives	197,500	284,000	1.44	318,500	660,000	2.07	61.3%	132.4%	44.1%
	Cereals	425,000	510,000	1.20	260,000	1,060,000	4.08	-38.8%	107.8%	239.7%

Source: Author's calculation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.10: Summary Analysis of Projected Impacts of the PMV at the Regional Level for Area, Production and Yield by 2020 (continued)

Region	Sector	Current			PMV targets			%Change		
		SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)	SAU (in Ha)	Production (in T)	Yield (in T/Ha)
Tanger-Tetouan [14]	Citrus	1,400	28,000	20.00	5,400	193,000	35.74	285.7%	589.3%	78.7%
	Olives	79,000	90,000	1.14	150,000	350,000	2.33	89.9%	288.9%	104.8%
	Sugar crops	8,500	480,000	56.47	12,000	780,000	65.00	41.2%	62.5%	15.1%

Source: Author's calculation (Data source: ADA, 2014 - http://www.ada.gov.ma/PlanRegionaux.php)

Table B4.11: Average Climate Change Impacts on Household Income — Without and With the PMV Strategy by 2050 (BASE in million MAD and % Change from BASE)

	Household Income by Household Type									
	BASE		Climate change impacts - without CO_2 fertilization				Climate change impacts - with CO_2 fertilization			
	Rural	Urban	Rural		Urban		Rural		Urban	
			A2	B2	A2	B2	A2	B2	A2	B2
CC-Only										
R1	2,226	8,140	-1.99	-1.46	-1.87	-1.37	-0.88	-0.79	-0.84	-0.75
R2	7,392	26,116	-1.50	-1.09	-1.47	-1.06	0.37	0.09	0.37	0.09
R3	5,231	18,418	-0.60	-0.52	-0.59	-0.51	1.02	0.75	1.00	0.74
R4	5,434	19,162	-2.21	-1.72	-2.17	-1.69	-1.40	-1.24	-1.37	-1.22
R5	6,925	24,444	-1.50	-1.14	-1.47	-1.11	-0.66	-0.63	-0.65	-0.61
R6	6,367	22,973	-1.50	-1.24	-1.43	-1.18	-0.52	-0.57	-0.50	-0.55
R7	23,032	84,279	-1.78	-1.30	-1.67	-1.21	-0.67	-0.62	-0.64	-0.59
R8	8,672	32,022	-2.27	-1.67	-2.11	-1.55	-1.16	-1.00	-1.09	-0.94
R9	5,490	19,252	-1.47	-0.93	-1.45	-0.92	-0.05	-0.32	-0.05	-0.32
R10	3,333	11,641	-0.43	-0.06	-0.43	-0.06	0.56	0.34	0.56	0.34
R11	6,023	21,643	-1.23	-1.15	-1.18	-1.10	-1.13	-0.97	-1.09	-0.94
R12	4,825	17,755	-2.28	-1.71	-2.12	-1.59	-1.17	-1.03	-1.10	-0.97
R13	3,389	11,478	-2.44	-1.79	-2.51	-1.84	-1.52	-1.23	-1.55	-1.26
R14	7,500	27,162	-1.51	-1.04	-1.43	-0.99	-0.20	-0.23	-0.20	-0.22

Table B4.11: Average Climate Change Impacts on Household Income — Without and With the PMV Strategy by 2050 (BASE in million MAD and % Change from BASE) (continued)

	Household Income by Household Type									
	BASE		Climate change impacts - without CO_2 fertilization				Climate change impacts - with CO_2 fertilization			
	Rural	Urban	Rural		Urban		Rural		Urban	
			A2	B2	A2	B2	A2	B2	A2	B2
CC-PMV										
R1	2,261	8,258	-2.05	-1.51	-1.93	-1.42	-0.92	-0.83	-0.88	-0.78
R2	7,633	26,953	-1.58	-1.17	-1.55	-1.15	0.58	0.21	0.57	0.21
R3	5,325	18,743	-0.39	-0.40	-0.38	-0.39	1.22	0.90	1.20	0.89
R4	5,484	19,336	-1.68	-1.30	-1.65	-1.27	-0.97	-0.89	-0.96	-0.88
R5	7,018	24,766	-1.52	-1.15	-1.49	-1.12	-0.71	-0.65	-0.69	-0.64
R6	6,493	23,406	-1.58	-1.30	-1.50	-1.24	-0.50	-0.57	-0.48	-0.55
R7	23,393	85,506	-1.81	-1.31	-1.69	-1.23	-0.69	-0.64	-0.66	-0.61
R8	8,791	32,422	-2.21	-1.62	-2.06	-1.51	-1.15	-0.98	-1.08	-0.92
R9	5,592	19,605	-1.31	-0.76	-1.29	-0.75	0.06	-0.19	0.06	-0.19
R10	3,363	11,748	-0.34	0.00	-0.34	0.00	0.66	0.40	0.66	0.40
R11	6,117	21,963	-0.91	-0.89	-0.87	-0.85	-1.01	-0.84	-0.98	-0.81
R12	4,900	18,009	-2.13	-1.58	-1.98	-1.47	-1.09	-0.95	-1.03	-0.90
R13	3,375	11,433	-2.09	-1.49	-2.15	-1.54	-1.32	-1.04	-1.35	-1.07
R14	7,569	27,397	-1.54	-1.06	-1.46	-1.01	-0.24	-0.26	-0.23	-0.25

Source: Simulation results

Table B4.12: Average Climate Change Impacts on Household Real Consumption Expenditure — Without and With the PMV Strategy by 2050 (BASE in million MAD and % Change from BASE)

	Household Real Expenditure by Household Type									
	BASE		Climate change impacts - without CO_2 fertilization				Climate change impacts - with CO_2 fertilization			
	Rural	Urban	Rural		Urban		Rural		Urban	
			A2	B2	A2	B2	A2	B2	A2	B2
CC-Only										
R1	973	6,718	-3.86	-2.87	-2.05	-1.49	-1.64	-1.48	-0.56	-0.57
R2	11,265	15,356	-2.12	-1.52	-1.94	-1.35	-0.07	-0.27	-0.27	-0.37
R3	5,835	7,294	-1.17	-0.94	-1.54	-1.20	1.16	0.79	0.38	0.20
R4	5,916	6,718	-5.04	-4.04	-4.49	-3.54	-3.52	-3.03	-2.90	-2.51
R5	10,049	11,133	-2.40	-1.79	-2.43	-1.75	-0.85	-0.84	-0.95	-0.86
R6	4,538	10,749	-2.63	-2.16	-2.30	-1.75	-0.65	-0.78	-0.55	-0.58
R7	1,459	51,249	-12.48	-9.15	-2.87	-2.09	-6.86	-5.58	-0.85	-0.82
R8	2,674	23,609	-5.61	-4.17	-3.37	-2.45	-2.81	-2.41	-1.49	-1.29
R9	7,375	7,678	-1.87	-1.36	-2.08	-1.47	0.36	-0.07	-0.02	-0.24
R10	6,240	6,334	-1.39	-0.88	-1.62	-1.01	0.71	0.27	0.21	-0.02
R11	5,025	11,901	-3.51	-2.58	-3.10	-2.19	-1.49	-1.34	-1.25	-1.08
R12	2,350	11,325	-4.66	-3.41	-3.34	-2.38	-2.00	-1.76	-1.20	-1.07
R13	10,292	5,374	-3.66	-2.74	-3.38	-2.47	-1.53	-1.39	-1.37	-1.20
R14	7,051	16,507	-2.99	-2.18	-2.61	-1.86	-0.47	-0.55	-0.47	-0.50

Table B4.12: Average Climate Change Impacts on Household Real Consumption Expenditure — Without and With the PMV Strategy by 2050 (BASE in million MAD and % Change from BASE) (continued)

	Household Real Expenditure by Household Type									
	BASE		Climate change impacts - without CO_2 fertilization				Climate change impacts - with CO_2 fertilization			
	Rural	Urban	Rural		Urban		Rural		Urban	
			A2	B2	A2	B2	A2	B2	A2	B2
CC-PMV										
R1	994	6,832	-3.94	-2.93	-2.13	-1.55	-1.79	-1.60	-0.61	-0.62
R2	11,658	15,920	-2.20	-1.59	-2.06	-1.45	-0.10	-0.31	-0.37	-0.45
R3	5,957	7,471	-1.06	-0.86	-1.54	-1.23	1.24	0.85	0.32	0.15
R4	5,988	6,828	-5.04	-4.04	-4.49	-3.54	-3.54	-3.04	-2.98	-2.57
R5	10,208	11,346	-2.38	-1.78	-2.52	-1.83	-0.84	-0.85	-1.10	-0.99
R6	4,648	11,015	-2.68	-2.18	-2.41	-1.84	-0.70	-0.80	-0.67	-0.67
R7	1,549	52,246	-12.80	-9.45	-2.94	-2.15	-7.87	-6.36	-0.97	-0.92
R8	2,737	23,996	-5.70	-4.25	-3.39	-2.47	-3.03	-2.58	-1.56	-1.35
R9	7,530	7,868	-1.82	-1.32	-2.11	-1.48	0.37	-0.04	-0.13	-0.31
R10	6,309	6,419	-1.43	-0.91	-1.72	-1.09	0.67	0.23	0.11	-0.11
R11	5,121	12,135	-3.49	-2.57	-3.10	-2.19	-1.53	-1.37	-1.33	-1.14
R12	2,401	11,535	-4.72	-3.48	-3.37	-2.41	-2.14	-1.88	-1.28	-1.14
R13	10,263	5,378	-3.61	-2.70	-3.39	-2.48	-1.51	-1.37	-1.45	-1.25
R14	7,140	16,725	-3.02	-2.22	-2.69	-1.94	-0.55	-0.62	-0.60	-0.60

Source: Simulation results

Table B4.13: Average Climate Change Impacts on Household Welfare — Without and With the PMV Strategy by 2050 (BASE in million MAD and % Change from BASE)

	Household Welfare by Household Type							
	Climate change impacts - without CO_2 fertilization				Climate change impacts - with CO_2 fertilization			
	Rural		Urban		Rural		Urban	
	A2	B2	A2	B2	A2	B2	A2	B2
CC-Only								
R1	-38	-28	-140	-101	-16	-15	-39	-39
R2	-245	-175	-303	-210	-13	-33	-46	-59
R3	-71	-56	-115	-89	62	43	22	12
R4	-315	-250	-315	-246	-221	-187	-204	-174
R5	-249	-184	-274	-197	-90	-88	-109	-98
R6	-122	-101	-250	-192	-32	-38	-63	-66
R7	-183	-134	-1,491	-1,082	-101	-82	-451	-433
R8	-153	-113	-815	-589	-76	-66	-358	-310
R9	-143	-104	-163	-114	19	-9	-7	-22
R10	-89	-56	-105	-65	42	16	12	-2
R11	-182	-132	-383	-266	-76	-69	-151	-130
R12	-113	-82	-391	-275	-48	-42	-139	-123
R13	-393	-290	-188	-136	-165	-148	-76	-66
R14	-214	-156	-438	-311	-36	-41	-83	-85

Table B4.13: Average Climate Change Impacts on Household Welfare — Without and With the PMV Strategy by 2050 (BASE in million MAD and % Change from BASE) (continued)

	Household Welfare by Household Type							
	Climate change impacts - without CO_2 fertilization				Climate change impacts - with CO_2 fertilization			
	Rural		Urban		Rural		Urban	
	A2	B2	A2	B2	A2	B2	A2	B2
CC-PMV								
R1	-40	-29	-147	-107	-18	-16	-43	-43
R2	-262	-189	-333	-235	-16	-39	-62	-74
R3	-66	-53	-118	-93	68	47	18	8
R4	-322	-254	-321	-250	-227	-191	-214	-181
R5	-248	-185	-290	-210	-90	-89	-127	-113
R6	-127	-104	-268	-206	-35	-40	-77	-77
R7	-199	-147	-1,553	-1,132	-123	-99	-520	-490
R8	-159	-118	-833	-603	-84	-72	-381	-328
R9	-143	-103	-169	-118	21	-8	-16	-28
R10	-93	-59	-112	-71	40	13	5	-8
R11	-185	-135	-391	-272	-80	-72	-164	-140
R12	-117	-85	-402	-284	-53	-46	-151	-133
R13	-386	-287	-189	-137	-162	-146	-80	-69
R14	-220	-161	-457	-327	-42	-46	-105	-103

Source: Simulation results

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Hard (Durum) Wheat										
Domestic Market										
Consumption	1,299	-13.31	-11.25	-9.03	-8.41	1,323	-14.22	-11.93	-9.61	-8.91
Production	4,414	-18.86	-15.96	-12.99	-12.09	3,303	-14.54	-12.00	-9.78	-8.92
Prices	1	18.86	16.01	13.35	12.45	1	18.60	15.50	13.04	11.97
Employment										
Capital	2,627	4.06	4.02	3.44	3.50	2,025	13.46	11.81	10.07	9.51
Labor	267	2.28	2.71	2.69	2.80	205	11.74	10.60	9.42	8.91
Irrigated Land	290					205				
Rainfed Land	1,230					868				
Wages										
Capital	1	-2.26	-1.66	-0.94	-0.88	1	-1.97	-1.42	-0.76	-0.71
Labor	1					1				
Irrigated Land	1	3.07	3.65	3.62	3.76	1	15.86	14.25	12.72	11.97
Rainfed Land	1	3.07	3.65	3.62	3.76	1	15.86	14.25	12.72	11.97
Trade										
Exports										
Imports	2,046	37.13	31.41	27.83	25.29	969	42.93	35.16	31.57	27.95
Net exports	-2,046	37.13	31.41	27.83	25.29	-969	42.93	35.16	31.57	27.95

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Soft (Common) Wheat										
Domestic Market										
Consumption	496	-12.06	-10.21	-6.93	-6.86	505	-13.02	-10.99	-7.58	-7.45
Production	8,005	-17.30	-14.67	-10.31	-10.06	6,471	-14.26	-12.05	-8.48	-8.28
Prices	1	14.92	12.59	8.66	8.54	1	14.78	12.42	8.73	8.52
Employment										
Capital	4,898	1.63	1.52	0.81	0.92	4,048	8.21	7.04	4.92	4.82
Labor	410	0.19	0.44	0.36	0.48	338	6.82	6.02	4.50	4.40
Irrigated Land	772					597				
Rainfed Land	1,925					1,488				
Wages										
Capital	1	-1.88	-1.40	-0.58	-0.58	1	-1.70	-1.25	-0.51	-0.51
Labor	1					1				
Irrigated Land	1	0.31	0.62	0.52	0.66	1	9.17	8.10	6.05	5.91
Rainfed Land	1	0.31	0.62	0.52	0.66	1	9.17	8.10	6.05	5.91
Trade										
Exports	17	-36.69	-31.80	-22.51	-22.27	59	-34.70	-29.72	-21.30	-20.65
Imports	3,228	26.79	23.00	17.25	16.65	1,645	30.27	25.78	19.54	18.77
Net exports	-3,210	27.13	23.30	17.47	16.87	-1,585	32.71	27.86	21.07	20.24

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Barley										
Domestic Market										
Consumption	357	-16.92	-12.53	-9.93	-7.89	364	-17.02	-12.63	-10.01	-7.97
Production	4,558	-7.77	-5.60	-4.30	-3.34	4,760	-7.93	-5.71	-4.46	-3.45
Prices	1	23.99	17.06	16.09	11.83	1	24.17	17.25	16.19	11.95
Employment										
Capital	2,242	19.15	13.95	13.54	10.06	2,334	18.84	13.77	13.26	9.89
Labor	487	17.14	12.55	12.76	9.34	505	17.04	12.53	12.62	9.29
Irrigated Land	344					361				
Rainfed Land	1,485					1,559				
Wages										
Capital	1	-2.20	-1.62	-0.87	-0.83	1	-1.98	-1.43	-0.72	-0.69
Labor	1					1				
Irrigated Land	1	23.78	17.29	17.72	12.87	1	23.64	17.27	17.52	12.80
Rainfed Land	1	23.78	17.29	17.72	12.87	1	23.64	17.27	17.52	12.80
Trade										
Exports	0									
Imports	256	94.30	60.93	65.04	42.63	279	94.87	61.65	65.38	43.11
Net exports	-256	94.30	60.93	65.04	42.63	-279	94.87	61.65	65.38	43.11

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Tomatoes										
Domestic Market										
Consumption	2,192	-0.67	-0.47	8.13	5.96	2,233	-0.76	-0.54	7.43	5.46
Production	1,859	-0.07	-0.05	13.11	9.58	1,915	0.09	0.07	13.58	9.95
Prices	1	-1.25	-0.90	-5.94	-4.60	1	-1.00	-0.73	-4.65	-3.60
Employment										
Capital	235	-0.17	-0.14	-0.16	-0.13	241	0.22	0.14	0.88	0.70
Labor	230	-1.41	-1.04	0.03	-0.11	235	-1.01	-0.75	1.18	0.80
Irrigated Land	887					915				
Rainfed Land	507					524				
Wages										
Capital	1	-1.66	-1.20	0.25	0.03	1	-1.63	-1.18	0.41	0.14
Labor	1					1				
Irrigated Land	1	-1.88	-1.39	0.07	-0.13	1	-1.32	-0.98	1.69	1.15
Rainfed Land	1	-1.88	-1.39	0.07	-0.13	1	-1.32	-0.98	1.69	1.15
Trade										
Exports	1,104	1.72	1.23	25.13	18.47	1,728	1.57	1.15	22.43	16.53
Imports	0	-6.03	-4.43	-17.16	-13.53	0	-5.58	-4.10	-15.65	-12.32
Net exports	1,104	1.72	1.23	25.13	18.47	1,728	1.57	1.15	22.43	16.53

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Other vegetables										
Domestic Market										
Consumption	9,396	-1.31	-0.76	5.39	3.76	9,574	-1.40	-0.83	5.27	3.67
Production	7,963	-1.13	-0.63	6.84	4.74	8,095	-1.23	-0.71	6.66	4.60
Prices	1	-1.40	-1.17	-5.92	-4.41	1	-1.33	-1.12	-5.90	-4.40
Employment										
Capital	3,964	-1.06	-0.77	-2.22	-1.70	4,034	-1.26	-0.93	-2.50	-1.92
Labor	1,445	-2.44	-1.81	-2.57	-2.08	1,464	-2.50	-1.86	-2.74	-2.21
Irrigated Land	1,169					1,189				
Rainfed Land	1,385					1,409				
Wages										
Capital	1	-1.85	-1.38	-0.46	-0.51	1	-1.67	-1.24	-0.34	-0.39
Labor	1					1				
Irrigated Land	1	-3.23	-2.40	-3.39	-2.75	1	-3.31	-2.47	-3.63	-2.93
Rainfed Land	1	-3.23	-2.40	-3.39	-2.75	1	-3.31	-2.47	-3.63	-2.93
Trade										
Exports	1,281	2.24	2.00	22.29	15.54	1,251	1.96	1.77	22.04	15.33
Imports	407	-5.06	-4.12	-12.98	-10.04	427	-4.98	-4.06	-12.98	-10.03
Net exports	874	5.63	4.85	38.71	27.45	824	5.55	4.79	40.19	28.47

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Other industrial vegetables										
Domestic Market										
Production	160	-3.26	-2.42	0.35	-0.07	165	-3.23	-2.40	0.24	-0.14
Prices	1	-2.01	-1.76	-8.20	-6.23	1	-1.98	-1.72	-8.26	-6.27
Employment										
Capital	36	-4.63	-3.81	-12.58	-9.71	37	-4.70	-3.86	-12.81	-9.88
Labor	52	-5.95	-4.82	-12.92	-10.08	53	-5.91	-4.76	-13.07	-10.17
Irrigated Land	33					34				
Rainfed Land	39					41				
Wages										
Capital	1	-1.84	-1.38	-0.50	-0.53	1	-1.67	-1.24	-0.38	-0.41
Labor	1					1				
Irrigated Land	1	-7.80	-6.34	-16.76	-13.16	1	-7.78	-6.30	-16.99	-13.30
Rainfed Land	1	-7.80	-6.34	-16.76	-13.16	1	-7.78	-6.30	-16.99	-13.30
Trade										
Exports	24	-3.65	-2.94	11.82	7.67	25	-3.78	-3.04	11.25	7.28
Imports										
Net exports	24	-3.65	-2.94	11.82	7.67	25	-3.78	-3.04	11.25	7.28

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Citrus										
Domestic Market										
Consumption	1,139	-1.23	-1.88	6.71	3.29	1,161	-1.31	-1.91	6.09	2.97
Production	2,225	-1.34	-2.27	9.30	4.53	2,960	-1.18	-2.26	9.51	4.69
Prices	1	-0.43	0.09	-2.55	-1.40	1	-0.29	0.06	-1.65	-0.91
Employment										
Capital	181	-0.36	-0.86	3.45	1.52	227	-0.13	-0.87	4.47	2.07
Labor	206	-1.50	-1.68	3.67	1.58	256	-1.24	-1.68	4.79	2.20
Irrigated Land	1,634					2,201				
Rainfed Land	204					275				
Wages										
Capital	1	-1.52	-1.10	0.28	0.07	1	-1.49	-1.10	0.38	0.14
Labor	1					1				
Irrigated Land	1	-1.97	-2.20	4.98	2.16	1	-1.59	-2.20	6.53	3.03
Rainfed Land	1	-1.97	-2.20	4.98	2.16	1	-1.59	-2.20	6.53	3.03
Trade										
Exports	2,184	-1.31	-2.48	11.13	5.44	3,639	-1.07	-2.36	10.81	5.36
Imports	0	-4.90	-1.35	-14.77	-8.55	0	-4.27	-1.31	-12.19	-7.11
Net exports	2,184	-1.31	-2.48	11.13	5.44	3,639	-1.07	-2.36	10.81	5.36

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Olives										
Domestic Market										
Consumption	492	-14.67	-10.04	-8.48	-6.32	501	-12.63	-8.56	-7.02	-5.27
Production	1,828	-13.27	-8.81	-8.00	-5.76	1,251	-10.74	-7.16	-6.25	-4.64
Prices	1	18.34	11.12	11.36	7.66	1	14.81	8.93	8.94	6.06
Employment										
Capital	555	10.99	6.99	7.48	5.01	398	15.55	9.61	10.06	6.65
Labor	542	9.06	5.64	6.65	4.29	387	13.71	8.36	9.29	6.00
Irrigated Land	203					130				
Rainfed Land	528					337				
Wages										
Capital	1	-2.27	-1.66	-1.01	-0.88	1	-2.08	-1.50	-0.91	-0.78
Labor	1					1				
Irrigated Land	1	12.33	7.62	9.01	5.80	1	18.59	11.20	12.49	8.04
Rainfed Land	1	12.33	7.62	9.01	5.80	1	18.59	11.20	12.49	8.04

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Other fruits										
Domestic Market										
Consumption	9,326	-7.36	-3.77	0.27	0.19	9,506	-7.42	-3.83	0.18	0.11
Production	10,993	-6.49	-3.42	0.08	0.02	11,287	-6.50	-3.44	-0.01	-0.05
Prices	1	7.01	2.57	-1.26	-1.15	1	7.16	2.66	-1.22	-1.11
Employment										
Capital	7,080	2.94	0.91	-0.80	-0.72	7,268	2.91	0.86	-0.93	-0.83
Labor	737	1.50	-0.17	-1.27	-1.19	753	1.59	-0.14	-1.32	-1.23
Irrigated Land	1,155					1,188				
Rainfed Land	2,020					2,078				
Wages										
Capital	1	-1.84	-1.43	-0.62	-0.63	1	-1.68	-1.30	-0.52	-0.53
Labor	1					1				
Irrigated Land	1	2.12	-0.20	-1.68	-1.57	1	2.27	-0.14	-1.74	-1.62
Rainfed Land	1	2.12	-0.20	-1.68	-1.57	1	2.27	-0.14	-1.74	-1.62
Trade										
Exports	341	-13.36	-5.52	4.17	3.54	328	-13.81	-5.91	3.86	3.26
Imports	305	16.13	4.43	-3.53	-3.34	325	16.46	4.54	-3.54	-3.33
Net exports	35	-268.22	-91.54	70.71	62.95	3	-3,532	-1,220	863.67	769.20

Table B4.14: Selected Indicators for the Agricultural Crop Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD) (continued)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Other crops										
Domestic Market										
Consumption	947	-5.66	-4.06	-1.13	-1.47	965	-5.66	-4.08	-1.20	-1.52
Production	7,248	-11.10	-7.98	-0.36	-1.92	7,558	-11.32	-8.17	-0.49	-2.05
Prices	1	5.67	3.88	-0.84	0.37	1	5.80	3.99	-0.71	0.48
Employment										
Capital	3,795	-2.42	-1.66	-1.59	-1.29	3,952	-2.74	-1.92	-1.69	-1.42
Labor	1,424	-3.48	-2.42	-1.55	-1.37	1,477	-3.64	-2.54	-1.55	-1.40
Irrigated Land	787					825				
Rainfed Land	1,241					1,304				
Wages										
Capital	1	-1.86	-1.36	-0.29	-0.38	1	-1.64	-1.18	-0.15	-0.25
Labor	1					1				
Irrigated Land	1	-2.48	-1.48	-0.30	-0.42	1	-2.63	-1.60	-0.25	-0.42
Rainfed Land	1	-5.40	-3.89	-2.72	-2.37	1	-5.64	-4.08	-2.76	-2.44
Trade										
Exports	284	-18.45	-13.99	3.76	-0.92	275	-18.80	-14.28	3.49	-1.15
Imports	7,498	5.90	3.74	-1.35	0.19	8,131	5.81	3.71	-1.16	0.30
Net exports	-7,214	6.86	4.44	-1.55	0.23	-7,856	6.67	4.34	-1.32	0.35

Source: Simulations results

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Dairy										
Domestic Market										
Consumption	6,890	-2.26	-1.74	-0.63	-0.63	7,022	-2.31	-1.78	-0.71	-0.69
Production	618	-1.95	-1.59	-0.20	-0.31	632	-2.01	-1.64	-0.28	-0.38
Prices	1	-0.50	-0.26	-0.64	-0.49	1	-0.49	-0.26	-0.63	-0.49
Employment										
Capital	503	-1.71	-1.42	-0.16	-0.26	515	-1.78	-1.48	-0.26	-0.33
Labor	115	-3.01	-2.35	-0.34	-0.52	117	-3.03	-2.36	-0.38	-0.55
Wages										
Capital	1	-1.76	-1.26	-0.25	-0.36	1	-1.69	-1.20	-0.17	-0.29
Labor	1					1				
Trade										
Exports	359	-0.77	-0.94	1.19	0.71	354	-0.83	-0.99	1.07	0.61
Imports	1,367	-3.08	-2.09	-1.96	-1.60	1,413	-3.12	-2.13	-2.04	-1.66
Net exports	-1,009	-3.91	-2.50	-3.08	-2.41	-1,059	-3.89	-2.52	-3.07	-2.42

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Hard wheat mill										
Domestic Market										
Consumption	2,899	-8.98	-7.66	-5.93	-5.67	2,954	-9.04	-7.62	-5.93	-5.60
Production	829	-7.76	-6.54	-4.83	-4.63	1,004	-7.96	-6.66	-4.97	-4.73
Prices	1	8.17	7.11	6.20	5.76	1	8.21	6.99	6.10	5.59
Employment										
Capital	750	-7.61	-6.43	-4.77	-4.57	909	-7.82	-6.56	-4.91	-4.68
Labor	79	-9.13	-7.58	-5.45	-5.21	95	-9.22	-7.61	-5.51	-5.25
Wages										
Capital	1	-2.22	-1.65	-0.97	-0.91	1	-2.05	-1.51	-0.87	-0.81
Labor	1					1				
Trade										
Exports										
Imports										
Net exports										

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Soft wheat mill										
Domestic Market										
Consumption	9,537	-10.31	-8.71	-6.04	-5.92	9,717	-10.81	-9.10	-6.41	-6.23
Production	1,098	-9.73	-8.19	-5.60	-5.50	1,405	-10.44	-8.73	-6.10	-5.90
Prices	1	9.38	8.08	5.97	5.81	1	10.06	8.58	6.35	6.14
Employment										
Capital	772	-9.31	-7.88	-5.45	-5.35	989	-10.06	-8.45	-5.97	-5.77
Labor	326	-10.69	-8.92	-5.96	-5.85	416	-11.34	-9.41	-6.41	-6.21
Wages										
Capital	1	-2.05	-1.53	-0.74	-0.72	1	-1.92	-1.42	-0.64	-0.63
Labor	1					1				
Trade										
Exports										
Imports										
Net exports										

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Oil processing										
Domestic Market										
Consumption	4,427	-2.99	-2.19	-1.01	-1.02	4,511	-3.03	-2.22	-1.09	-1.08
Production	746	-3.63	-2.66	-0.90	-1.07	761	-3.67	-2.70	-0.99	-1.15
Prices	1	0.58	0.42	-0.05	0.11	1	0.60	0.44	-0.02	0.13
Employment										
Capital	501	-3.13	-2.28	-0.73	-0.92	512	-3.19	-2.34	-0.86	-1.01
Labor	245	-4.64	-3.42	-1.22	-1.40	249	-4.65	-3.43	-1.27	-1.43
Wages										
Capital	1	-2.09	-1.55	-0.66	-0.66	1	-2.03	-1.50	-0.56	-0.58
Labor	1					1				
Trade										
Exports	44	-4.32	-3.15	-0.58	-1.09	43	-4.41	-3.22	-0.71	-1.19
Imports	1,977	-1.94	-1.43	-1.06	-0.78	2,031	-1.92	-1.41	-1.06	-0.78
Net exports	-1,933	-1.89	-1.39	-1.07	-0.77	-1,987	-1.87	-1.37	-1.07	-0.77

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Olive oil processing										
Domestic Market										
Consumption	3,112	-10.76	-7.22	-6.35	-4.65	3,170	-8.80	-5.84	-5.01	-3.70
Production	353	-13.02	-8.64	-7.82	-5.64	471	-9.97	-6.53	-5.79	-4.17
Prices	1	12.00	7.19	7.56	5.04	1	8.13	4.82	5.04	3.36
Employment										
Capital	218	-12.47	-8.21	-7.57	-5.41	291	-9.45	-6.14	-5.56	-3.97
Labor	135	-13.90	-9.33	-8.21	-6.00	180	-10.79	-7.15	-6.14	-4.50
Wages										
Capital	1	-2.22	-1.64	-0.96	-0.86	1	-2.00	-1.46	-0.84	-0.75
Labor	1					1				
Trade										
Exports	21	-31.63	-21.53	-22.04	-15.24	47	-23.61	-15.39	-15.93	-10.74
Imports	229	18.88	10.73	12.20	7.91	156	12.09	6.90	7.78	5.15
Net exports	-208	23.98	13.99	15.65	10.25	-109	27.68	16.65	18.15	12.09

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Whole olives processing										
Domestic Market										
Consumption	758	-8.24	-5.37	-5.02	-3.57	773	-6.33	-4.01	-3.84	-2.71
Production	320	-12.75	-8.14	-8.41	-5.71	445	-9.46	-5.70	-6.24	-4.08
Prices	1	3.46	1.98	2.35	1.49	1	1.69	0.89	1.20	0.72
Employment										
Capital	242	-12.40	-7.87	-8.25	-5.56	337	-9.12	-5.44	-6.09	-3.94
Labor	78	-13.83	-8.99	-8.89	-6.15	109	-10.48	-6.49	-6.70	-4.49
Wages										
Capital	1	-2.21	-1.64	-0.96	-0.86	1	-2.02	-1.48	-0.89	-0.78
Labor	1					1				
Trade										
Exports	838	-17.03	-10.71	-11.56	-7.68	1,271	-11.42	-6.76	-7.71	-4.94
Imports										
Net exports	838	-17.03	-10.71	-11.56	-7.68	1,271	-11.42	-6.76	-7.71	-4.94

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Sugar processing										
Domestic Market										
Consumption	4,740	-2.49	-1.77	-0.60	-0.67	4,829	-2.54	-1.81	-0.68	-0.74
Production	1,933	-2.70	-1.90	-0.28	-0.52	1,964	-2.77	-1.96	-0.38	-0.60
Prices	1	0.06	0.01	-0.33	-0.17	1	0.09	0.04	-0.30	-0.15
Employment										
Capital	1,215	-2.26	-1.58	-0.27	-0.47	1,236	-2.35	-1.66	-0.37	-0.56
Labor	718	-3.44	-2.44	-0.30	-0.60	728	-3.48	-2.47	-0.38	-0.66
Wages										
Capital	1	-1.62	-1.17	-0.05	-0.19	1	-1.55	-1.11	-0.01	-0.15
Labor	1					1				
Trade										
Exports										
Imports	2,264	-2.46	-1.81	-1.18	-0.98	2,320	-2.44	-1.80	-1.21	-1.00
Net exports	-2,264	-2.46	-1.81	-1.18	-0.98	-2,320	-2.44	-1.80	-1.21	-1.00

Table B4.15: Selected Indicators for the Food Processing Sectors—Without and With the PMV Strategy by 2050 (BASE values in million MAD)

	Climate Change Only (CC-Only)					Climate Change with PMV (CC-PMV)				
		Without CO_2 fertilization		With CO_2 fertilization			Without CO_2 fertilization		With CO_2 fertilization	
	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)	BASE	A2 (%Δ)	B2 (%Δ)	A2 (%Δ)	B2 (%Δ)
Other food processing										
Domestic Market										
Consumption	46,125	-3.11	-2.28	-0.96	-0.92	47,002	-3.07	-2.25	-1.00	-0.94
Production	16,854	-3.25	-2.40	-0.80	-0.83	17,337	-3.18	-2.33	-0.82	-0.83
Prices	1	0.61	0.46	-0.04	0.02	1	0.53	0.39	-0.08	-0.01
Employment										
Capital	13,407	-2.96	-2.18	-0.72	-0.74	13,805	-2.89	-2.12	-0.75	-0.75
Labor	3,447	-4.37	-3.23	-1.09	-1.14	3,532	-4.27	-3.13	-1.09	-1.12
Wages										
Capital	1	-1.95	-1.43	-0.51	-0.55	1	-1.90	-1.38	-0.46	-0.50
Labor	1					1				
Trade										
Exports	13,913	-4.31	-3.20	-0.63	-0.82	14,004	-4.09	-3.01	-0.60	-0.75
Imports	5,521	-1.11	-0.78	-0.93	-0.73	5,649	-1.31	-0.96	-1.04	-0.85
Net exports	8,392	-6.41	-4.80	-0.44	-0.88	8,355	-5.97	-4.40	-0.30	-0.69

Source: Simulations results

Table B5.1: Regional Matching Between the GTAP and IFPRI Regions

GTAP region		IFPRI region	
Code	Description	Code	Description
BRA	Brazil	BRA	"Brazil"
CAN	Canada	CAN	"Canada"
EAsia	East Asia	CHN	"China"
EAsia	East Asia	JAP	"Japan"
EAsia	East Asia	MON	"Mongolia"
EAsia	East Asia	NOK	"North Korea"
EAsia	East Asia	SKO	"South Korea "
EastEU	Eastern Europe	ADR	"Adriatic"
EastEU	Eastern Europe	CEU	"Central Europe"
EastEU	Eastern Europe	POL	"Poland"
FrmUSSR	Former USSR	CAU	"Caucus"
FrmUSSR	Former USSR	KAZ	"Kazakhstan"
FrmUSSR	Former USSR	KYR	"Kyrgyzstan"
FrmUSSR	Former USSR	RUS	"Russia"
FrmUSSR	Former USSR	TAJ	"Tajikistan"
FrmUSSR	Former USSR	TKM	"Turkmenistan"
FrmUSSR	Former USSR	UKR	"Ukraine"
FrmUSSR	Former USSR	UZB	"Uzbekistan"
MOR	Morocco	MOR	"Morocco"
Oceania	Oceania	AUS	"Australia"
Oceania	Oceania	NZE	"New Zealand"
Oceania	Oceania	PNG	"Papua New Guinea"
OecdEU	OECD Europe	AEU	"Alpine Europe"
OecdEU	OECD Europe	BAL	"Baltic"
OecdEU	OECD Europe	BEL	"Belgium"
OecdEU	OECD Europe	BRI	"Britain British Isles"
OecdEU	OECD Europe	FRA	"France"
OecdEU	OECD Europe	GER	"Germany"
OecdEU	OECD Europe	IBE	"Iberia"
OecdEU	OECD Europe	ITA	"Italy"
OecdEU	OECD Europe	NET	"Netherlands"
OecdEU	OECD Europe	SCA	"Scandinavia"

Table B5.1: Regional Matching Between the GTAP and IFPRI Regions (continued)

GTAP region		IFPRI region	
Code	Description	Code	Description
SAsia	South Asia	AFG	"Afghanistan"
SAsia	South Asia	BAN	"Bangladesh"
SAsia	South Asia	BHU	"Bhutan"
SAsia	South Asia	IND	"India"
SAsia	South Asia	NEP	"Nepal"
SAsia	South Asia	PAK	"Pakistan"
SAsia	South Asia	SRL	"Sri Lanka"
SEAsia	Southeast Asia	INO	"Indonesia"
SEAsia	Southeast Asia	MLY	"Malaysia"
SEAsia	Southeast Asia	MYN	"Myanmar"
SEAsia	Southeast Asia	PHI	"Philippines"
SEAsia	Southeast Asia	SEA	"SE Asia"
SEAsia	Southeast Asia	SIN	"Singapore"
SEAsia	Southeast Asia	THA	"Thailand"
SEAsia	Southeast Asia	VIE	"Vietnam"
SSA	Sub-Saharan Africa	ANG	"Angola"
SSA	Sub-Saharan Africa	BEN	"Benin"
SSA	Sub-Saharan Africa	BOT	"Botswana"
SSA	Sub-Saharan Africa	BUF	"Burkina Faso"
SSA	Sub-Saharan Africa	BUR	"Burundi"
SSA	Sub-Saharan Africa	CAM	"Cameroon"
SSA	Sub-Saharan Africa	CAR	"Central African Republic"
SSA	Sub-Saharan Africa	CHA	"Chad"
SSA	Sub-Saharan Africa	CON	"Congo"
SSA	Sub-Saharan Africa	DJI	"Djibouti"
SSA	Sub-Saharan Africa	DRC	"Democratic Republic of Congo"
SSA	Sub-Saharan Africa	EQG	"Equatorial Guinea"
SSA	Sub-Saharan Africa	ERI	"Eritrea"
SSA	Sub-Saharan Africa	ETH	"Ethiopia"
SSA	Sub-Saharan Africa	GAB	"Gabon"
SSA	Sub-Saharan Africa	GAM	"Gambia"

Table B5.1: Regional Matching Between the GTAP and IFPRI Regions (continued)

GTAP region		IFPRI region	
Code	Description	Code	Description
SSA	Sub-Saharan Africa	GHA	"Ghana"
SSA	Sub-Saharan Africa	GUB	"Guinea Bissau"
SSA	Sub-Saharan Africa	GUI	"Guinea"
SSA	Sub-Saharan Africa	IVC	"Ivory Coast"
SSA	Sub-Saharan Africa	KEN	"Kenya"
SSA	Sub-Saharan Africa	LES	"Lesotho"
SSA	Sub-Saharan Africa	LIB	"Liberia"
SSA	Sub-Saharan Africa	MAD	"Madagascar"
SSA	Sub-Saharan Africa	MAL	"Mali"
SSA	Sub-Saharan Africa	MAU	"Mauritania"
SSA	Sub-Saharan Africa	MLW	"Malawi"
SSA	Sub-Saharan Africa	MOZ	"Mozambique"
SSA	Sub-Saharan Africa	NAM	"Namibia"
SSA	Sub-Saharan Africa	NIA	"Nigeria"
SSA	Sub-Saharan Africa	NIG	"Niger"
SSA	Sub-Saharan Africa	RWA	"Rwanda"
SSA	Sub-Saharan Africa	SAF	"South"
SSA	Sub-Saharan Africa	SEN	"Senegal"
SSA	Sub-Saharan Africa	SLE	"Sierra Leone"
SSA	Sub-Saharan Africa	SOM	"Somalia"
SSA	Sub-Saharan Africa	SUD	"Sudan"
SSA	Sub-Saharan Africa	SWA	"Swaziland"
SSA	Sub-Saharan Africa	TAN	"Tanzania"
SSA	Sub-Saharan Africa	TOG	"Togo"
SSA	Sub-Saharan Africa	UGA	"Uganda"
SSA	Sub-Saharan Africa	ZAM	"Zambia"
SSA	Sub-Saharan Africa	ZIM	"Zimbabwe"
TKY	Turkey	TKY	"Turkey"
UNS	United States	UNS	"United States"
XLatAmer	Rest of Latin America	ARG	"Argentina"
XLatAmer	Rest of Latin America	CCA	"Caribbean"
XLatAmer	Rest of Latin America	CHL	"Chile"

Table B5.1: Regional Matching Between the GTAP and IFPRI Regions (continued)

GTAP region		IFPRI region	
Code	Description	Code	Description
XLatAmer	Rest of Latin America	COL	"Colombia"
XLatAmer	Rest of Latin America	CSA	"Central South America"
XLatAmer	Rest of Latin America	ECU	"Ecuador"
XLatAmer	Rest of Latin America	MEX	"Mexico"
XLatAmer	Rest of Latin America	NSA	"Northern South America"
XLatAmer	Rest of Latin America	PER	"Peru"
XLatAmer	Rest of Latin America	URU	"Uruguay"
XMidEast	Rest of Middle-East	CYP	"Cyprus"
XMidEast	Rest of Middle-East	GUL	"Gulf States"
XMidEast	Rest of Middle-East	IRN	"Iran"
XMidEast	Rest of Middle-East	IRQ	"Iraq"
XMidEast	Rest of Middle-East	ISR	"Israel"
XMidEast	Rest of Middle-East	JOR	"Jordan"
XMidEast	Rest of Middle-East	LEB	"Lebanon"
XMidEast	Rest of Middle-East	SYR	"Syria"
XNAfrica	Rest of North Africa	ALG	"Algeria"
XNAfrica	Rest of North Africa	EGY	"Egypt"
XNAfrica	Rest of North Africa	LBY	"Libya"
XNAfrica	Rest of North Africa	TUN	"Tunisia"

Source: Author's construction
(Data: GTAP database version 7 and IFPRI Food Security CASE maps, 2010)

Table B5.2: Regional Matching between the GTAP and IMAGE Regions

GTAP region	IMAGE region
Oceania	Oceania
East Asia	East Asia, Japan
Southeast Asia	Southeast Asia
South Asia	South Asia
Canada	Canada
United States of America	USA
Rest of Latin America	Central America, South America
Brazil	South America
OECD Europe	OECD Europe
Rest of Middle East	Middle East
Eastern Europe	Eastern Europe
Former USSR	Former USSR
Turkey	Middle East
Rest of North Africa	Northern Africa
Morocco	Northern Africa
Sub-Saharan Africa	Eastern Africa, Southern Africa, Western Africa

Source: Author's construction
(Data: GTAP database version 7 and IMAGE 2.2, 2010)

Table B5.3: Aggregate and Regional Distribution of Average Allocative Efficiency Effects by Scenario by 2050 (in million US$)

GTAP region	Allocative efficiency (in million US$)												
	Climate change only	Climate change & Trade liberalization						Net impacts of trade liberalization					
	CCONLY	CCAGLIBEU	CCAGMENA	CCAGMULTI	CCMENA	CCMULTI	CCTRLIBEU	AGLIBEU	AGMENA	AGMULTI	MENA	MULTI	TRLIBEU
Aggregate results													
World	-4,075.6	-4,076.5	-4,030.9	22,334.5	-3,524.8	72,854.8	-3,524.8	-0.9	44.7	26,410.1	357.6	76,930	550.8
By region													
Oceania	106	106	106	121	107	647	103	-0.5	0.1	15	1	541	-3
East Asia	415	422	421	21,272	309	36,076	381	7	6	20,857	-107	35,660	-34
Southeast Asia	-78	-79	-78	110	-112	2,379	-85	-0.2	0.1	189	-34	2,457	-7
South Asia	-190	-188	-189	104	-264	4,199	-194	2	1.3	294	-75	4,389	-4
Canada	-112	-109	-111	-117	-112	637	-111	3	0.8	-6	-1	749	0.3
United States	-548	-537	-542	-469	-575	232	-539	11	6	79	-26	780	9
Brazil	-307	-304	-306	-443	-306	-510	-311	3	0.5	-137	1	-204	-4
Rest of Latin America	-826	-814	-821	-1,557	-829	-346	-793	13	5	-730	-3	481	33
OECD Europe	-1,965	-1,995	-1,954	1,577	-2,450	17,420	-1,507	-30	11	3,542	-486	19,385	458
Rest of the Middle-East	-173	-175	-172	214	1,474	3,087	-189	-2	2	387	1,648	3,260	-16
Eastern Europe	-365	-367	-364	135	-427	675	-313	-1	1.2	501	-62	1,040	52
Former USSR	-121	-124	-120	43	-22	2,924	-130	-3	1.0	164	99	3,045	-9
Turkey	-4	-15	1	837	-333	904	-39	-12	4	841	-329	908	-35
Rest of North Africa	11	10	15	104	-140	1,176	-8	-1	4	93	-151	1,165	-19
Morocco	78	86	78	319	-37	1,332	215	8	0.5	241	-114	1,254	137
Sub-Saharan Africa	4	7	5	86	-1	2,022	-1	3	0.2	81	-5	2,018	-5

Source: Simulation results

Table B5.4: Decomposition of Average Allocative Efficiency Effects by Tax Instrument under Climate Change Only under the 'CCAGLIBEU' Scenario by 2050 (in million US$)

GTAP region	Climate change only							Net impact trade liberalization						
	contax	govtax	inputtax	mtax	pfacttax	prodtax	xtax	contax	govtax	inputtax	mtax	pfacttax	prodtax	xtax
Aggregate														
World	-2,985.04	-151.97	-856.96	357.72	-635.04	136.21	59.50	24.22	1.86	-1.24	25.74	-23.49	-24.73	-3.15
By region														
Oceania	126.54	1.00	-12.54	54.10	-13.45	-32.64	-16.82	-0.80	-0.01	0.31	-0.77	0.17	0.46	0.17
East Asia	167.58	0.08	87.82	-249.23	196.02	153.01	60.10	0.91	0.00	0.67	2.43	2.32	2.73	-2.22
Southeast Asia	-20.00	-0.01	-4.67	-35.04	-0.11	-17.30	-1.16	0.19	0.00	0.12	-0.83	-0.01	0.38	-0.08
South Asia	36.04	0.04	-19.61	-116.89	-0.69	-74.30	-14.42	0.00	0.00	0.78	-1.19	-0.03	2.08	0.22
Canada	-21.49	0.00	-6.30	1.24	-68.59	-16.78	0.26	-0.97	0.00	0.63	-0.86	3.13	0.65	-0.03
United States	-145.23	0.00	-80.23	-70.85	-180.43	-67.20	-4.54	0.43	0.00	2.24	-2.77	6.32	4.74	0.44
Rest of Latin America	-360.31	-19.33	-93.21	-46.48	-51.63	-255.59	0.18	0.33	-0.15	0.61	-0.89	0.33	12.39	-0.06
Brazil	-221.98	0.00	-54.03	-34.37	-13.47	11.84	5.21	-0.17	0.00	1.47	-1.48	0.16	2.37	0.17
OECD Europe	-2,137.80	-129.95	-496.20	562.49	-324.57	551.08	10.32	14.97	1.47	-0.41	25.00	-31.03	-39.40	-1.17
Rest of the Middle-East	-37.70	-1.05	-21.07	14.95	1.89	-134.93	4.44	0.06	0.00	0.07	-2.24	-0.03	0.45	0.00
Eastern Europe	-115.97	-3.34	-81.50	1.59	-119.59	-45.87	-0.75	3.42	0.21	-3.08	9.27	-5.85	-5.14	-0.11
Former USSR	-172.61	-0.29	-73.84	52.41	-37.50	76.35	34.20	0.60	-0.01	2.57	-3.35	0.54	-2.73	-0.35
Turkey	-103.33	-0.77	10.36	70.56	-24.55	38.53	5.42	4.99	0.37	-7.44	-2.25	0.54	-7.06	-0.65
Rest of North Africa	-0.09	0.02	0.15	7.30	-0.96	7.25	-2.88	0.00	0.00	0.00	-0.94	-0.01	-0.03	0.18
Morocco	-0.01	0.00	0.00	79.15	0.00	-1.53	-0.03	-0.01	0.00	-0.01	5.04	0.00	2.64	0.11
Sub-Saharan Africa	21.31	1.64	-12.10	66.76	2.59	-55.71	-20.03	0.25	-0.01	0.25	1.58	-0.03	0.74	0.23

Source: Simulation results

Table B5.5: Impact on Domestic and Import Prices and Quantities for Private Household and Firms in OECD Europe by Commodity under 'CCAGLIBEU' Scenario by 2050 (in % change)

Commodity	Private household								Firms							
	Climate change only				Net impact trade liberalization				Climate change only				Net impact trade liberalization			
	Domestic		Imports		Domestic		Imports		Domestic		Imports		Domestic		Imports	
	ppd	qpd	ppm	qpm	ppd	qpd	ppm	qpm	pfd	qfd	pfm	qfm	pfd	qfd	pfm	qfm
Paddy rice	8.46	-19.51	-0.97	26.04	-0.10	-2.36	-1.00	2.11	8.46	-26.19	-0.97	9.98	-0.10	-3.19	-1.00	1.01
Wheat	15.60	-5.85	9.60	18.70	0.26	-0.27	0.04	0.72	15.60	-8.44	9.60	14.77	0.26	-0.26	0.04	0.70
Coarse grains	14.32	-1.19	11.03	2.29	0.05	-0.05	-0.08	0.12	14.32	-0.89	11.03	2.56	0.05	0.10	-0.08	0.26
Vegetables, fruits, and nuts	8.85	-2.32	5.49	3.22	0.04	-0.14	-0.14	0.20	8.85	-1.82	5.49	3.70	0.04	0.02	-0.14	0.35
Oilseeds	6.70	-3.47	3.39	3.36	0.05	-0.08	-0.01	0.07	6.70	-3.56	3.39	2.55	0.05	0.07	-0.01	0.20
Sugar cane, Suger beet	11.32	-0.26	4.64	18.58	0.05	0.00	0.01	0.12	11.32	-1.45	4.64	16.56	0.05	0.15	0.01	0.24
Other crops nes	6.28	-2.34	3.88	4.29	0.06	-0.06	-0.01	0.14	6.28	-1.56	3.88	5.05	0.06	0.10	-0.01	0.29
Meat, livestock, raw milk	0.72	-0.60	0.82	-0.88	0.03	-0.02	0.02	0.02	0.72	0.44	0.82	0.15	0.03	0.15	0.02	0.19
Forest, fish & minerals	-0.12	-0.14	-0.12	-0.14	0.00	0.00	0.00	0.00	-0.12	0.39	-0.12	0.40	0.00	0.16	0.00	0.16
Vegetable oils and fats	0.88	-0.37	1.27	-1.65	0.01	-0.03	-0.02	0.06	0.88	0.92	1.27	-0.38	0.01	0.12	-0.02	0.21
Other processed food	0.58	-0.58	0.61	-0.64	0.01	0.00	-0.01	0.03	0.58	0.41	0.61	0.35	0.01	0.15	-0.01	0.18
Textile and apparel	-0.04	-0.16	-0.01	-0.27	0.00	-0.01	-0.01	0.04	-0.04	0.44	-0.01	0.33	0.00	0.14	-0.01	0.19
Manufactures	-0.11	-0.12	-0.08	-0.22	0.00	0.00	0.00	0.01	-0.11	0.43	-0.08	0.33	0.00	0.16	0.00	0.16
Utilities and Construction	-0.12	-0.14	-0.10	-0.17	0.00	0.00	0.00	0.00	-0.12	0.40	-0.10	0.36	0.00	0.16	0.00	0.16
Transportation and Services	-0.11	-0.14	-0.08	-0.21	0.00	0.00	0.00	0.01	-0.11	0.40	-0.08	0.33	0.00	0.16	0.00	0.17

Source: Simulations results

Table B5.6: Impacts on Import Prices and Quantities of Trade Liberalization by Sector and by Scenario in Morocco and Turkey by 2050

	Sector	AGLIBEU		AGMENA		AGMULTI		MENA		MULTI		TRLIBEU	
		piw	qiw	piw	qiw	piw	qiw	piw	qiw	piw	qiw	piw	qiw
Morocco	Paddy rice (pdr)	1.10	74.87	0.00	-0.19	-3.30	88.93	-0.04	0.61	-3.85	96.21	1.11	90.07
	Wheat (wht)	3.25	102.51	-0.02	-0.09	2.61	132.48	-0.06	0.30	2.79	132.70	3.27	113.21
	Coarse grains (gro)	0.11	6.46	-0.01	-0.03	1.39	77.14	-0.07	-0.12	1.81	81.81	0.08	13.61
	Vegetables, fruits, and nuts (VegtFrut)	0.78	46.04	0.23	27.15	-0.32	64.46	0.60	26.02	-0.32	67.66	0.78	55.34
	Oilseeds (osd)	0.04	1.78	-0.01	0.13	-0.07	10.02	-0.09	-0.02	0.97	51.54	-0.03	59.70
	Sugar cane, Suger beet (c_b)	1.30	32.19	-0.01	-0.08	1.04	28.28	-0.07	0.34	0.25	42.10	1.28	65.46
	Other crops nes (OthCrop)	0.26	5.23	0.09	1.44	-1.12	19.36	0.11	1.21	-1.31	20.12	0.26	10.69
	Meat, livestock, raw milk (MtLkMlk)	0.01	-4.80	-0.01	-0.10	-0.42	-7.89	-0.06	1.20	0.65	822.87	-0.06	172.33
	Forest, fish, minerals (Extract)	0.00	1.21	0.00	0.03	0.02	2.74	0.31	10.24	-0.13	15.81	-0.01	2.60
	Vegetable oils and fats (VegtOil)	-0.01	-2.40	-0.01	-0.08	0.12	-6.98	0.00	1.12	-0.06	8.91	-0.17	9.27
	Other processed food (XPrFood)	0.00	-4.19	0.00	-0.07	-0.58	-7.69	0.11	3.33	-0.53	53.19	-0.03	41.84
	Textile and apparel (TextApp)	0.00	1.31	0.00	0.02	-0.19	2.87	0.22	7.38	-1.28	62.36	0.00	55.84
	Manufactures (Mnfctrs)	0.00	-0.71	0.00	-0.02	-0.04	-1.28	0.13	3.97	-0.82	23.85	0.01	19.81
	Utilities and Construction (UtilCons)	0.00	-0.91	0.00	-0.03	-0.07	-1.61	-0.02	-0.67	-1.01	-2.99	0.01	-0.40
	Transportation and Services (Svces)	0.00	-1.52	0.00	-0.04	-0.03	-2.83	0.00	-0.34	-0.62	-3.21	0.00	-0.32

Table B5.6: Impacts on Import Prices and Quantities of Trade Liberalization by Sector and by Scenario in Morocco and Turkey by 2050 (continued)

	Sector	AGLIBEU		AGMENA		AGMULTI		MENA		MULTI		TRLIBEU	
		piw	qiw	piw	qiw	piw	qiw	piw	qiw	piw	qiw	piw	qiw
Turkey	Paddy rice (pdr)	-0.03	15.35	-1.44	72.69	7.18	62.19	-1.11	90.44	9.18	65.89	-0.10	17.89
	Wheat (wht)	0.51	9.31	-0.02	0.24	1.97	44.64	-0.05	27.99	2.26	62.66	0.50	12.68
	Coarse grains (gro)	0.07	4.24	0.00	0.17	0.88	15.70	-0.04	5.09	0.13	19.23	0.05	4.91
	Vegetables, fruits, and nuts (VegtFrut)	-0.11	29.77	0.86	28.29	0.30	88.37	0.88	41.32	-0.47	100.48	-0.11	31.44
	Oilseeds (osd)	0.11	1.03	0.07	0.02	0.55	4.26	0.04	9.83	0.04	13.20	0.07	7.04
	Sugar cane, Suger beet (c_b)	-0.05	0.62	-0.01	0.09	1.03	49.04	0.02	15.28	-1.58	70.24	-0.07	3.60
	Other crops nes (OthCrop)	0.04	3.11	0.01	0.45	-0.09	64.32	-0.02	8.57	-0.39	69.64	0.02	4.51
	Meat, livestock, raw milk (MtLkMlk)	0.00	0.24	-0.01	0.02	-0.50	-0.52	-0.10	18.97	-0.30	69.45	-0.01	9.65
	Forest, fish, minerals (Extract)	0.00	-0.06	0.00	0.00	0.03	0.17	0.34	0.94	-0.11	0.94	-0.02	0.07
	Vegetable oils and fats (VegtOil)	-0.01	-0.06	-0.01	0.00	-0.25	-0.45	-0.03	9.50	-0.57	47.09	-0.10	28.34
	Other processed food (XPrFood)	0.00	-0.01	0.00	-0.05	-0.36	-1.78	0.00	15.39	-1.44	52.98	-0.02	25.09
	Textile and apparel (TextApp)	0.00	-0.05	0.00	0.00	-0.21	0.02	-0.08	3.82	-1.90	6.54	-0.05	0.58
	Manufactures (Mnfctrs)	0.00	0.01	0.00	0.00	-0.03	-0.04	-0.01	4.26	-0.94	3.78	0.00	0.89
	Utilities and Construction (UtilCons)	0.00	0.08	0.00	0.01	0.04	-0.18	0.07	6.24	-1.13	3.52	-0.01	1.26
	Transportation and Services (Svces)	0.00	0.07	0.00	0.01	-0.04	-0.03	-0.01	6.49	-0.77	3.01	0.00	1.25

Source: Simulation results

Table B5.7: Impacts on Export Prices and Quantities of Trade Liberalization by Sector and by Scenario in Morocco and Turkey by 2050 (% change)

	Sector	AGLIBEU		AGMENA		AGMULTI		MENA		MULTI		TRLIBEU	
		pxw	qxw	pxw	qxw	pxw	qxw	pxw	qxw	pxw	qxw	pxw	qxw
Morocco	Paddy rice (pdr)	-3.84	31.51	-0.06	-0.06	-7.03	-34.50	0.22	-3.63	-5.89	-35.97	-0.80	-2.91
	Wheat (wht)	-4.41	38.38	-0.05	0.34	-7.84	10.32	0.15	-1.54	-7.06	0.95	-1.77	10.60
	Coarse grains (gro)	-2.22	7.63	-0.06	0.10	-6.00	4.38	0.16	-0.62	-5.12	1.41	1.19	-1.22
	Vegetables, fruits, and nuts (VegtFrut)	-1.95	13.09	-0.10	0.47	-5.11	-2.02	0.10	0.40	-4.62	-5.37	0.87	5.71
	Oilseeds (osd)	-2.05	14.89	-0.06	1.56	-5.20	12.94	0.13	0.12	-2.41	-0.07	4.14	-15.51
	Sugar cane, Suger beet (c_b)	-2.08	10.42	-0.06	-0.13	-4.75	24.85	0.15	-1.28	-3.80	15.40	1.85	-9.57
	Other crops nes (OthCrop)	-2.04	42.82	-0.06	3.32	-4.97	38.12	0.07	2.65	-4.87	39.91	0.34	25.09
	Meat, livestock, raw milk (MtLkMlk)	-1.70	13.02	-0.04	0.25	-3.86	25.83	0.11	-2.01	-5.10	-17.75	-0.02	29.69
	Forest, fish, minerals (Extract)	-0.09	0.96	0.00	0.03	-0.17	1.96	-0.81	12.34	-2.67	32.10	-0.64	6.55
	Vegetable oils and fats (VegtOil)	-1.56	10.33	-0.06	0.35	-4.64	32.39	-0.18	1.04	-6.43	995.55	-0.51	1192.53
	Other processed food (XPrFood)	-2.60	10.09	-0.05	0.16	-5.60	21.44	0.00	1.45	-6.66	29.44	-1.34	11.59
	Textile and apparel (TextApp)	-0.75	5.51	-0.02	0.12	-1.73	11.46	-0.79	6.70	-12.19	101.20	-7.85	77.88
	Manufactures (Mnfctrs)	-0.53	3.76	-0.01	0.09	-1.16	8.09	-0.86	7.44	-5.31	34.18	-1.70	12.39
	Utilities and Construction (UtilCons)	-0.65	3.12	-0.02	0.08	-1.40	6.65	-0.39	1.88	-3.26	12.97	-0.19	0.90
	Transportation and Services (Svces)	-0.79	2.84	-0.02	0.07	-1.69	6.22	0.01	0.04	-2.11	7.22	0.51	-1.72

Table B5.7: Impacts on Export Prices and Quantities of Trade Liberalization by Sector and by Scenario in Morocco and Turkey by 2050 (% change) (continued)

Turkey	Paddy rice (pdr)	5.20	25124.52	-2.03	21.73	-2.11	1699.71	2.36	-18.93	0.03	1320.64	5.62	24340.75
	Wheat (wht)	0.10	120.27	0.01	0.57	-0.97	25.91	5.66	-38.32	1.89	-10.35	0.68	109.80
	Coarse grains (gro)	0.16	70.74	0.01	1.30	-0.70	53.01	6.91	-14.06	3.11	35.84	0.71	68.56
	Vegetables, fruits, and nuts (VegtFrut)	0.21	6.04	0.02	3.12	-0.92	-4.72	5.62	-12.77	1.95	-14.85	0.82	4.22
	Oilseeds (osd)	-0.09	2.66	0.00	4.00	-1.08	160.36	4.35	-14.56	0.95	92.69	0.64	-1.41
	Sugar cane, Suger beet (c_b)	0.16	-0.84	0.02	-0.74	-0.70	1.01	5.33	-24.79	1.83	-17.18	0.81	-4.29
	Other crops nes (OthCrop)	0.03	2.18	0.00	1.26	-1.96	196.20	3.66	-18.15	-0.67	194.79	0.49	-0.57
	Meat, livestock, raw milk (MtLkMlk)	0.10	-0.64	0.00	-0.03	-0.91	1.85	6.24	2322.28	2.34	2332.58	0.63	9.48
	Forest, fish, minerals (Extract)	0.01	-0.04	0.00	-0.01	0.01	0.23	1.28	2.34	0.45	10.32	0.14	-1.14
	Vegetable oils and fats (VegtOil)	-0.05	0.20	-0.01	0.02	-0.58	0.86	2.61	12.09	-1.21	194.34	-0.07	294.79
	Other processed food (XPrFood)	-0.01	0.01	-0.03	0.11	-1.52	3.81	3.46	1.77	-0.60	19.04	0.47	19.03
	Textile and apparel (TextApp)	0.03	-0.24	0.00	-0.03	-0.16	-0.35	2.48	-6.32	-0.43	-9.40	0.49	-1.58
	Manufactures (Mnfctrs)	0.02	-0.14	0.00	-0.01	-0.09	0.40	2.03	2.03	-0.21	5.73	0.40	-0.09
	Utilities and Construction (UtilCons)	0.04	-0.16	0.00	-0.02	-0.12	0.54	2.73	-11.51	0.41	-5.27	0.53	-2.40
	Transportation and Services (Svces)	0.04	-0.13	0.00	-0.01	-0.15	0.60	3.28	-10.28	0.74	-2.97	0.64	-2.11

Source: Simulation results

Table B5.8: Impact on Output Disposal, Domestic Sales and Import Sales in Morocco and Turkey under Climate Change Only by 2050 (in % Change)

	Sector	Output disposal		Domestic sales			Import sales		
		Domestic	Exports	Hhds	Gov	Firm	Hhds	Gov	Firm
Morocco	Paddy rice (pdr)	2.76	156.17	6.02	14.56	-3.62	-30.70	-29.37	-32.70
	Wheat (wht)	1.02	8.94	-0.47	-9.18	3.26	35.14	19.74	45.74
	Coarse grains (gro)	10.69	2.01	10.37	-0.94	11.19	13.11	1.30	14.07
	Vegetables, fruits, and nuts (VegtFrut)	-1.43	30.74	-1.08	0.06	-2.54	-5.30	-4.71	-6.56
	Oilseeds (osd)	1.56	32.26	3.56	3.44	0.02	-0.91	-2.62	-2.57
	Sugar cane, Suger beet (c_b)	18.47	-25.14	17.34	-0.26	18.64	55.09	29.21	57.15
	Other crops nes (OthCrop)	1.86	15.17	1.08	-0.67	2.40	3.00	1.19	5.44
	Meat, livestock, raw milk (MtLkMlk)	-0.31	-0.34	-0.10	-0.24	-0.46	0.05	-0.09	-0.51
	Forest, fish, minerals (Extract)	-0.39	0.14	-0.97	-0.17	-0.27	-1.15	-0.35	-0.46
	Vegetable oils and fats (VegtOil)	0.56	-4.03	0.65	-0.33	-0.03	0.82	-0.16	0.13
	Other processed food (XPrFood)	0.89	-6.16	0.97	-0.62	0.78	3.76	2.11	3.85
	Textile and apparel (TextApp)	-1.36	-1.36	-1.10	-0.67	-1.49	-0.43	-0.01	-0.90
	Manufactures (Mnfctrs)	-0.52	0.31	-1.10	-0.21	-0.45	-1.14	-0.26	-0.49
	Utilities and Construction (UtilCons)	-0.58	0.32	-1.08	-0.23	-0.52	-1.15	-0.31	-0.55
	Transportation and Services (Svces)	-0.59	-0.03	-1.23	-0.23	-0.47	-1.23	-0.24	-0.40

Table B5.8: Impact on Output Disposal, Domestic Sales and Import Sales in Morocco and Turkey under Climate Change Only by 2050 (in % Change) (continued)

Turkey	Paddy rice (pdr)	-13.20	9.46	-20.84	-7.96	-13.18	-2.73	13.56	7.14
	Wheat (wht)	6.55	14.67	9.35	-0.97	5.83	49.27	33.97	42.05
	Coarse grains (gro)	15.55	5.06	7.73	-2.85	16.24	11.44	0.49	18.90
	Vegetables, fruits, and nuts (VegtFrut)	10.24	-2.56	10.55	-1.04	11.09	16.47	4.13	16.79
	Oilseeds (osd)	3.00	-59.93	25.61	-5.70	-6.36	122.31	59.17	36.00
	Sugar cane, Suger beet (c_b)	39.82	-65.85	37.65	-11.82	39.83	127.78	39.40	124.63
	Other crops nes (OthCrop)	1.94	-21.61	2.68	-3.31	1.63	19.40	12.39	11.77
	Meat, livestock, raw milk (MtLkMlk)	2.51	-19.71	1.64	-2.20	4.15	10.46	6.24	12.49
	Forest, fish, minerals (Extract)	-0.26	0.69	-1.13	-0.92	0.14	-1.55	-1.34	-0.08
	Vegetable oils and fats (VegtOil)	-0.46	-2.05	-0.07	-1.35	-0.96	1.94	0.61	1.01
	Other processed food (XPrFood)	1.20	-6.09	1.25	-1.04	1.06	4.31	1.95	4.13
	Textile and apparel (TextApp)	0.05	1.03	-0.99	-0.90	0.52	-1.57	-1.48	0.14
	Manufactures (Mnfctrs)	-0.38	1.14	-1.23	-0.72	0.05	-1.77	-1.27	-0.48
	Utilities and Construction (UtilCons)	-0.89	0.70	-1.34	-0.96	-0.85	-1.59	-1.21	-1.19
	Transportation and Services (Svces)	-1.14	0.67	-1.61	-0.96	-0.63	-1.87	-1.23	-1.17

Source: Simulation results

Table B5.9: Net Impacts of Trade Liberalization on Total Output Disposal in Morocco and Turkey by Sector by 2050 (in % change)

	Sector	BASELINE		Trade liberalization net effects (in % change)											
				AGLIBEU		AGMENA		AGMULTI		MENA		MULTI		TRLIBEU	
		domestic	export	domestic	export	domestic	export	domestic	export	domestic	export	domestic	export	domestic	export
Morocco	Paddy rice (pdr)	3.07	0.05	-20.21	25.39	-0.29	-7.05	-24.84	-36.58	-0.70	-10.2	-27.58	-39	-22.39	-5.59
	Wheat (wht)	2389.46	31.86	-33.32	39.48	-0.10	-0.63	-49.61	8.75	-0.57	-2.54	-50.68	-1.23	-35.46	12.92
	Coarse grains (gro)	1072.52	15.32	-2.46	5.41	-1.10	-0.17	-20.64	-1.99	-1.32	-0.69	-17.92	-4.03	4.24	-0.17
	Vegetables, fruits, and nuts (VegtFrut)	1901.69	857.60	-2.83	8.28	-0.90	-2.24	-5.94	-9.15	-1.03	-2.13	-4.42	-11.99	1.67	3.92
	Oilseeds (osd)	195.02	2.45	-0.81	8.72	-0.25	-1.20	-6.53	4.87	-0.86	-2.39	34.49	-4.14	54.57	-14.40
	Sugar cane, Suger beet (c_b)	198.32	0.00	-1.40	13.44	-1.74	3.49	-1.12	24.54	-1.85	2.49	3.44	15.85	13.16	-4.39
	Other crops nes (OthCrop)	692.62	50.47	-2.89	38.28	-0.63	1.88	-9.03	29.72	-0.88	1.32	-8.95	30.95	-2.31	23.51
	Meat, livestock, raw milk (MtLkMlk)	5474.47	118.32	-0.60	10.96	0.02	0.25	-1.22	20.98	0.21	-1.86	-16.50	-22	5.02	29.61
	Forest, fish, minerals (Extract)	1755.05	950.52	1.31	0.85	0.07	0.01	2.91	1.77	-10.13	11.41	-23.74	28.55	-9.65	5.84
	Vegetable oils and fats (VegtOil)	231.76	103.24	1.18	9.07	-0.02	0.76	4.38	26.80	-2.40	1.33	-6.40	932	2.79	1193
	Other processed food (XPrFood)	6206.83	1292.20	-1.25	8.18	-0.12	0.85	-2.47	15.65	-0.79	2.19	-10.33	21.86	-4.82	11.05
	Textile and apparel (TextApp)	3743.79	3525	3.05	4.81	0.21	0.26	6.19	9.69	-2.65	6.03	-26.64	76.86	-21.74	64.11
	Manufactures (Mnfctrs)	20916	5096	0.78	3.12	0.07	0.04	1.72	6.80	-1.76	6.49	-14.02	27.06	-10.65	10.43
	Utilities and Construction (UtilCons)	8026.81	27.64	-0.76	2.38	0.04	0.03	-1.66	5.12	1.29	1.45	4.47	9.27	6.09	0.66
	Transportation and Services (Svces)	40690	5425	-0.65	2.26	0.05	0.06	-1.14	4.83	-0.30	0.02	-2.06	4.30	-0.38	-1.40

Table B5.9: Net Impacts of Trade Liberalization on Total Output Disposal in Morocco and Turkey by Sector by 2050 (in % change) (continued)

Turkey	Paddy rice (pdr)	46.82	0.20	-3.50	25848	-40.71	17.11	-39.68	1616	-43.69	-18.6	-37.76	1281	-3.32	25110
	Wheat (wht)	4077.63	11.74	-1.16	119	-0.69	-0.68	-4.24	28.86	12.24	-35.5	4.61	-5.34	-0.48	110
	Coarse grains (gro)	2038.56	18.06	-1.58	70.01	-1.52	0.80	-3.22	51.22	30.02	-8.57	20.66	39.43	-1.22	68.75
	Vegetables, fruits, and nuts (VegtFrut)	14862.20	2319.09	-1.16	6.60	-1.33	3.49	-2.89	-5.14	3.92	-7.57	-0.43	-12.77	-0.40	5.40
	Oilseeds (osd)	756.13	64.45	-1.48	19.44	-0.39	21.58	-4.00	204	0.65	4.08	-2.66	130	2.98	15.60
	Sugar cane, Suger beet (c_b)	774.98	0.01	-3.00	20.51	-3.13	20.66	-3.25	22.26	2.50	-3.93	-1.16	2.64	-1.33	17.08
	Other crops nes (OthCrop)	4843.05	742.54	-0.95	5.38	-0.32	4.39	-31.56	202	3.27	-13	-30.60	205	-0.54	3.02
	Meat, livestock, raw milk (MtLkMlk)	11166.16	185.00	-0.07	2.19	-0.31	2.69	-0.91	3.71	8.19	2555	-0.66	2470	-0.11	13.20
	Forest, fish, minerals (Extract)	5582.67	859.17	-0.01	-0.11	0.03	-0.08	0.23	0.17	-1.65	3.57	-1.61	10.72	-0.27	-1.08
	Vegetable oils and fats (VegtOil)	2798.74	260.26	0.06	0.39	0.05	0.25	0.09	0.55	2.44	15.32	-4.98	192	3.45	296
	Other processed food (XPrFood)	30715	2862	-0.13	0.72	-0.15	0.80	-1.01	2.99	3.85	6.06	-1.67	19.19	-0.11	20.45
	Textile and apparel (TextApp)	12872.97	17863	-0.11	-0.32	-0.02	-0.14	-0.27	-0.63	-3.08	-4.01	-10.08	-10.2	-0.77	-1.20
	Manufactures (Mnfctrs)	83831.05	37149	0.01	-0.25	0.04	-0.13	0.11	0.18	-0.54	3.93	-2.98	5.39	-0.02	0.19
	Utilities and Construction (UtilCons)	45907.63	785.38	0.13	-0.20	0.11	-0.09	-0.02	0.34	4.34	-9.16	0.54	-4.96	1.03	-1.96
	Transportation and Services (Svces)	192256	17429	0.16	-0.18	0.13	-0.08	0.10	0.26	3.58	-8.60	0.89	-4.28	0.83	-1.82

Source: Simulation results

Table B5.10: Net Impacts of Trade Liberalization on Domestic Sales Disposal in Morocco and Turkey by Sector by 2050 (in % change)

	Sector	Trade liberalization net effects (in % change)																	
		AGLIBEU			AGMENA			AGMULTI			MENA			MULTI			TRLIBEU		
		Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm
Morocco	Paddy rice (pdr)	-26	-28.3	-11.4	-5.68	-12.7	3.77	-31	-31.7	-14.6	-6.08	-14	3.46	-32.3	-35.8	-20.3	-27.8	-32.2	-13.94
	Wheat (wht)	-35.8	-23	-29.1	0.47	10.1	-3.14	-53.7	-40.6	-43.3	-0.05	8.78	-3.49	-54.1	-43.5	-45.2	-38.1	-27.5	-30.83
	Coarse grains (gro)	-11.6	-0.8	-9.90	-9.43	0.90	-10	-31	-7.83	-22.2	-9.64	0	-10.2	-30.6	-11.3	-16.6	-10.2	-2.45	3.39
	Vegetables, fruits, and nuts (VegtFrut)	-2.79	-2.8	2.31	-0.09	-0.7	1.90	-6.36	-4.67	0.66	-0.22	-1.6	1.78	-6.04	-8.24	6.32	-0.85	-4.23	15.59
	Oilseeds (osd)	-5.68	-5.12	0.68	-3.57	-3.43	-0.06	-14.03	-10.38	-2.71	-4.06	-4.51	-0.76	-14.09	-15.14	71.03	-8.53	-11.33	102.65
	Sugar cane, Suger beet (c_b)	-16.51	-1.40	-15.40	-14.82	0.22	-15.72	-18.42	-2.81	-15.15	-14.94	-0.69	-15.81	-17.74	-6.41	-11.19	-13.77	-2.73	-2.76
	Other crops nes (OthCrop)	-4.85	-1.88	-4.21	-1.76	0.32	-2.58	-13.73	-6.69	-8.34	-2.14	-0.63	-2.74	-13.87	-10.25	-8.11	-5.59	-4.42	-2.75
	Meat, livestock, raw milk (MtLkMlk)	-1.40	-1.26	0.50	0.06	0.20	0.46	-2.85	-2.51	0.49	-0.38	-0.74	1.13	-34.12	-26.36	-2.74	-4.87	-5.40	13.02
	Forest, fish, minerals (Extract)	0.62	-1.33	1.87	0.97	0.13	0.31	0.70	-2.60	3.77	-5.52	-6.67	-10.65	-14.32	-19.75	-25.25	-3.90	-6.77	-10.39
	Vegetable oils and fats (VegtOil)	0.39	0.75	2.69	-0.61	0.36	0.10	3.36	3.61	7.36	-3.05	-2.00	-1.78	-12.01	-10.85	29.79	-5.80	-5.81	59.96
	Other processed food (XPrFood)	-2.62	-0.62	-1.10	-0.99	0.58	-0.78	-4.32	-1.67	-1.56	-1.88	-0.56	-1.09	-13.53	-9.78	-7.13	-7.85	-5.16	-2.00
	Textile and apparel (TextApp)	1.18	0.37	5.87	1.11	0.66	1.61	1.55	0.33	10.43	-2.42	-3.17	-0.99	-31.72	-32.85	-22.79	-26.03	-26.61	-18.18
	Manufactures (Mnfctrs)	1.00	-0.83	1.30	1.11	0.18	0.47	1.39	-1.59	2.33	-1.99	-2.10	-1.20	-16.60	-16.29	-13.20	-12.17	-11.22	-9.97
	Utilities and Construction (UtilCons)	0.20	-1.40	-0.29	1.07	0.19	0.50	-0.33	-2.81	-1.24	0.22	-0.71	2.01	-1.84	-6.41	5.84	0.15	-2.73	7.43
	Transportation and Services (Svces)	0.15	-1.37	0.30	1.22	0.19	0.47	-0.45	-2.74	0.25	0.47	-0.71	0.54	-0.93	-6.35	0.30	0.50	-2.75	1.28

Table B5.10: Net Impacts of Trade Liberalization on Domestic Sales Disposal in Morocco and Turkey by Sector by 2050 (in % change) (continued)

Turkey	Paddy rice (pdr)	5.31	-0.1	9.37	-50.4	-27	-32.6	-50	-26	-31.6	-57	-31.3	-36	-49	-26	-2	3.7	-0.3	9.58
	Wheat (wht)	-8.46	1.01	-6.21	-8.54	0.98	-5.52	-9.29	0.80	-10.1	-3.42	4.61	9.92	-6.78	1.51	0.96	-7.90	1.61	-5.53
	Coarse grains (gro)	-10.08	2.16	-13.87	-7.31	2.89	-13.99	-20.80	-0.88	-14.75	-5.83	5.37	15.38	-20.71	-0.99	7.55	-9.92	2.67	-13.55
	Vegetables, fruits, and nuts (VegtFrut)	-9.68	0.92	-10.02	-9.83	0.89	-10.22	-11.34	0.30	-11.47	-4.98	4.45	-5.35	-8.99	0.95	-9.37	-9.11	1.51	-8.78
	Oilseeds (osd)	-20.78	5.85	5.07	-20.4	6.03	6.69	-22.05	5.17	1.69	-18.06	9.04	6.50	-21.19	5.42	3.32	-20.37	6.34	12.52
	Sugar cane, Suger beet (c_b)	-27.2	13.3	-28.4	-27.3	13.39	-28.5	-28	4.05	-28.6	-23.7	14.40	-24.3	-26.7	1.52	-27	-27	13.6	-27.1
	Other crops nes (OthCrop)	-3.25	2.97	-2.65	-2.70	3.35	-1.76	-31.73	-17.96	-39.75	-0.73	5.66	6.29	-32.03	-18.40	-35.07	-2.93	3.41	-2.04
	Meat, livestock, raw milk (MtLkMlk)	-1.56	2.25	-3.56	-1.62	2.25	-4.08	-2.05	2.23	-4.96	2.34	3.70	11.59	-6.95	-5.86	4.01	-1.73	1.92	-3.36
	Forest, fish, minerals (Extract)	1.16	0.96	-0.19	1.15	0.93	-0.14	1.31	0.77	0.09	2.38	4.11	-3.12	1.27	1.16	-2.55	1.36	1.50	-0.66
	Vegetable oils and fats (VegtOil)	0.06	1.42	0.99	0.06	1.37	0.97	-0.06	1.35	1.23	1.83	3.65	4.20	-7.71	-4.73	-0.49	-3.10	-1.00	13.13
	Other processed food (XPrFood)	-1.23	1.08	-1.05	-1.26	1.05	-1.07	-2.13	0.91	-1.87	2.02	4.49	4.92	-3.41	0.84	-0.64	-1.55	1.38	-0.06
	Textile and apparel (TextApp)	1.01	0.93	-0.67	1.00	0.90	-0.53	0.97	0.72	-0.88	1.35	3.61	-5.20	-3.87	-0.22	-13.03	1.07	1.36	-1.66
	Manufactures (Mnfctrs)	1.25	0.73	-0.10	1.24	0.72	-0.05	1.41	0.61	-0.03	1.97	2.00	-1.30	-0.63	-1.06	-3.66	1.37	0.89	-0.21
	Utilities and Construction (UtilCons)	1.39	1.01	0.89	1.36	0.97	0.87	1.44	0.80	0.73	4.38	4.60	5.23	2.00	1.50	1.29	1.93	1.60	1.83
	Transportation and Services (Svces)	1.67	1.00	0.64	1.64	0.97	0.63	1.72	0.80	0.54	5.55	4.56	3.50	2.83	1.49	0.96	2.38	1.59	1.34

Source: Simulation results

Table B5.11: Net Impacts Trade Liberalization on Imports Sales Disposal in Morocco and Turkey by Sector by 2050 (in % change)

	Sector	Trade liberalization net effects (in % change)																	
		AGLIBEU			AGMENA			AGMULTI			MENA			MULTI			TRLIBEU		
		Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm	Hhds	Gov	Firm
Morocco	Paddy rice (pdr)	102.8	112.5	130.4	44.01	41.30	48.3	107.4	121.8	144	45.11	41.31	49.67	116.2	121.7	142.9	121.1	124.95	149.67
	Wheat (wht)	-2.85	22.24	5.50	-26.1	-16.6	-31.5	5.33	41.77	24.91	-25.86	-16.90	-31.12	6.40	37.41	23.06	1.92	25.24	12.51
	Coarse grains (gro)	-13.49	-2.70	-11.89	-11.63	-1.34	-12.3	-19.61	7.68	-9.43	-11.77	-2.18	-12.45	-19.00	3.77	-0.96	-11.17	-3.33	4.78
	Vegetables, fruits, and nuts (VegtFrut)	20.33	20.91	26.57	14.71	14.69	16.8	24.69	27.52	33.90	14.35	13.46	16.45	25.86	23.44	44.54	25.76	21.98	49.51
	Oilseeds (osd)	-1.08	1.17	3.69	0.87	2.68	2.69	-3.32	2.56	7.56	0.74	1.91	2.33	-0.71	-0.18	103.96	4.81	3.41	139.95
	Sugar cane, Suger beet (c_b)	-23.58	-8.05	-22.60	-35.61	-22.70	-36.4	-28.01	-12.65	-25.13	-35.40	-23.04	-36.20	-24.93	-13.05	-17.67	-15.46	-2.91	-2.91
	Other crops nes (OthCrop)	-3.00	0.08	-3.93	-2.33	-0.25	-4.25	1.07	9.29	3.81	-2.53	-1.01	-4.16	1.27	5.54	4.94	1.20	2.54	3.77
	Meat, livestock, raw milk (MtLkMlk)	-4.96	-4.81	-3.47	-0.16	-0.02	0.43	-10.34	-10.02	-8.01	0.16	-0.19	1.15	405.94	465.54	588.83	61.46	60.57	90.22
	Forest, fish, minerals (Extract)	0.41	-1.53	1.77	1.15	0.30	0.49	0.09	-3.19	3.41	11.17	9.82	3.27	25.08	17.16	3.82	7.63	4.43	-1.51
	Vegetable oils and fats (VegtOil)	-3.31	-2.96	-1.02	-0.90	0.07	-0.18	-7.69	-7.46	-3.85	-0.85	0.22	0.43	-4.47	-3.21	47.20	-0.48	-0.50	76.69
	Other processed food (XPrFood)	-7.91	-5.99	-6.72	-3.70	-2.15	-3.76	-11.99	-9.52	-9.72	-2.98	-1.66	-2.34	8.25	12.98	17.00	8.10	11.29	15.39
	Textile and apparel (TextApp)	-1.54	-2.32	3.22	0.38	-0.06	0.96	-3.30	-4.45	5.57	1.33	0.56	2.96	9.10	7.31	25.13	10.54	9.67	22.96
	Manufactures (Mnfctrs)	-0.27	-2.06	-0.06	1.12	0.20	0.48	-1.31	-4.21	-0.57	0.97	0.86	1.88	4.41	4.82	8.71	5.78	6.94	8.63
	Utilities and Construction (UtilCons)	-0.48	-2.06	0.16	1.13	0.25	0.54	-1.79	-4.22	-0.23	-0.14	-1.06	0.29	-4.32	-8.77	-2.39	-0.02	-2.88	0.72
	Transportation and Services (Svces)	-0.56	-2.05	-0.63	1.20	0.18	0.38	-1.94	-4.19	-1.58	0.48	-0.70	0.54	-2.26	-7.60	-1.68	0.96	-2.30	1.11

Table B5.11: Net Impacts Trade Liberalization on Imports Sales Disposal in Morocco and Turkey by Sector by 2050 (in % change) (continued)

Turkey	Paddy rice (pdr)	6.21	0.10	7.39	-7.37	36.72	21.32	-7.21	35.37	21.88	-5.44	51.01	34.57	-5.37	36.85	27.06	6.53	1.79	9.73
	Wheat (wht)	-27.65	-19.45	-25.02	-32.87	-25.21	-29.47	-7.37	3.88	-8.44	-14.25	-6.26	-9.97	4.01	14.31	3.25	-25.74	-17.34	-22.69
	Coarse grains (gro)	-11.88	0.13	-15.14	-10.34	-0.46	-15.84	-18.54	1.96	-13.07	-7.06	4.01	-7.68	-17.31	3.27	-8.44	-11.58	0.79	-13.70
	Vegetables, fruits, and nuts (VegtFrut)	-5.37	5.86	-5.54	-5.67	5.70	-5.90	15.95	31.33	16.05	4.02	14.51	3.85	22.59	36.15	22.29	-4.27	7.03	-3.70
	Oilseeds (osd)	-54.41	-36.14	-26.77	-54.97	-37.10	-26.47	-53.57	-34.21	-26.97	-50.73	-31.21	-19.27	-51.29	-31.55	-20.95	-53.68	-35.13	-22.23
	Sugar cane, Suger beet (c_b)	-55.85	-28.06	-55.23	-56.07	-28.24	-55.45	-43.75	-14.75	-43.03	-49.60	-21.08	-48.67	-37.24	-9.30	-36.57	-55.06	-27.07	-53.91
	Other crops nes (OthCrop)	-14.51	-8.97	-10.05	-16.00	-10.74	-10.43	48.27	78.27	1.54	-7.53	-1.54	-5.09	53.06	83.85	4.00	-13.38	-7.68	-8.82
	Meat, livestock, raw milk (MtLkMlk)	-9.24	-5.69	-10.87	-9.45	-5.86	-11.09	-10.73	-6.80	-12.52	7.09	8.55	9.04	35.70	37.36	40.84	-4.09	-0.50	-5.71
	Forest, fish, minerals (Extract)	1.60	1.41	0.02	1.58	1.36	0.08	1.67	1.13	0.28	7.60	9.42	1.01	4.99	4.87	0.59	2.50	2.64	0.08
	Vegetable oils and fats (VegtOil)	-1.99	-0.64	-1.07	-1.91	-0.61	-1.01	-2.75	-1.36	-1.48	6.43	8.35	8.89	21.96	25.92	31.49	9.38	11.77	27.74
	Other processed food (XPrFood)	-4.14	-1.89	-3.98	-4.19	-1.94	-4.02	-6.20	-3.28	-5.95	6.46	9.04	8.13	21.12	26.46	23.20	6.58	9.76	8.20
	Textile and apparel (TextApp)	1.69	1.61	-0.25	1.61	1.51	-0.15	1.71	1.46	-0.42	10.03	12.47	1.45	10.86	15.07	-1.86	3.24	3.54	-0.05
	Manufactures (Mnfctrs)	1.87	1.35	0.48	1.81	1.29	0.49	1.83	1.03	0.38	7.85	7.89	4.06	5.20	4.75	1.39	2.99	2.50	1.26
	Utilities and Construction (UtilCons)	1.69	1.30	1.27	1.62	1.23	1.21	1.51	0.86	0.89	7.83	8.05	8.78	4.08	3.58	3.13	2.82	2.49	2.82
	Transportation and Services (Svces)	1.99	1.31	1.24	1.92	1.25	1.19	1.89	0.97	1.08	8.97	7.94	6.77	4.53	3.16	2.78	3.26	2.46	2.33

Source: Simulation results

VITA

VITA

Ismail Ouraich was born in Goulmima, Morocco on July 8, 1983, the son of Mohamed Ouraich and Rkia Berrad Ouraich. After completing high school at Lycee Mly Abdellah in Errachidia, Morocco in 2001, Ismail attended the Ecole Nationale de Commerce et de Gestion (ENCG) in Agadir, Morocco. He graduated in June 2006 with a Bachelor in Accounting and Financial Management. Ismail began graduate studies in the Department of Business Economics and Management at the Mediterranean Agronomic Institute of Chania (MAICh) in August 2006. He received a Master of Science (M.Sc.) degree on Business Economics and Management in August 2008. He entered the Department of Agricultural Economics at Purdue University in August 2008.