82588

Climate Change and Agriculture in South Asia: Alternative Trade Policy Options

David Laborde, Csilla Lakatos, Gerald Nelson,

Richard Robertson and Marcelle Thomas

(IFPRI)

in cooperation with Winston Yu and Hans G.P. Jansen

(World Bank)

0 Executive Summary

Climate change typically involves changes in water availability and temperature - and both of these affect crop yields. Changes in crop yields in turn influence prices –of commodities as well as production factors. Changes in relative factor prices will stimulate their reallocation in the economy and result in changes in sectoral specialization. Sectoral incomes will be affected which, together with changes in sectoral specialization, will result in adjustments in sectoral demand and supply. These changes however, do not occur in a closed economy but at a global level with heterogeneous effects across countries and commodities. Comparative advantages evolve, trade patterns adapt and countries are affected by both the domestic effects of climate change and by changes in relative prices in world markets (terms of trade effects). Over time, considering income and current account constraints, production will be reallocated across sectors and across regions to adapt to the exogenous changes in yields. General equilibrium effects may mitigate or magnify the initial impacts.

Given the complex relationships described above, adequately modeling of the economy-wide effects of climate change requires linking of climate models (Global Circulation Models) to economy-wide models (computable general equilibrium or CGE models). In this paper we combine climate models with a world-wide CGE model to analyze the economic impacts of climate change in South Asia. First, we use IFPRI's IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) framework to assess the effects of climate change (i.e. changes in water availability and temperature) on crop yields under the assumption of no changes in economic behavior. Subsequently we feed these exogenous changes in a global computable general equilibrium model (MIRAGE – Modeling International Relationships in Applied General Equilibrium) to assess the economic impact of climate change. For the purposes of this paper MIRAGE was expanded to provide a more accurate description of land use and long term dynamic issues. MIRAGE is also used to analyze the impact of different climate change scenarios with different socio-economic baselines including alternative trade policies.

At the global level, South Asia is an important player in terms of production and consumption of key cereals and other staple foods such as pulses (an important element of South Asia traditional diet). South Asia has managed to cope with increasing domestic demand for these

commodities by improving yields but the region as a whole is not a significant grain exporter. In an attempt to maintain food security, most South Asian countries protect their domestic grain markets from world markets through interventionist policies and do not rely on trade. Nevertheless there exist differences between individual grain crops and across countries. For example in the case of rice, increases in yields have allowed most South Asian countries to improve their degree of self-sufficiency. For wheat on the other hand, while India has managed to export wheat in some years, the smaller economies of the region (Sri Lanka, Nepal, Bangladesh) remain dependent on large imports. While the overall situation for cereals remains satisfactory, limited yield gains for pulses have increased the demand-supply gap over time and made South Asia increasingly dependent on imports.

Continuing increases in crop yields are required in South Asia in order to ensure that supply keeps up with demand. In this context the slowdown in yield increases seen in the region over the past decade or so is worrisome and any further perturbation coming from climate change can lead to a quick deterioration of the regional staple food balance.

The paper begins by investigating to what extent yield increases have impacted self sufficiency ratios. ***The results show that while changes in yields may lead to improvement or deterioration in the degree of domestic self sufficiency, the link is robust only in the case of rice and depends on the origin of the change in yields - either of short term nature such as climatic events or of more long term character such as technological change.*** Yield changes can be expected to influence land allocation decisions by farmers making modeling such land use changes important. Yield reductions can be expected to result in price increases which in turn will translate into demand reductions and detrimental effects on the nutritional status of especially the poor. Trade liberalization may help to mitigate such price increases and protect consumers against nutritional shortfalls.

The paper further investigates the link between changes in domestic production and net exports of South Asian countries. The findings show that ***countries use trade to balance disruptions in domestic production in the case of pulses but hardly in the case of cereals***. This is due to the combination of a lack of large storage capacity for pulse crops and more liberal trade policies compared to cereal crops. For example in Pakistan and India import tariffs on pulses are 50 percent or less compared to tariff on wheat, rice and maize imports.

General circulation models (GCMs) were used to translate different green house gas (GHG) emission scenarios into varying temperature and precipitation outcomes. While the general consequences of increasing atmospheric concentrations of GHGs are increasingly well known, great uncertainty remains about how climate change will play out in specific locations. Therefore this paper relies on 12 alternative climate change scenarios which together help define the range of potential outcomes from climate change in South Asia. These 12 scenarios result from combining alternative GHG paths and different GCM models. Yields changes resulting from alternative climate change scenarios for selected crops (maize, wheat, rice, soybeans and groundnuts) as estimated by the DSSAT model are discussed. ***Decreases in average global yields across the different scenarios vary from 0.6 percent to 11 percent. Wheat and maize yields are more affected than yields of rice (rainfed) and soybeans even though the variance across scenarios is higher for the latter.*** For all crops average yield changes weighted by initial production levels are larger than average changes weighted by area –suggesting that high productivity regions will be relatively more affected by climate change than less productive regions. This could in turn lead to significant changes in trade patterns to the extent that high productivity regions are currently the main sources of exports. Yield decreases are largest for wheat and soybean - 11.5 percent and 8.2 percent respectively (weighted by area). Further decomposition shows that all four South Asian countries considered in our analysis are negatively impacted, with Pakistan and India most severely affected (showing average yield decreases of respectively 9.6 percent and 3.9 percent when weighted by initial production).

The exogenous yield changes coming out of the climate models were fed into a modified MIRAGE model. Since policy makers have a certain degree of control over trade measures, eight alternative trade policy scenarios were analyzed that could be implemented between 2010 and 2024. These different trade policy scenarios involve potential tariff reductions from their starting levels in 2007 with varying degrees of liberalization and regional integration. In this manner a total of 124 different combinations of trade policies and climate change scenarios were simulated.

The results confirm that South Asia will be significantly affected in terms of the impact of climate change on crop yields. Climate change affects both the overall level of economic activity and trade flows – resulting in an average 0.5 percent decrease in real income for the region as a

whole but with big differences across individual countries. For example whereas Pakistan may suffer an income decrease of up to 4 percent, India is least affected – changes there vary between a 0.6 percent income decrease to a 0.5 percent increase depending on the climate change scenario.

Since the share of agriculture in world GDP is expected to continue to decline, and even more so in a high-growth economy like India's, the findings regarding the impact of climate change on real incomes are perhaps not surprising. On the other hand it is important to keep in mind that this paper models only part of the possible consequences of climate change, i.e. only changes in crop yields due to changes in precipitation and temperature are taken into account. We do not consider the possibility of new pest and diseases arising as a result of changes in climatic conditions, the shift in cattle productivity due to temperature changes, or more generally any negative productivity shocks associated with a warmer climate. Last but not least, extreme events (flooding) or loss of agricultural area due to possible rises in sea levels are not taken into account.

Uncertainty about the exact intensity of climate change and its exact geographical location, embodied in the 12 SRES scenarios considered in the analysis, has significant impacts in terms of variability of the results. ***Based on the simple average between SRES scenarios, it seems that except for India all other South Asian countries should favor the status quo or the deepening of regional integration focused on SAFTA.*** India may have a preference for more ambitious trade policies consisting of a trade agreement agenda at the pan Asia level or even at a global scale. Nonetheless, India would need to obtain access to foreign markets in order to choose this path and unilateral trade liberalization is not an optimal strategy for managing the impact of climate change since the exact nature, location and effects of climate change remain highly uncertain.

The specific case of India warrants closer attention since it has implications for the South Asian region as a whole. On the one hand, India is a large and fast growing country, and by 2050 can be expected to have even larger market power. Unilateral trade liberalization by India may expose the country to negative price shocks and large terms of trade losses. By maintaining trade restrictions, India could use its market power and the traditional "optimal tariff argument" to mitigate the impact of increases in world prices on domestic prices and limit the deterioration of its terms of trade. At the same time, India would benefit from the opening of foreign

markets. But the strengths of India go even beyond its international market power. The size of its domestic market enables India to reallocate production factors across crops while allowing regions to redefine an optimal production pattern compatible with changing climatic conditions. In particular, India may rely on vast amounts of land currently used for cotton to produce additional food crops. For smaller countries, such an internal diversification strategy is much less feasible. ***This stresses the importance for the region as a whole of having flexible commodity as well as factor markets in order to ensure sufficient adaptation capacity and efficient allocation resources.***

Besides its effect on real GDP, it is important to consider the distributional impact of climate change. ***Our analysis suggests that climate change has a negative impact on the real wage of unskilled labor (a proxy for poor people's income)***. This is not unexpected since unskilled labor is directly impacted by the change in agricultural productivity. In the case of Pakistan, the losses exceed 5.5 percent in real terms. For India, while on average the real wage of unskilled labor increases by 1.6 percent under a status quo policy, the range of uncertainty is large: between +8.2 percent and -9.1 percent depending on the climate change scenario. For the poor in India unilateral trade liberalization may be the best strategy. But India is the exception also in this respect – for the poor in other countries the status quo is preferred, with the exception of the worst climate change scenario in which case unilateral trade liberalization is also the preferred strategy for the poor in other South Asian countries.

Even if trade policies are unable to significantly mitigate the impacts of climate change, trade liberalization can still play an important role in restoring market equilibrium. For example, South Asia's imports of major food crops are simulated to increase by 6 percent on average across all SRES scenarios. Trade liberalization, especially at the world level, would mitigate the price increases for these food imports. Uncertainties regarding the exact nature of climate change again lead to widely diverging predictions: global trade in agriculture may increase or decrease depending on how traditional exporters (e.g. countries belonging to the Cairns group) would be affected and how traditional importers would need to find new trade partners or develop domestic solutions. Indeed, agricultural trade liberalization would also lead to important market opportunities for South Asia in other developed and developing markets. When climate change occurs, exports can focus on sub regional markets, thus significantly mitigating crop price increases driven by reductions in yields.

Finally, the analytical framework in this paper based on a large number of simulations has generated valuable information, not only regarding average outcomes but also regarding the risk driven by climate change of different trade policy options. Adopting a risk analysis approach and assuming different levels of risk aversion among regional policy makers could provide guidance regarding the choice of an "optimal" strategy, taking simultaneous account of levels and variance of expected outcomes (as in a portfolio approach). The degree of hysteresis and the sunk cost nature of some investments will be very important aspects in assessing the costs of ex-post modification of trade policy options once they have been chosen ex-ante.

Table of Contents

List of Figures

List of Tables

List of Acronyms

AEZ	Agro-Ecological Zone
ASEAN	Association of Southeast Asian Nations
ANZCERTA	Australia New Zealand Closer Economic Relations Trade Agreement
AVE	Ad Valorem Equivalent
CGE	Computable General Equilibrium Model
DSSAT	Decision Support System for Agrotechnology Transfer
FDI	Foreign Direct Investment
FPU	Food Production Unit
FTA	Free Trade Area
GCM	General Circulation Models
GHG	Greenhouse Gas
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IPCC	Intergovernmental Panel on Climate Change
MIRAGE	Modeling Interregional Relations in Applied General Equilibrium
NAFTA	North American Free Trade Association
SAARC	South Asian Association for Regional Cooperation
SAFTA	South Asian Free Trade Area
SRES	Special Report on Emissions Scenarios of the Intergovernmental Panel on Climate Change
TFP	Total Factor Productivity

1 Introduction

There is increasing evidence suggesting that climate change will negatively impact agricultural production in South Asia. Decreased domestic production may make South Asian countries more dependent on imports. Given that (i) world markets for some of the major agricultural commodities consumed in South Asia are relatively thin (especially rice but also wheat and pulses) and (ii) the size of domestic markets in South Asia is large and growing, increased import demands of South Asian countries may result in substantial price increases in world markets and bring renewed concerns regarding food security and welfare throughout the world.

The extent to which South Asia would need to increase its imports as a result of climate change would presumably depend on the degree to which the latter would affect domestic output. The capability of South Asia to import more, and the costs associated with these higher imports, would in turn depend on the degree to which climate change might have a positive impact on production elsewhere in the world and lead to higher exportable surpluses. Thus, modeling the effect of climate change on agricultural production, both regionally in South Asia and worldwide, is required to be able to assess its impact on global trade in agricultural commodities; and to analyze the effect on world market prices. At the same time, the capacity of South Asia to tackle the new situation will depend largely about how growth will increase income and help to diversify economic activities. Indeed, at the macro level, if agriculture plays an important role in total GDP for some countries, they will be particularly exposed in the case of negative productivity shocks in this sector.

The effects of climate change on agriculture may well differ substantially for individual South Asian countries and indeed for regions within a given country which can be approximated by food production units (see next Chapter). Besides trade between South Asia as a region and the rest of the world, intraregional trade between South Asian countries may be able to dampen the effects of climate change on domestic supplies and prices at the level of the individual countries. This calls for an analysis of climate change effects on trade flows under alternative trade policy regimes both for agriculture and non agricultural sectors.

Substantial work has been carried out regarding the welfare benefits of worldwide trade liberalization (e.g. World Bank DEC, IFPRI etc) using different global trade models. Recently IFPRI completed a paper for the World Bank regarding the potential benefits of intra-regional

trade liberalization in South Asia (Bouet and Corong, 2009) and its effects on prices of agricultural commodities within the region. The main result was that the effect on domestic food prices in South Asia of the implementation of trade policies as stipulated in the South Asian Free Trade Area (SAFTA) agreement would be quite limited.

However, no analytical work has been done so far that reconciles the effects of climate change on agricultural production with its potential impact on trade flows of agricultural commodities and corresponding prices. This is important because if climate change is going to substantially increase South Asia's import demand and exportable surpluses elsewhere in the world do not match this increased demand, there is likely to be upward pressure on prices.

The specific objectives of the paper include the following:

- Analyze the extent to which agricultural production in South Asia and elsewhere in the world may be affected by different scenarios regarding climate change.
- Analyze the extent to which changes in domestic production in South Asia resulting from climate change would lead to increased demand for imports by South Asian countries.
- Analyze the effects of increased import demand in South Asia and changing exportable surpluses elsewhere on world market prices of major agricultural commodities consumed in South Asia.
- To the extent that South Asian governments allow transmission of changes in world market prices to domestic prices, analyze the potential welfare effects of changes in the latter.
- Analyze if, and to what extent, worldwide trade liberalization and implementation of SAFTA would dampen the effects of climate change on domestic agricultural prices in South Asia.

To answer these questions, Chapter II of the paper describes the methodology used - with particular attention to how different models and modeling techniques are linked to produce an as accurate as possible assessment based on state-of-the-art knowledge. Chapter III provides an up-to-date analysis of trade flows, trade policies and production patterns for key food products in South Asia to explain the context in which climate change is taking place. It also shows the role of agricultural trade for the region for coping with growing demand, climatic shocks and

food security targets. Chapter III also justifies the regional and sectoral disaggregations used in the paper. Chapter IV describes the climate change scenarios and illustrates their consequences for crop yields at a global level and for South Asia - and in particular shows the vulnerability of the region to these changes. Baseline design, simulations and results are discussed in Chapter V. The final Chapter provides a short summary, discusses the limitations of the analysis and derives suggestions and guidelines for future research.

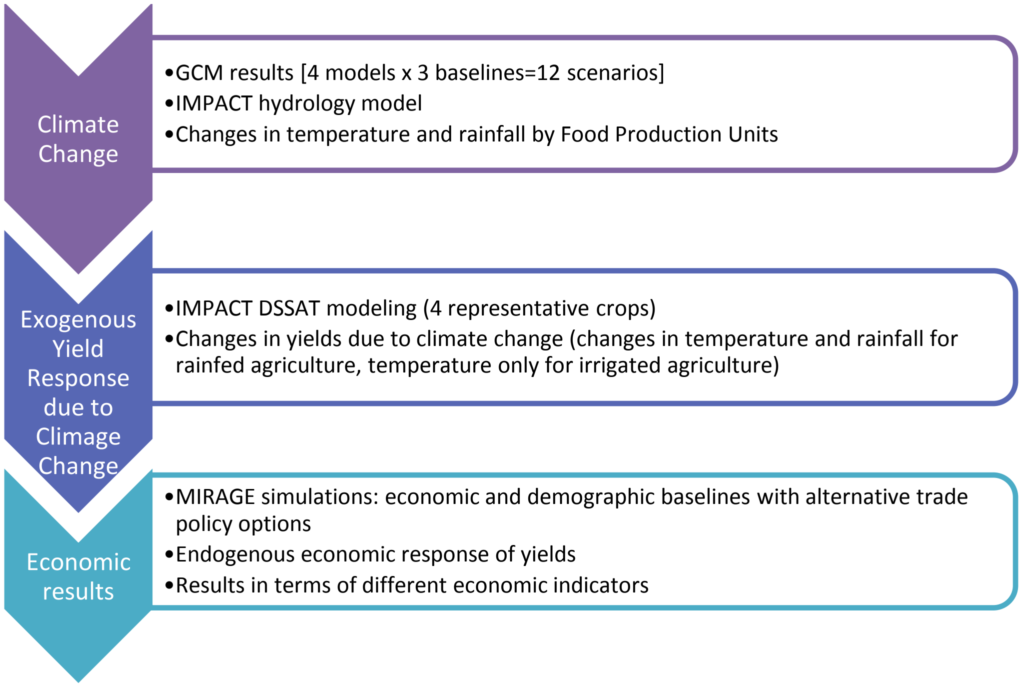
2 Methodology

Modeling the economic impact of climate change on the agricultural sectors of South Asian countries by 2050 is a challenging task and requires combining different models. The modeling framework employed in this paper is depicted in Figure 1. Taking results from different climate models (Global Circulation Models (GCM) listed in Table 1) regarding the probable evolution of temperature and rainfall, a number of IFPRI tools that are part of the IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) framework are used to assess the effects of changes in water availability and temperature on crop yields - while assuming economic behavior as constant. These exogenous changes are subsequently plugged into the MIRAGE (Modeling International Relationships in Applied General Equilibrium) global computable general equilibrium model (CGE) to assess the overall economic consequences of these evolutions. The CGE model is also used to analyze the different climate change scenarios with different socio-economic baselines - including alternative trade policies.

Table 1 List of GCM used as inputs for determining climate change effects in terms of changes in temperature and precipitation

Label	**Description**
CNR(M)	Centre National de Recherches Météorologiques (Météo-France); abbreviation for the CNRM-CM3 general circulation model
CSIRO	Commonwealth Scientific and Industrial Research Organization; abbreviation for the CSIRO-Mk3.0 general circulation model
ECH(AM)	Abbreviation for the ECHam5 general circulation model, developed by the Max Planck Institute for Meteorology, Germany
MIROC	Abbreviation for the MIROC 3.2 medium resolution general circulation model - produced by the Center for Climate System Research, University of Tokyo; the National Institute for Environmental Studies; and the Frontier Research Center for Global Change, Japan

Figure 1 Modeling Framework



2.1 Modeling the effects of Climate Change on Crop Yields

The guiding principle for linking biophysical characteristics into the economic model is that climate change will affect the supply functions differently in different regions by altering the trajectory of productivity growth. These effects are projected by calculating location-specific yields for each of the crops modeled with DSSAT (currently maize, soybeans, rice, wheat, and groundnuts) for both the year 2000 climate and future climates and calculating an annual growth rate. The growth rate is used to alter the intrinsic productivity growth trajectories of crops in economic models (IMPACT, MIRAGE).

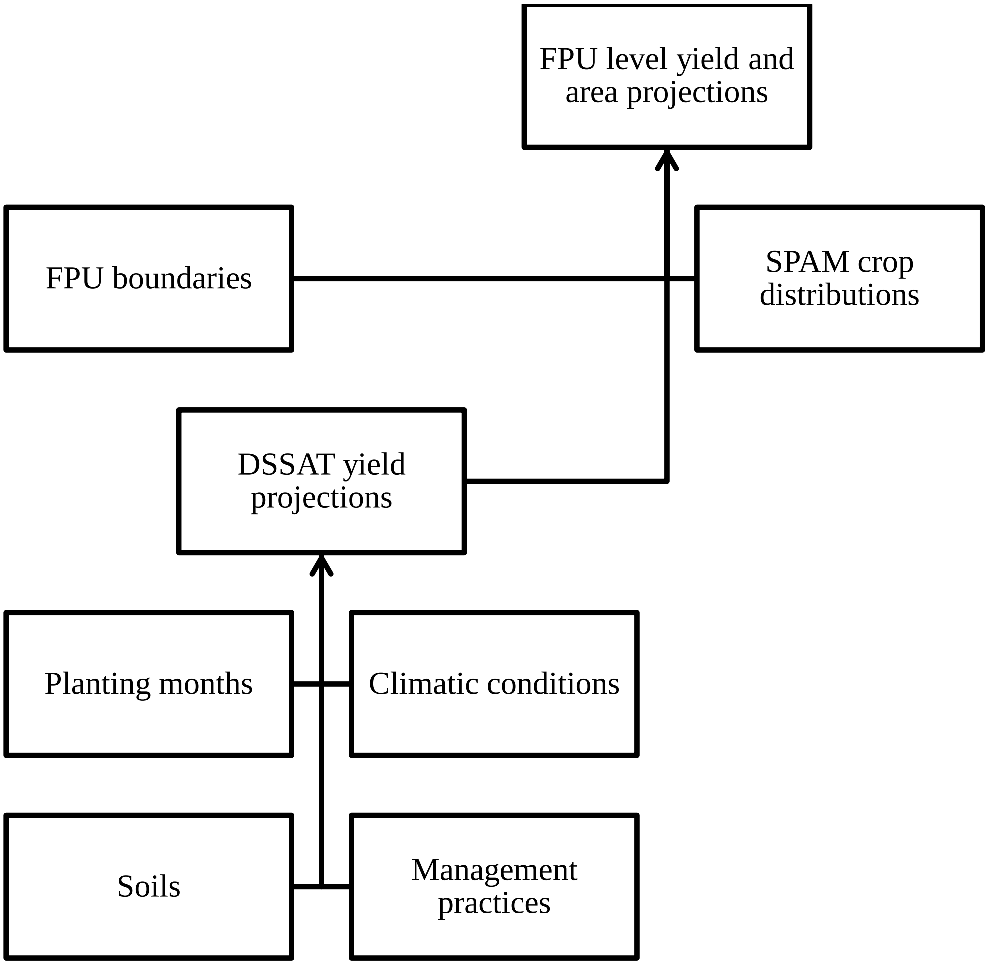
2.1.1 The IMPACT framework

The adjustments caused by climate change that will affect intrinsic crop productivity growth rates are needed for each Food Production Unit (FPU) in IMPACT.

The overall linkages and dependencies leading to the yield projections at the FPU level are depicted in Figure 2. At the top of the diagram are the yields and areas that are used to compute the adjustments to the growth rates. These immediately depend on the pixel level yields projected by DSSAT which are aggregated up to the regional FPU level based on the geographic boundaries of the FPUs and are weighted by the crop distribution found in the SPAM

datasets. Yield projections are based on four major inputs: climatic conditions, planting month, soils, and management practices.

Figure 2 Links leading to the incorporation of climate change in IMPACT



Regarding the yield impact of changes in water availability resulting from climate change, the modeling procedures followed for rainfed crops and irrigated crops differ. For rainfed crops, yield levels are determined by the crop simulation model based on the available precipitation. These yields are then used in the IMPACT model directly - without any adjustment for water stress since that has already been accounted for in the yield projections.

Irrigated crops are handled in a two-step process since the water stress is determined by the amount of water available for irrigation which in turn depends on more than the precipitation projections alone. The first step is to use FAO's empirical crop water production function to estimate yields in the absence of any water stress. The second step introduces water stress

defined by climatic conditions. The stress is introduced through both a hydrologic model and a water simulation model built into IMPACT. The hydrologic model is a semi-distributed macro-scale module that covers the entire global land mass (except Antarctica). Based on the precipitation projections (and other climatic factors), the hydrologic model determines water availability and potential evapotranspiration under given climatic conditions. The water simulation model then uses the output of the hydrologic model to determine how much water would actually be available for irrigation - as compared to how much might be desired.

The economic portion of IMPACT works at a regional level known as the Food Production Unit (FPU). The biophysical/crop modeling analyses are done in a grid based framework at a much finer resolution. One of the more challenging aspects of developing the linkages between these models is dealing with spatial aggregation issues to determine the appropriate typical values when moving between resolutions. More specifically, the aggregation needs to take yield and area outputs from the crop modeling process at a fine pixel level to the IMPACT FPUs regional level.

This is done in the following manner: First, the FPU is chosen along with its geographic boundary. This is a vector (not a pixel or raster) boundary that encompasses the region and used to determine which pixels fall within the FPU. Next, the appropriate SPAM data set that corresponds to the crop/management combination is chosen. The SPAM data come in raster format, with a spatial resolution of 5 arc-minutes (approximately 10 km at the equator). The physical area under cultivation in the SPAM data set is used as the weight to calculate the average yield across the FPU. The areas for the baseline and future years are determined by adding up the physical areas from SPAM over only the pixels for which it was possible to obtain yield projections. The total production is computed by taking the SPAM physical area and multiplying by the projected yield (pixel by pixel) and summing over all locations. The weighted average yield is then simply calculated as total production divided by total area for the year.

2.1.2 DSSAT Yield Projections

Yield projections are generated using the DSSAT suite of crop simulation modeling tools (DSSAT 2009) on a regular grid covering the surface of the earth. The crop model numerically "grows" the crop by providing a daily snapshot of how the plant is developing – e.g. number of leaves that have come out, size of the grains, biomass accumulated etc. The most relevant characteristic for the IMPACT model is the yield at the end of the season. The data needed to

run the crop simulation models can be grouped into four major categories: soil, management practices, climatic conditions, and planting month (see also Fig. 2 above).

Soil types

DSSAT requires a characterization of the soil properties such as water holding capacity, root penetration, and nutrient characteristics. This information is needed for several soil layers in the top two meters of soil. The soil profiles currently used consist of 3×3×3 = 27 generic soil profiles reflecting high/medium/low fertility, shallow/medium/deep root penetrability, and sandy/loamy/clay predominant composition. The profiles for each location were assigned based on interpretation of the FAO harmonized soil maps of the world (FAO 2009, Harmonized World Soil Database 2009).

Management practices

The management practice category of inputs includes water source, fertilizer application details, seed choice and planting density. The source of water can be either rainfall or irrigation. With irrigation, there are several controls that can be specified to reflect how, when, and how much water is delivered. The amount, type, and timing of fertilizer applications are additional important considerations. The DSSAT system allows for different varieties or cultivars within each crop. A major example of this is rice where both *japonica* and *indica* varieties are considered - and separately assigning the results to the geographic locations where each predominates.

While not a directly controllable management practice, the atmospheric CO_2 concentration would generally fall into this category of inputs. Even though DSSAT has the capability to consider the CO_2 concentration, it is unclear what the effect of CO_2 fertilization would actually be in the field. Additionally, the reliability of its representation in DSSAT is not clear. These uncertainties led to the choice to run simulations under a "no carbon dioxide fertilization" assumption where the same value is used in both baseline and future situations for the atmospheric concentration. This is meant to reflect the case where CO_2 fertilization ends up being inconsequential.

Climatic conditions

Climate data are derived from downscaled GCM projections which provide monthly precipitation, average minimum temperatures, and average maximum temperatures for each location. Companion downscaling techniques provide the monthly average number of rainy days and the average incident shortwave solar radiation flux. These techniques are still an area of active research. The most recent developments and a more detailed description of the process can be found online at the website listed in the references (Climate Projection Data Download 2009).

The downscaled datasets are monthly averages, while the crop simulation models work on a daily time-step requiring daily weather values. One of the tools in the DSSAT suite is a stochastic weather generator. The generator takes a random seed along with the monthly averages and generates daily weather profiles that are consistent with the averages using a Monte Carlo process attuned to weather applications. Since weather is an extremely important determinant of crop yields, the final yield used for analysis is the mean over the yields resulting from many weather realizations.

Planting date

Planting date is a critical element of crop management practice. Modeling planting dates on a global scale has proven to be challenging. Most of the readily available cropping calendar information is anecdotal and not systematically georeferenced. Attempts have been made to systematize much of this information into GIS formats (SAGE 2009), but it is still limited by the underlying sparseness of the data. Furthermore, this information does not provide guidance for use with future climate scenarios. To address this, rule-based methods were implemented based on monthly climate data. The baseline rules were calibrated to mimic as closely as possible the information available from the anecdotal evidence. Comparisons with the SAGE data have been encouraging. The rules can then be applied to the future climate data to determine likely planting dates under those conditions.

There are three sets of calendars that have been developed for use with IMPACT so far: general rainfed crops, general irrigated crops, and spring wheat. For rainfed crops, the idea is to find a block of months that are not excessively hot, avoid freezing, and have a reasonable amount of monthly rainfall throughout the block. For those places in the tropics that meet these criteria

year-round, the planting month is keyed off of the rainy season. For irrigated crops, the first choice is the rainfed planting month. When that is unavailable, then a series of special cases are considered for South Asia, Egypt, and the rest of the northern hemisphere. Otherwise, the planting month is keyed off of the dry season.

Spring wheat has a complicated set of rules. In the northern hemisphere, the planting month is based on finding a block of months that are sufficiently warm but not excessively so. If all months qualify, then the month is keyed off of the dry season. In the southern hemisphere, spring wheat tends to be grown during the meteorological wintertime as a second crop. Hence, the planting month does not depend so much on what is optimal for wheat, but rather when the primary crop is harvested. Hence, the planting date is based on a shift from the rainfed planting month. Failing that, the planting month is based on the rainy season.

Selected crops

To capture the different capacity of crops to react to climate change, based on their carbon fixation and photosynthesis capacity, a mix of C3 and C4 plants have been simulated with DSSAT. Currently, results for all SRES scenarios in the IMPACT framework include groundnut, maize, rice, soybean and wheat. These crops cover directly, or indirectly, most of the nutritional needs of animals and humans.

For other crops in the model, simple averages of the relevant C3 or C4 simulated crops based on the plant category were used. This method is imperfect but at least offers a consistent framework. In addition, assuming no change in yield for non-simulated crops would be an even more challenging choice since it would assume that they perfectly adapt to climate change and will expand strongly. By choosing a simple average, extreme behavior is ruled out and it is ensured that these crops will follow the main trend.

2.2 The MIRAGE model for Climate Change Analysis

To assess the economy-wide effects of global climate changes, the CGE provides the most appropriate framework. Climate change modifies agricultural productivity and will have a direct impact on agricultural commodity prices and factor prices. Through the factor price channels, factors will be reallocated in the economy and as a result sectoral specialization will change. In addition, incomes will be affected and demand behavior will be modified. Demand will also be

affected by change in prices and food consumption, even if inelastic, will be impacted as well. Since agricultural products (crops but also fibers and animal products) are important inputs for many sectors, changes in their prices will affect other sectors. All these channels require the use of a CGE model that is capable of tracking these changes. In addition, these changes do not occur in a closed economy but at a global level with heterogeneous effects across countries and commodities. Comparative advantages evolve, trade patterns adapt and countries are affected by both the domestic effects of climate change and by the modifications of relative prices in world markets (terms of trade effects). Over time, considering income and current account constraints, production will be reallocated across sectors and across regions to adapt to exogenous changes in yields. Depending on the specific situation, general equilibrium effects will mitigate or magnify the initial impacts. For example, capital may leave agriculture due to the negative shock on returns, accelerating the fall in the yields and production levels in one country; or alternatively may move to this sector attracted by high prices thus compensating, at least partially, for the exogenous reduction in yields. This is the reason why a multi country, multi sector, dynamic CGE model is needed. The analysis in this paper uses an upgraded and adapted version of the MIRAGE model. Below follows a description of the core MIRAGE model as well as of the modifications that are required to enable to use the model for long term projections.

In terms of trade analysis, the choice of the Armington assumption (differentiating goods by country of origin) is important and a major difference when compared with most partial equilibrium analysis frameworks, including the IMPACT model. The Armington assumption implies imperfect price transmission between international and domestic markets, and specific trade patterns at the bilateral level. On the contrary, partial equilibrium assuming perfect substitution implies a single world market for each agricultural commodity, and unilateral net trade flows (except for spatial trade models). Nevertheless, while the latter approach has certain advantages in terms of ease of tracking quantities and simplifying the modeling framework, the empirical literature (see Villoria 2009 for a recent analysis) strongly argue in favor of the features that result from adopting the Armington assumption: price transmission is imperfect, there is no such thing as a single world market, and geography, as well as history, matter for explaining trade patterns.

The sectoral (20 sectors) and regional (20 countries and regions) disaggregations used in this paper are listed in Table 2 and 3, respectively. They cover the most important trade blocks and commodities for the purpose of this study. Chapter III provides further justifications for these choices by discussing trade and production patterns.

Table 2 Sectoral decomposition of the MIRAGE model

Code Sector	Description	Code Sector	Description
cattle	Cattle	**ffl**	Fossil Fuels
coarse	Coarse Grains	**forestry**	Forestry
cotton	Cotton	**omn**	Other Minerals
maize	Maize	**crp**	Chemical rubbers and plastics
oagr	Other Ag. Products	**mmet**	Mineral and metals
oilseed	Oilseeds	**moto**	Motor vehicles
pulses	Pulses	**ome**	Machinery and equipment
rice	Rice	**omf**	Other manufacture products
sugar	Sugar	**p_c**	Petroleum & coal products
veget	Vegetables	**text**	Textiles
wheat	Wheat	**wap**	Wearing apparel
dairymeat	Dairy and Meat products	**wpp**	Wood and paper products
ofood	Other Processed Food	**serv**	Services
vegoils	Vegetal Oils	**trade**	Trade
fishing	Fishing	**trans**	Transportation

Table 3 Regional decomposition of the MIRAGE model

Code Region	Description	Code Region	Description
ANZCERTA	Aus, NZ	**NAFTA**	NAFTA
CHN	China	**ARG**	Argentina
RAS	Rest of Asia	**LAC**	Latin America
CEA	Central Asia	**BRA**	Brazil
ASEAN	ASEAN	**CAM**	Central America
BGD	Bangladesh*	**EU27**	EU27
IND	India*	**XER**	Russia & Ukraine
PAK	Pakistan*	**MED**	Mediterranean Region
SLK	Sri Lanka*	**WAF**	Sub Saharan Africa
XAS	Rest of South Asia*	**SAF**	South Africa

*Note: An asterisk * indicates countries/regions belonging to South Asia.*

2.2.1 Generic features of the MIRAGE model

MIRAGE is a multi-sector, multi-region Computable General Equilibrium (CGE) model for trade policy analysis. The model operates in a sequential dynamic recursive way: it is solved for one period, and then all variable values, determined at the end of a period, are used as the initial

values for the next period. Macroeconomic data and social accounting matrixes, in particular, are derived from the GTAP 7 database (see Narayanan, 2008), which describes the world economy in 2004. At the supply side, the production function in each sector is a Leontief function of value-added and intermediate inputs: one output unit needs for its production x percent of an aggregate of productive factors (labor, unskilled and skilled; capital; land and natural resources) and $(1 - x)$ percent of intermediate inputs. The intermediate inputs function is an aggregate CES function of all goods: this means that substitutability exists between two intermediate goods, depending on the relative prices of these goods. This substitutability is constant and at the same level for any pair of intermediate goods. Similarly, in the generic version of the model, value-added is a constant elasticity of substitution (CES) function of unskilled labor, land, natural resources, and of a CES bundle of skilled labor and capital. This nesting allows the modeler to introduce less substitutability between capital and skilled labor than between these two and other factors. In other words, whenever the relative price of unskilled labor increases, this factor is replaced by a combination of capital and skilled labor, which are more complementary.[1]

Factor endowments are fully employed. The only factor whose supply is constant is natural resources with a few exceptions detailed later. The supply of capital is modified each period because of depreciation and investment. Growth rates of labor supply are fixed exogenously. Land supply is endogenous; it depends on the real remuneration of land. In some countries land is a scarce factor (for example, Japan and the EU) reflected in a low elasticity of supply. In others (such as Argentina, Australia, and Brazil) land is more abundant and the supply elasticity is higher.

Skilled labor is the only factor that is perfectly mobile. Installed capital and natural resources are sector specific. New capital is allocated among sectors according to an investment function. Unskilled labor is imperfectly mobile between agricultural and nonagricultural sectors according to a constant elasticity of transformation (CET) function: unskilled labor's remuneration in agricultural activities is different to that in nonagricultural activities. This factor is distributed

[1] In the generic version, the substitution elasticity between unskilled labor, land, natural resources, and the bundle of capital and skilled labor is 1.1 - for all sectors except for agriculture where it is equal to 0.1. On the other hand, the substitution elasticity is only 0.6 between capital and unskilled labor.

between these two series of sectors according to the ratio of remunerations. Land is also imperfectly mobile between agricultural sub-sectors.

In the MIRAGE model there is full employment of labor; more precisely, there is a constant aggregate employment in all countries (wage flexibility). It is quite feasible to assume that total aggregate employment is variable and that there is unemployment; but this choice greatly increases the complexity of the model, so that simplifying assumptions have to be made in other areas (such as the number of countries or sectors). This assumption could amplify the benefits of trade liberalization for developing countries: in full-employment models, increased demand for labor (from increased activity and exports) leads to higher real wages, such that the origin of comparative advantage is progressively eroded; but in models with unemployment, real wages are constant and exports increases are larger.

Capital (either domestic or foreign) in a given region is assumed to be obtained by combining intermediate inputs according to a specific combination. The capital good is the same across sectors. The version of the MIRAGE model used in this paper assumes that all sectors operate under perfect competition, there are no fixed costs, and prices equal marginal costs.

The demand side is modeled in each region through a representative agent whose propensity to save is constant. The rest of the national income is used to purchase final consumption. Preferences between sectors are represented by a linear expenditure system – i.e. constant elasticity of substitution (LES-CES) function. This implies that consumption has a non-unitary income elasticity; when consumer's incomes are augmented by *x* percent, consumption levels are not systematically raised by the same percentage, other things being equal. The sectors' sub-utility functions used in MIRAGE are a nesting of four CES-Armington functions that define the origin of the goods. In this paper, Armington elasticities are drawn from the GTAP 7 database and are assumed to be identical across regions.

Macroeconomic closure is obtained by assuming that the sum of the balance of goods and services and foreign direct investments (FDIs) is constant.

2.2.2 Adapting MIRAGE for climate change analysis

To be able to tackle issues related to climate change, the MIRAGE model was modified in several respects. New crops were introduced, followed by land use modeling to integrate the change in yields derived from the IMPACT model and adapted to operate at the water basin level,

matching the IMPACT FPUs. Finally numerous modifications were performed to reconcile the dynamic aspect of long term projections.

Introduction of new crops

To consider the heterogeneous effects of climate change on different crops and the important role of pulses in South Asia diet, two sectors were added to the GTAP7 database: maize and pulses. The former has been “extracted” from the “other coarse grains” sector while pulses have been taken from the “vegetable and fruits” GTAP sector. Information on their production levels was obtained from FAOSTAT. Trade information and tariffs are based on ADEPTA (Laborde, 2010).

Land use and yield impacts

The first important modification of the MIRAGE model consisted of a breakdown of land allocation decisions by water basins. Each region / country in the model has a land market operating at the infra-regional level, mimicking the FPUs in the IMPACT model. Using the FPU and the underlying river basin decomposition appears to be more robust for climate change analysis than using agro ecological zones (AEZ) as done in previous studies on medium term land uses effects (see Al Riffai, Laborde and Dimaranan 2010 for an illustration). Indeed, the AEZ classification incorporates elements regarding precipitation, water and cropping periods that are highly endogenous to some of the main issues analyzed in this paper.

The model contains 161 land markets (region times basin) in which producers allocate land among crops, through a CET function (elasticity of transformation of 0.5 for all basins), mimicking the standard land supply representation in MIRAGE at the national level. The same river basin can be shared by several countries. In such cases, markets are segmented by both the river basin and political borders. Each segment will have its own land price and producers will take independent decisions. However, crop yield patterns in these differentiated segments may be correlated due to climatic events. At the national level, all sub-regional land supplies for a given crop are aggregated through a CET function (with an elasticity of transformation equal to 6) and provide the aggregate land supply for the production function. This large but imperfect substitution captures the fact that production can be redistributed among different regions of a country in the long run while respecting biophysical yield.

This modeling approach is important for a number of reasons. First and by considering only one national land market, the yield shifts coming from the crop models need to be aggregated at the national level using certain weights. Using fixed weights, e.g. the initial area, would fix the link between geographical distribution of production within a country and yield changes – in other words would not allow the capture of endogenous reallocation effects. Furthermore, it would not allow for distinguishing between geographical yield changes and sectoral yield changes. For the sake of illustration, consider a country with two regions (A and B) and two crops (X and Y). Yields are initially homogenous. Assume that A & B have the same area and A is specialized at 90 percent in X and B at 90 percent in Y; and that region A is strongly affected by climate change resulting in a yield decrease of 50 percent, while region B remains unaffected. Operating with a single land market and importing aggregated yield would lead to the conclusion that production of crop X and Y decrease by respectively 45 percent and 5 percent. Except in the case of extremely inelastic demand in a closed economy, substitution effects would dominate and production factors (such as capital) would flow from X to Y. In addition, since the change in yield is sector specific and with a standard MIRAGE closure, productivity of land moved from X to Y would increase. However, this effect is erroneous since the new land taken from X comes from region A which has lower yields for both crops. With the basin/FPU approach adopted in this paper, the output from the crop model is expressed by river basin and for each specific crop.

A second important issue is the manner in which irrigation is treated in the model. Irrigation expenditures or their effects are not modeled in the CGE. Even if agriculture can become more intensive (more labor and/or capital per unit of land) and physical productivity of land will increase, this is not necessarily associated with concrete investment projects in physical infrastructure (irrigation, roads, drainage) or immaterial assets (R&D, new crop varieties). The IMPACT framework provides the change in yield for irrigated and rainfed crops separately. It is assumed that the ratio between rainfed and irrigated areas will remain constant for each crop, and each FPU, for all years and all scenarios. Therefore, an average yield by crop, and its changes, can be computed for each FPU using the initial ratio between irrigated and rainfed production. Since irrigation activity is not modeled in the CGE, neither is the water market. A limitation of this approach is that during expansion of crops that are initially highly irrigated, it is assumed that the required infrastructure is provided for free, underestimating the real cost of expansion. However, the problem is only significant when large areas initially occupied by a rainfed crop are replaced by a strongly irrigated crop. With the lack of representation of the

water market and irrigation in the CGE, it also implies that expansion of an irrigated crop will lead to an incremental demand of water is not considered a scarce resource. In other words, this increased water demand will not be in competition with other sectors or crops and will not generate water stress elsewhere.

Finally, it is important to properly model yield shocks. Indeed, the crop models provide information regarding changes in yield - based on changes in temperature and water availability - for a defined technology (fertilizers, other inputs) for each period. Therefore, there is a need to calibrate the model, using the existing technologies (i.e. production functions and elasticities), the shift in land productivity at the FPU level that will generate for each crop the same change in physical yield (units produced per unit of land) estimated by the crop model. This procedure is straightforward since the CES function can be used that defines value added and then rearrange it to compute a parameter γ for each FPU and each crop that multiplies the amount of land used in this sector generating the targeted yield assuming other factors constant. Then, during the simulations, this parameter is fixed and producers will modify their factor demands to take into account this factor-specific productivity shifter. This procedure amounts to assuming a non-neutral productivity shock. Depending on the elasticities in the model, other production factors can be used to compensate for the productivity loss of land and support production; or alternatively leave the sector as result of a decline in their marginal productivity (positively correlated with the exogenous productivity of other factors). For example for capital, new investment would be avoided resulting in an erosion of the capital stock.

Dynamic perspectives

Projecting the world economy to 2050, in particular when focusing on a fast growing and large region such as South Asia, is a challenging task that requires adapting the dynamic structure of MIRAGE as well as making careful choices in terms of baseline assumptions. Dynamic modeling choices significantly affect the comparative advantage in the baseline since they modify relative factor endowments in the various economies. The following specific choices were made:

First, the model operates not on a yearly basis but in steps of five years. This solution saves computational time and since no scenario information is provided with more accuracy - climate impacts are estimated for 2050 and then backwardly interpolated linearly - there is no gain to use a yearly frequency. In terms of factor supply, a number of modifications were introduced.

Physical investment decisions follow the same behavior as in the standard version of MIRAGE. No foreign direct investment is allowed. Saving rates in the different economies are not readjusted since these parameters are impacted by many different mechanisms, some of which are known (demography) while other remain unknown (future social safety nets, pension system reform etc.). The only exception in this regard is China that stands as an outlier in the GTAP database (saving rate exceeding 40 percent) while all other important economies have savings rates between 15 percent and 25 percent. In the model the saving rate of China is decreased linearly to 30 percent by 2050 to avoid the explosive investment path that would otherwise be generated. A more important modification is done for the labor accumulation. The total number of workers is based on population projections (United Nations data) and an activity rate (ILO data). The split between skilled and unskilled evolves through a wage gap equation that is aimed to mimic incentives for education. The ratio between skilled and unskilled labor of the representative household is an iso-elastic function of the ratio between the last ten year moving average of skilled labor and unskilled labor. The elasticity has been calibrated (0.9) for all countries in order to have a meaningful dynamic path in terms of catching up by developing economies. Finally and to avoid an explosion of natural resource prices, especially minerals, we consider an iso-elastic supply of natural resources (production factor) in the mining sector, but not for fossil fuels. All these mechanisms are activated only during the baseline calibration. These factor supplies remain constant between all alternative trade policy baselines and climate change scenarios.

In terms of demand, two modifications were made to the standard MIRAGE model. First and regarding final demand, a dynamic recalibration of the CES – LES was introduced which aims to capture the evolution of the standard of living. Indeed without such a dynamic recalibration, the CES LES displays an increase in the price elasticity for countries where the rise in income has brought current levels of consumption, in particular for food products, far from their base levels. The dynamic recalibration allows to redefine the minimum per capita consumption of the CES LES and the elasticity of substitution, between each period in order to remain as close as possible to the targeted income and price elasticity for each commodity and region. This recalibration is only performed in the baseline and temporal values of parameters are used in the simulations. This allows maintaining the same preference structure between the baseline and the simulations, as well as performing welfare analysis. Second, an energy efficiency parameter on the use of fossil fuels (oil and natural gas) was introduced. This parameter was

calibrated and applied homogenously on all demand, to reproduce the IEA energy price projections.

Finally, to avoid explosion of cumulated current account imbalances, all current accounts were forced to converge to zero by 2050. Consequently, in each country the real exchange rate adjusts endogenously to adjust the trade balance.

In addition to the other dynamic calibration steps described above, additional assumptions and mechanisms were introduced that allow building a dynamic baseline. The main target is a GDP growth based on World Bank projections as used in the central scenario of IMPACT long term projections (see Nelson et al., 2010). With the total labor force treated as exogenous (population and activity rate assumptions), endogenous capital accumulation and endogenous skilled / unskilled labor ratios, the model has only one degree of freedom by region to reach the GDP target: the total factor productivity (TFP) for all sectors and factors. Therefore calibration was performed endogenously following normal MIRAGE procedures. However, if this TFP is applied to all factors, agricultural yields will grow quite fast, especially in India. Therefore, this TFP was adjusted with an agriculture-specific TFP that reduces the generic term. This additional term is country and sector specific and is freed during the calibration stage to target the (exogenous) growth rate of physical yield in agriculture based on the IMPACT baseline that provides detailed assumption for different crops and regions.

Using this procedure, a dynamic baseline was constructed that exhibits a number of desirable features: evolution of the economic size of the different regions (GDP), per capita income, relative prices between factors, relative productivity between sectors etc. Finally, it is important to note three additional characteristics of the model. First, the baseline is independent of the SRES scenarios in terms of emissions. Indeed, the same GDP growth can be achieved through very different technological pathways in terms of GHG effects. Second, the calibration process is implemented with a status quo assumption in terms of trade policy. This paper includes different trade policy options to study the role of the trade environment on the consequences of climate change. However, these trade policy modifications are implemented in the last stage of the baseline, during the policy pre-experiment and not during the calibration stage. This implies that while the GDP of countries will change between alternative trade policy baselines, the TFP remains constant. Finally, demand of agricultural feedstock for biofuels is not taken into account. Instead it is assumed that first-generation biofuels, and potentially the second

generation, will be phased out by 2050 and that bioenergy programs will not lead to increased pressure on agricultural land.

3 Trade policies and patterns, and production and consumption

3.1 Overview of current tariff barriers[2]

This section provides a short overview of the structure of current tariff barriers in SAFTA countries. Subsequent subsections describe the structure of protection on agricultural goods in general, followed by a focus on food products and the structure of tariffs according to respectively calorie, protein and fat contents of trade.

SAFTA countries have highly restrictive trade policies - tariffs applied on their imports are about twice as high as the tariffs faced by their exports in 2006 (Bouet and Corong, 2009). Non-food tariff barriers are the highest in Bangladesh while on the other extreme Sri Lanka's average industrial protection rates do not exceed 7 percent. Tariffs on textiles and wearing apparel are high in Bangladesh (30 percent) and Pakistan (24 percent) while Sri Lanka's tariffs in this sector are the lowest among SAFTA countries. Whereas Sri Lanka is the least protectionist among the SAFTA countries, India has by far the most protectionist trade regime – with an average tariff on ag-food imports of 58 percent and even higher tariffs on rice imports (80 percent) and on imports of wheat and processed sugar (100 percent). Note that despite the preferential access granted by India to other SAFTA countries, tariff barriers are still high.

3.1.1 Tariffs on Agricultural Goods

SAFTA as a whole[3] applies higher tariff rates on imported agricultural products from the rest of the world (47.3 percent on average) than the tariff rates faced by SAFTA's agricultural exports (23.9 percent on average). Average tariff rates applied on agricultural imports from the main continents are fairly even: North American products face the highest import tariffs (52.2 percent), followed by European and South American products (49.7 percent each). On the other hand, SAFTA's agricultural exports face the highest average import tariffs in Asia & Oceania (29.7 percent) and the lowest in North America (9.2 percent). These results are consistent with global

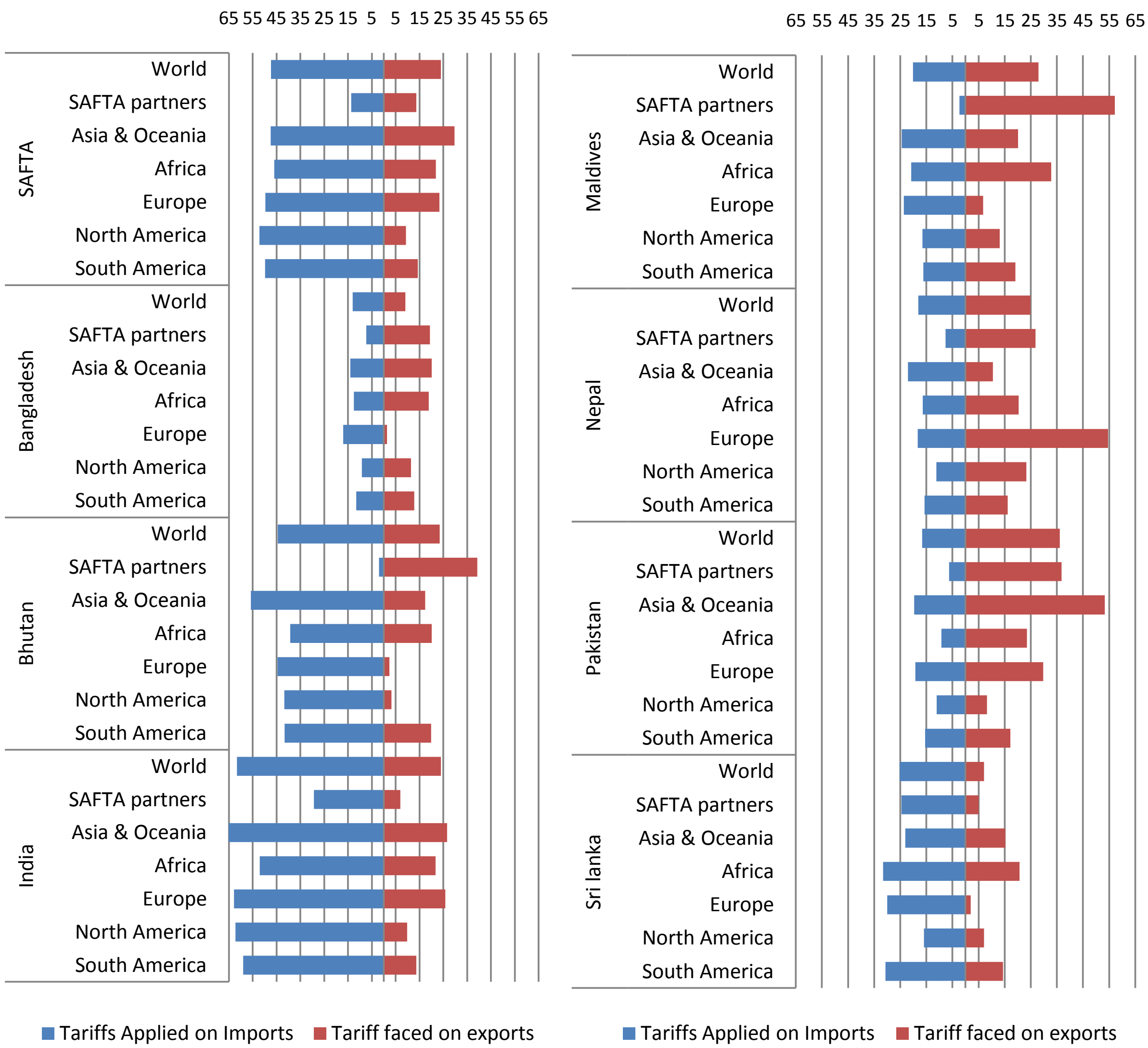
[2] This section focuses on tariff barriers. Indeed, they are the primary policy instrument used in the model scenarios. However, agricultural trade in South Asia is also subject to a wide array of non-tariff barriers and export policies (subsidies or restrictions based on conjectural needs). The distortive role of these policies should not be neglected as well as the potential for further trade liberalization that they represent.

[3] Weighted average - SAFTA figures are largely driven by Indian policies.

protection patterns and do not display any sign of negative discrimination. Note that intra-regional tariff rates among SAFTA member countries still pertain (13.7 percent in agriculture) – mainly because a number of sensitive products (negative list) are excluded from full liberalization under SAFTA's free trade agreement.

Among SAFTA's member countries, India applies the highest rates of protection on agricultural products (62.7 percent), compared to 13 percent in Bangladesh which is the least protective among SAFTA members. Interestingly, it is the LDC (Least Developed Countries) member countries of SAFTA such as Maldives, Nepal and Pakistan that are relatively less protectionist with respect to their agricultural imports originating from the rest of the world - their tariff rates applied on imported agricultural products are lower than the tariffs faced by their agricultural exports (see Figure 3).

Figure 3 Average Tariffs on Agricultural products in 2007 for South Asian countries (Reference group weighted)



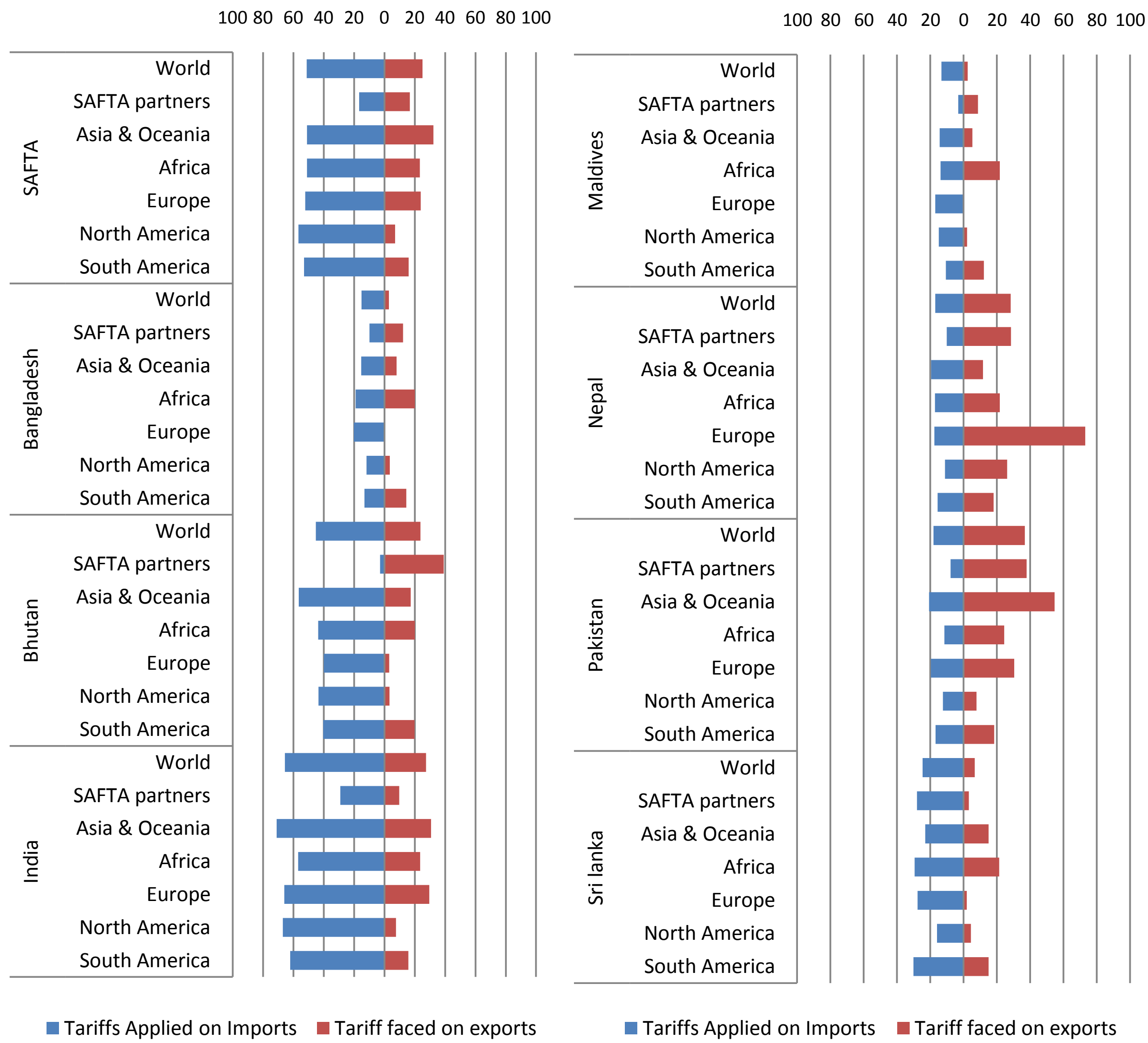
Source: ADEPTA database (Laborde, 2010). Authors' computations.

3.1.2 Tariffs on Food Products

Average protection levels applied to imports and faced by exports of food products of SAFTA countries do not differ all that much from those of agricultural commodities (Figure 4). Nevertheless, average import tariffs on food imports of SAFTA are 4 percentage points higher (51.1 percent) than average import tariffs on agricultural commodities, while in the rest of the world food exports of SAFTA face slightly higher barriers (25.1 percent) than agricultural products. Once again, India is the most protectionist country regarding food imports with 65.6 percent average tariff rates - and even higher tariffs (71.1 percent) on food imports originating from Asia & Oceania. Note that among the highest tariffs applied on exports of SAFTA countries

are those in European countries which apply an average 73.1 percent tariff on food imports from Nepal.

Figure 4 Average Tariffs on Food products for South Asian countries (Reference group weighted)

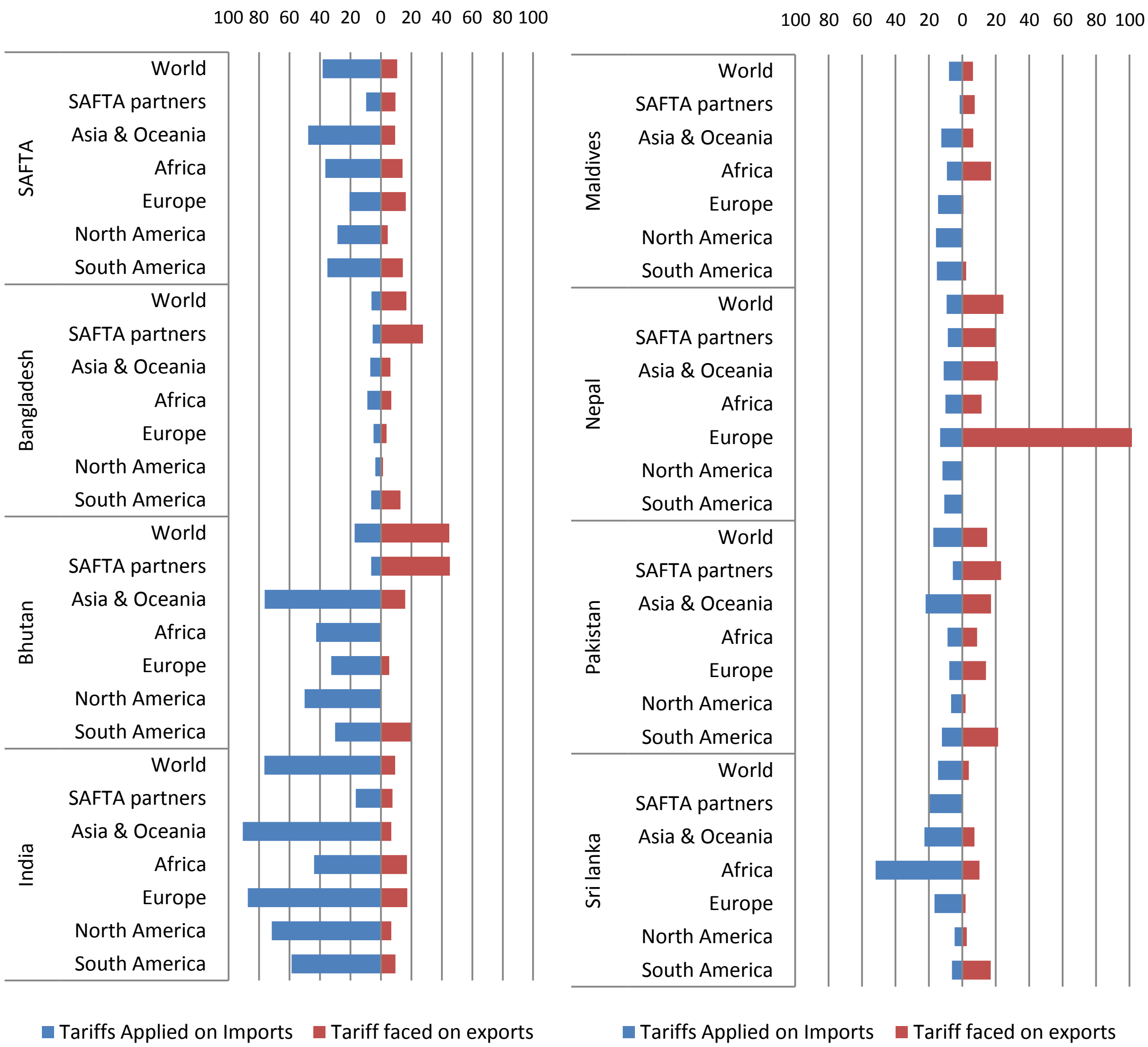


Source: ADEPTA database (Laborde, 2010). Authors' computation.

Note that the average tariff levels discussed above are computed using a trade value weighted scheme. While average tariffs provide key messages in terms of overall economic distortions, it is difficult to draw conclusions in terms of the nutritional consequences of these trade barriers.

Therefore Figure 5, Figure 6 and Figure 7 below provide a decomposition of average tariff rates using as weights the calorie, fat and protein content of trade, respectively.[4]

Figure 5 Average Tariffs on Calories for South Asian countries



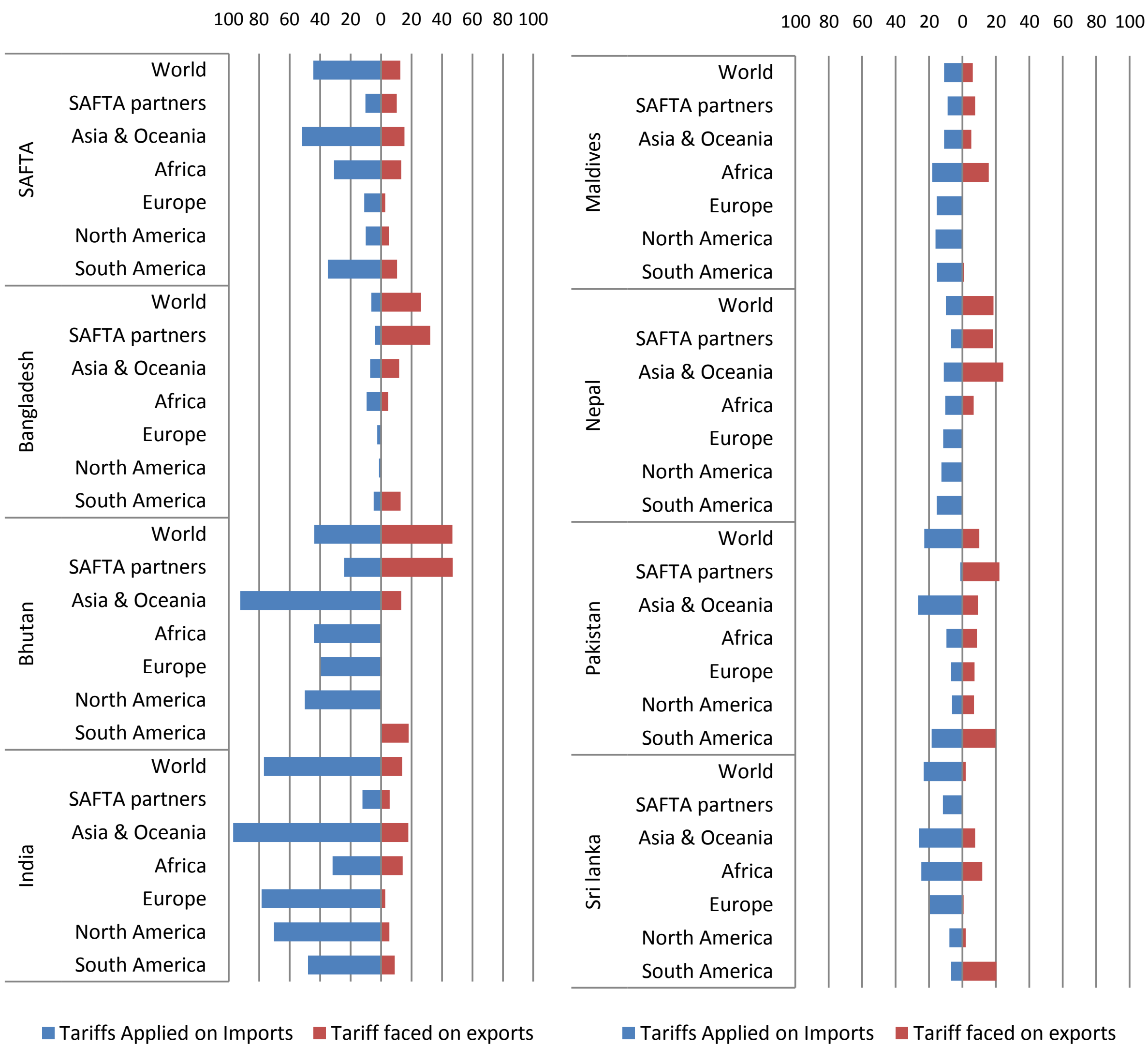
Source: ADEPTA database (Laborde, 2010). Authors' computation.

Figure 5 shows that overall across SAFTA members and their trading partners, average tariff levels faced by SAFTA's exports weighted by the calorie content of trade are relatively low (10.7 percent). Notable exceptions include tariff rates faced by exports of calories of Nepal to Europe

[4] Note that while average tariffs on agriculture and food have been built using the reference group weight (Laborde, 2010), in the case tariffs on calories, fats and proteins the bilateral trade nutritional contents weighting scheme has been applied. Given the different weighting schemes, one cannot directly compare average protection rates in agriculture and food with that of calories, fats and proteins.

(126.1 percent) due to the role of sugar exports and the regime of tariff rate quotas which was still in effect in 2007; and the exports of Bhutan to remaining SAFTA member countries (45.1 percent). On the other hand, average tariffs applied on imports by SAFTA countries weighted by calorie content of trade (38.2 percent on average) are dominated by the high tariffs of India and Bhutan. More specifically, India applies a 76.4 percent tariff rate on calorie imports from the rest of the world, and an even higher rate (87.1 percent) on calorie imports originating from Asian & Oceania. High tariffs on calorie imports in India are a particular burden for the poor who spend a large proportion of their income on calorie-rich foods.

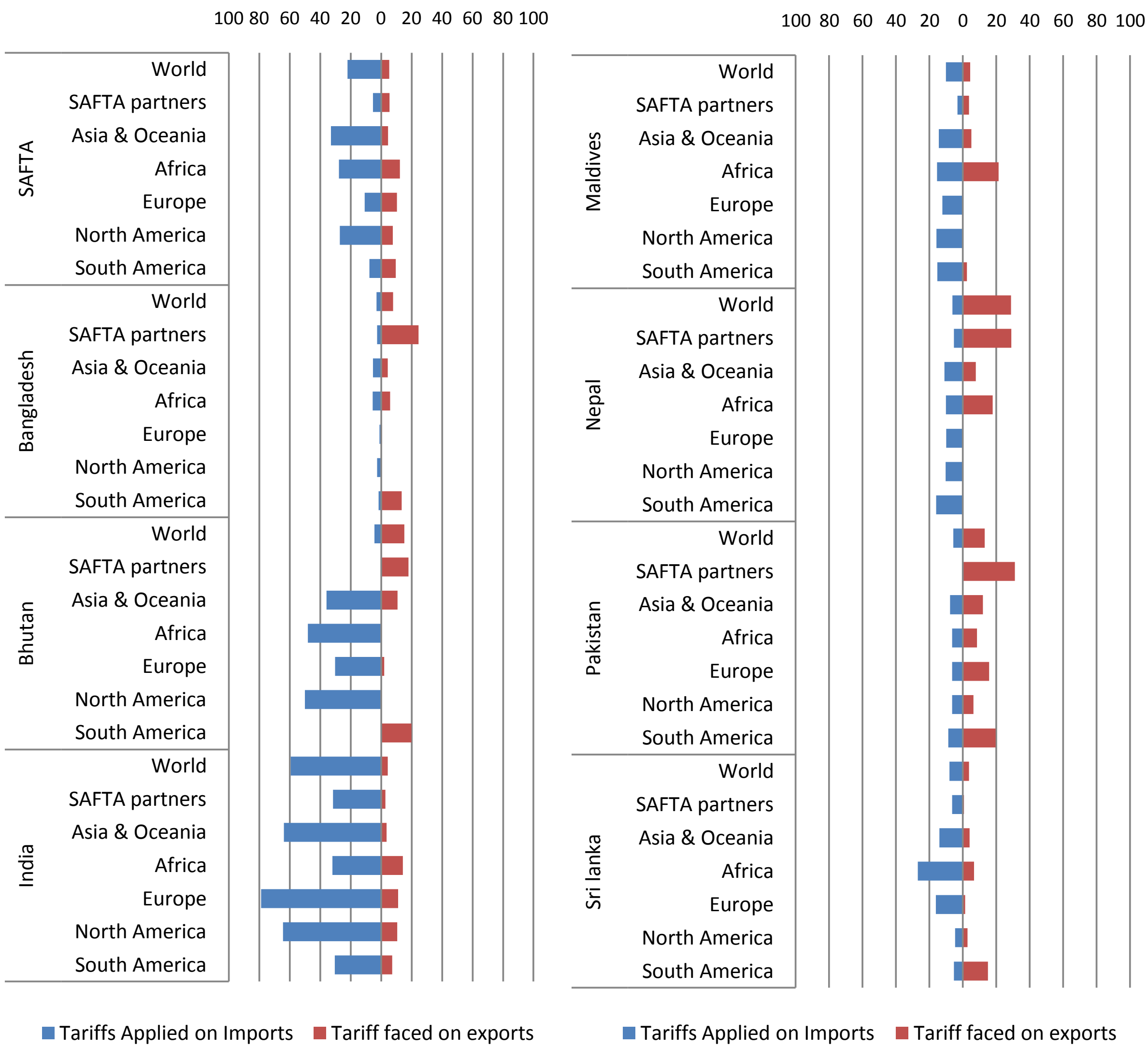
Figure 6 Average Tariffs on Fats for South Asian countries



Source: ADEPTA database (Laborde, 2011). Authors' computation.

Average tariff rates weighted by the fat content of trade are slightly higher than when weighted by calories (Figure 6). On the one hand, SAFTA applies an average 44.4 percent tariff rate on fat imports (4.2 percent higher than for calorie imports). India again proves to be the most protectionist country in South Asia, with an average tariff rate on fat imports of 76.9 percent, followed by Bhutan with 43.9 percent. On the other hand, fat exports of SAFTA to the rest of the world face an average tariff of 12.6 percent, or only 1.9 percent higher than that on calories. The highest average tariffs on fats are applied to exports of Bhutan (45 percent). This high import duty is mainly defined by the high protection rate applied on Bhutan's exports to other SAFTA member countries (45.2 percent) - an indication that the fact that Bhutan's exports to other SAFTA members are intensive in fat content while the list of sensitive products is dominated by products with high fat content.

Figure 7 Average Tariffs on Proteins for South Asian countries



Source: ADEPTA database (Laborde, 2011). Authors' computation.

When compared to calories and fats, proteins have the lowest import duties across SAFTA member countries and their trading partners (see Figure 7). Average tariffs applied on imports of proteins are only about half of those applied on fats, i.e. 22.2 percent for SAFTA as a whole, while average tariffs faced by the exports of proteins of SAFTA are similarly lower (5.4 percent overall).

In summary, the structure of protection applied on imports to SAFTA countries is mainly dominated by high tariffs in India and Bhutan. LDC member countries of SAFTA are less protective towards their imports than other SAFTA members, and in addition tend to apply

lower protection levels on their imports compared to protection levels faced by their exports. Average protection rates that pertain among SAFTA member countries indicate that the list of sensitive products is intensive in fat and calorie content, but less so in protein content.

3.2 The evolution of trade flows by region

Figure 8, Figure 9 and Figure 10 describe the evolution of trade flows of SAFTA decomposed by respectively major geographical partners and calorie, protein and fat content. This decomposition of trade flows by nutritional content compared to the more traditional decomposition in value terms is essential in determining the role of trade in food security.

A number of clear patterns emerge. First and in line with the gravity model of trade, variables such as geographical distance, trade costs or preferences highly influence trade patterns – as a result intra-regional trade and trade with relatively close neighbors (rest of Asia, Australia and New Zealand) represent a significant share of total trade. Second, Africa is an important destination market for SAFTA ag-food exports. Last and not surprisingly, the Americas (North and South) are net exporters of ag-food products to SAFTA given their strong comparative advantage in producing such products. Thus, geography matters which justifies the use of the Armington assumption (Armington, 1969) in the CGE model (Hertel and Villoria, 2009).

SAFTA as a whole has been a net importer of calories throughout the 1997 – 2007 period (see Figure 8 - 1996 is an exception). During that period, the share of imports of calories in total trade has increased faster than the share of calorie exports. The overall trade balance with respect to calories deteriorated from 1997 to 1999, then improved slightly until 2004 and followed by a further deterioration until 2007. Exports of calories have approximately doubled from 62,227 billion in 1996 to 102,628 billion in 2007, while imports of calories have increased more than three-fold from 59,244 billion in 1996 to 175,249 billion during the same period. In per capita terms, the evolution of trade balances follows the general trend in the sense that the increase of imports is not so much due to a population increase but rather the result of increases in income and/or competitiveness of imports.

Asian & Oceania is SAFTA’s most significant trading partner, accounting for 50 percent of total caloric exports of SAFTA in 2007 and 64 percent of caloric imports. Other significant export markets are SAFTA's intra-regional market and Europe. While Africa in 2007 accounted for 15 percent of caloric exports of SAFTA, its share in total imports of calories of SAFTA is insignificant.

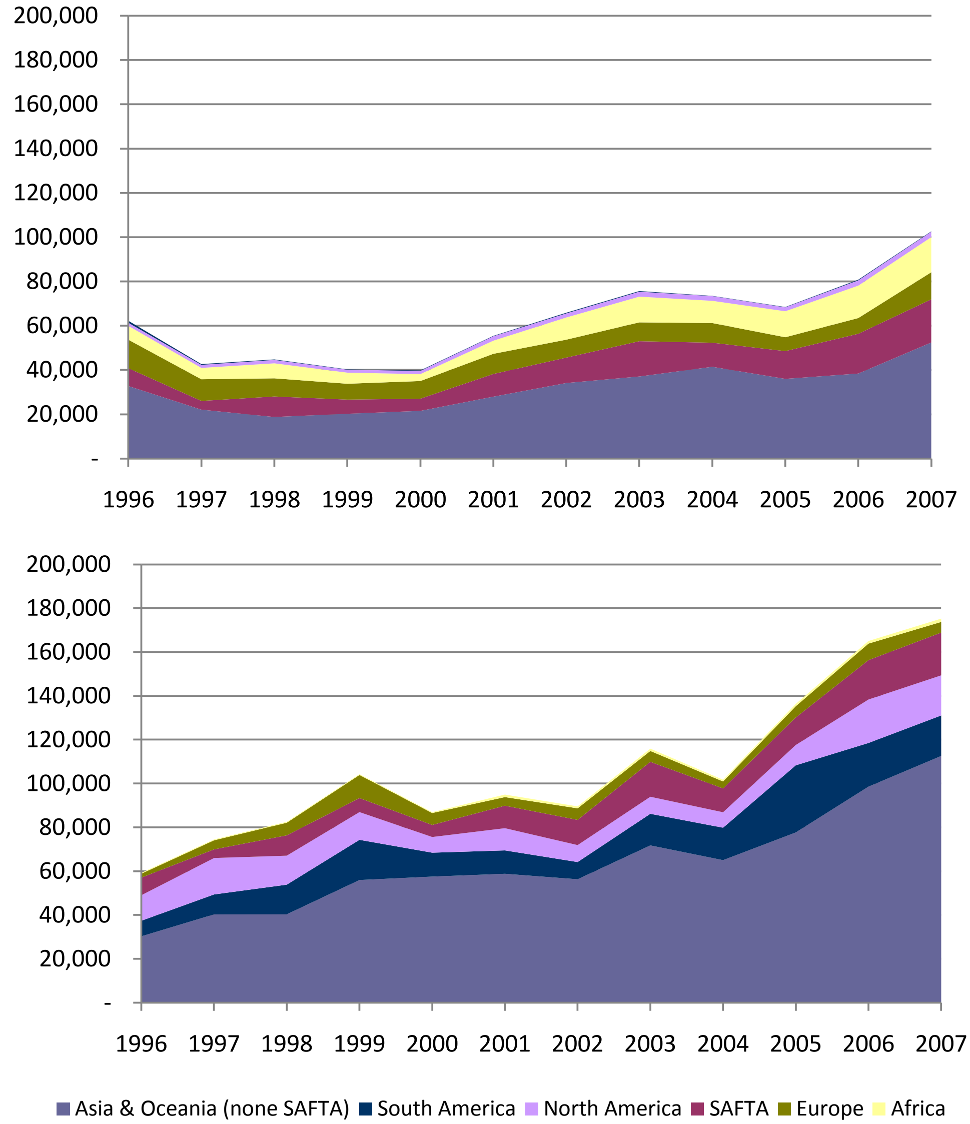
On the other hand, while imports of calories from North America and South America accounted for about 10 percent each of SAFTA's total caloric imports in 2007, these regions are not important markets for SAFTA's caloric exports.

During the period 1996-2007 SAFTA was a net protein exporter (Figure 9). Exports of proteins increased from 3,447 kilotons in 1996 to 4,770 kilotons in 2007, while imports grew from 1,015 kilotons in 1996 to 4,264 kilotons in 2007. As in the case of trade of calories, Asia & Oceania is SAFTA's most important protein trade partner - accounting for 73 percent of total protein exports and 49 percent of total protein imports in 2007. North America is the second largest import market (accounting for 20 percent of SAFTA's total protein imports in 2007) but not a significant export market; Africa is the third largest export market (accounting for 6 percent of SAFTA's total protein exports in 2007) but not an important import market for proteins.

The SAFTA region is a net fat importer (Figure 10). Between 1996 and 2007 fat exports approximately doubled (from 991 kilotons to 1,865 kilotons) but fat imports increased three-fold (from 3,754 kilotons in 1996 to 10,142 kilotons in 2007). Europe and SAFTA's intra-regional markets are important export destinations, while North and South America are significant sources of SAFTA's fat imports.

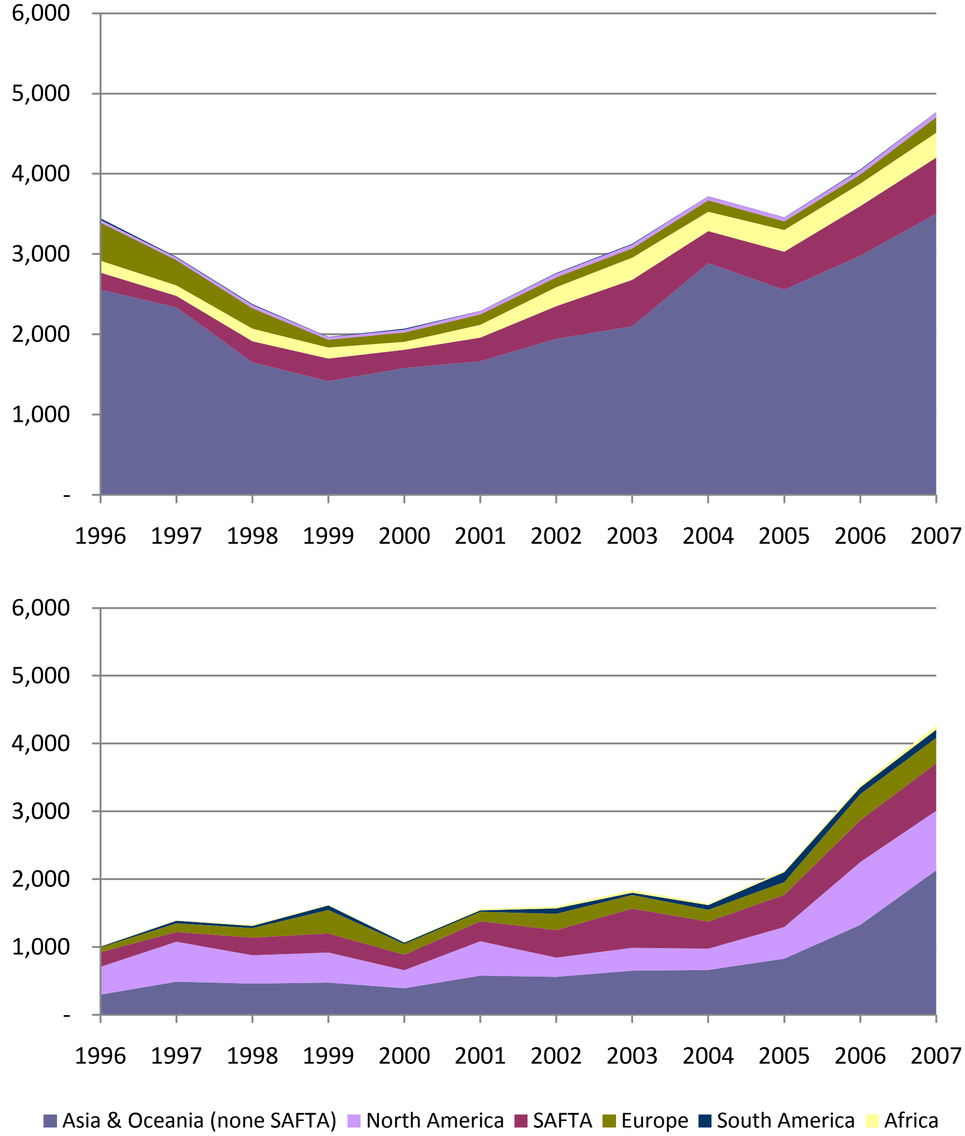
To conclude, SAFTA is a net importer of calories and fats and a net exporter of proteins. Asia & Oceania constitutes by far the most important export and import market for SAFTA's exports and imports of calories, proteins and fats. North and South America are important import markets but their share in total exports of SAFTA is small. Africa on the other hand is an important export market, but not an important source of imports. Finally, the regional decomposition of trade has stayed rather constant over time.

Figure 8 Exports and Imports of Calories by Region (billions)



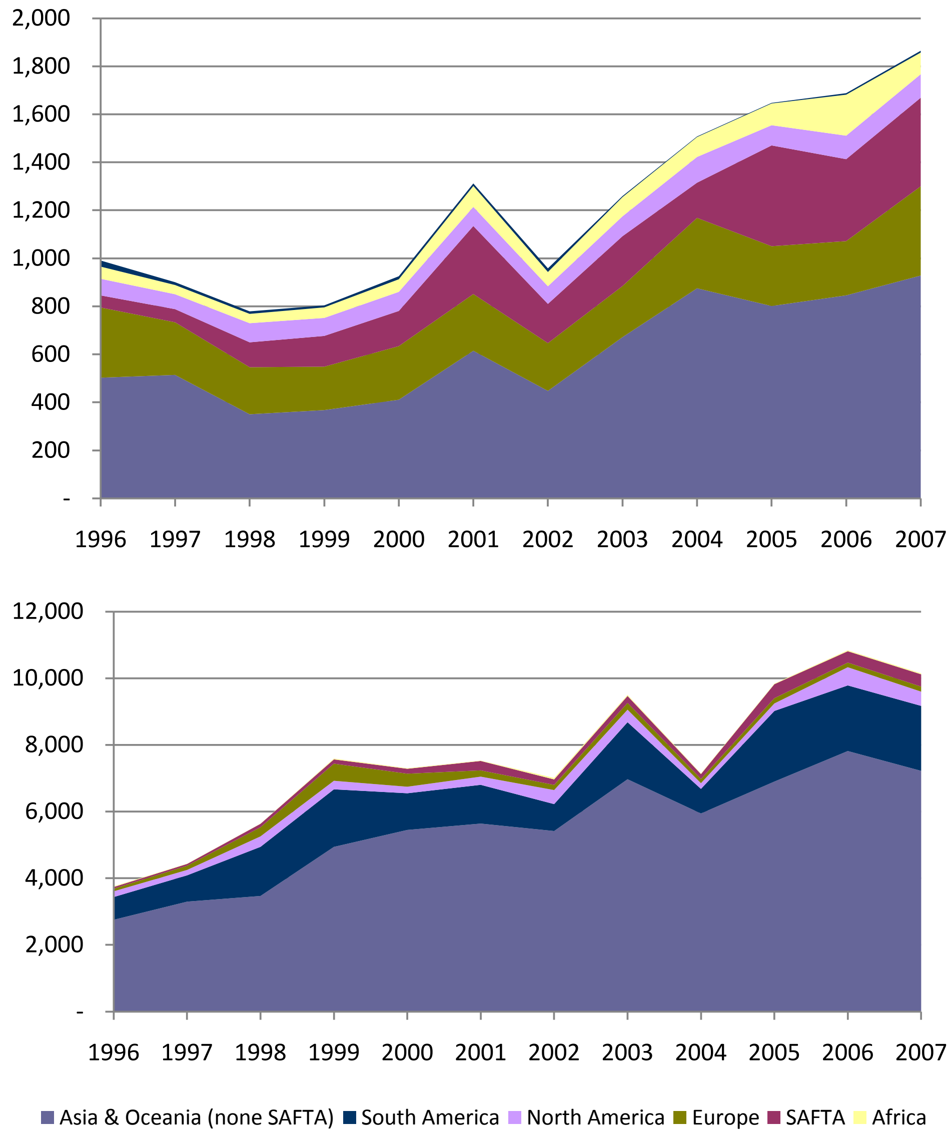
Note: Upper graph is exports, lower graph is imports.

Figure 9 Exports and Imports of Proteins by Region (kilotons)



Note: Upper graph is exports, lower graph is imports.

Figure 10 Exports and Imports of Fats by Region (kilotons)



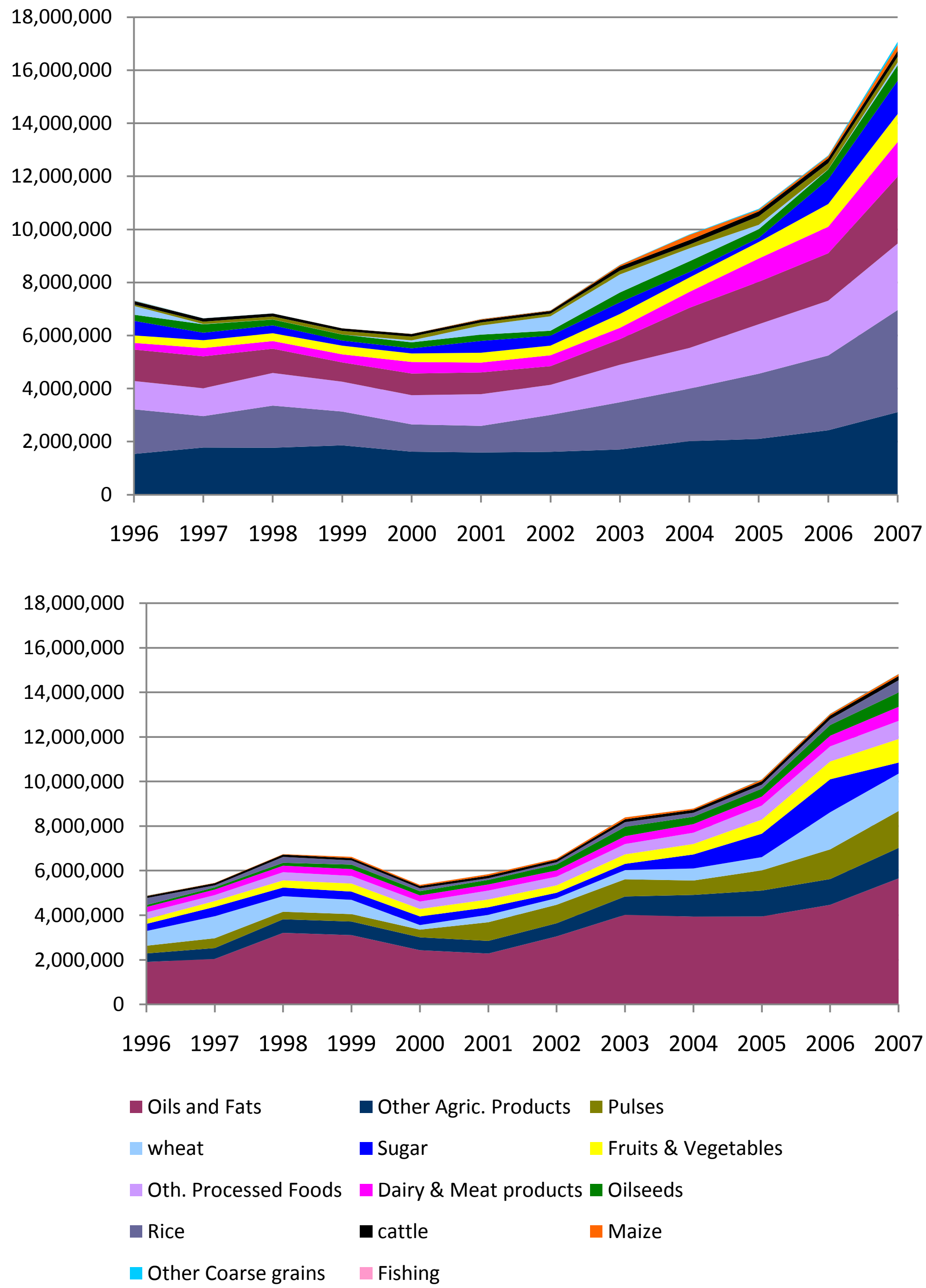
Note: Upper graph is exports, lower graph is imports.

3.2.1 The evolution of trade flows by sector

Figure 11-15 provide a sectoral decomposition of trade flows during the period 1996-2007 in terms of respectively value, calories, fats and proteins.

SAFTA was a net exporter of ag-food commodities in value terms between 1996-2007 (except in 1999 – see Figure 11). Net exports amounted to $2.44 billion in 1996 and $2.24 billion in 2007. The most important export commodities are rice, other agricultural products, and oils and fats with 22 percent, 18 percent and 14 percent of total ag-food exports in 2007. SAFTA's most significant ag-food import commodities include oils and fats (including meals) representing 38 percent of total ag-food imports in 2007, followed by other agricultural products and pulses. SAFTA's trade profile in food and other agricultural commodities has stayed relatively constant over time - commodity shares in total trade did not change significantly during 1996-2007.

Figure 11 Exports and Imports by Sectors in 10^3 US dollars

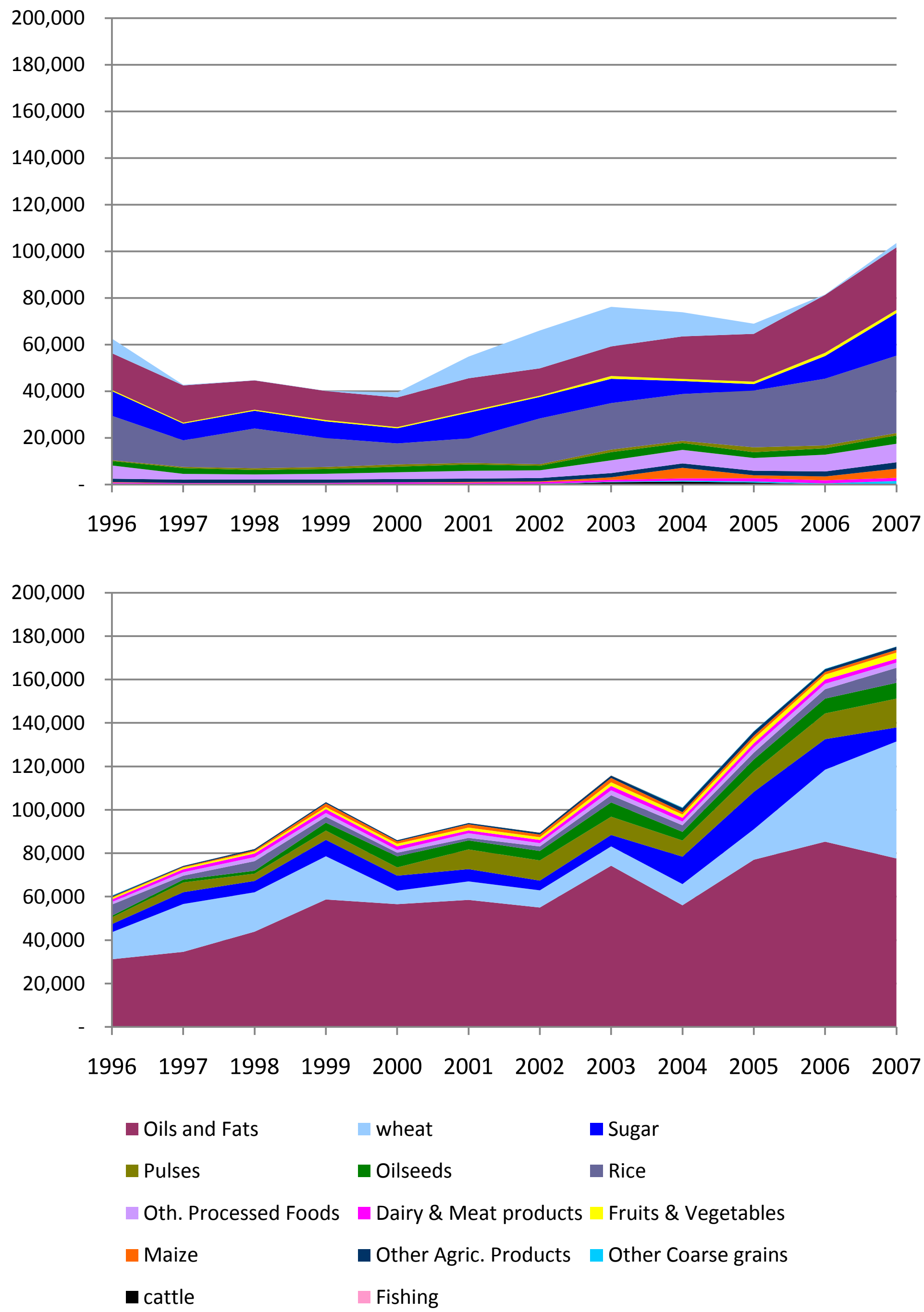


Note: Upper graph is exports, lower graph is imports.

Figure 12 illustrates the evolution of SAFTA's ag-food commodity trade decomposed by the calorie content of these sectors. Oils and fats are the most significant source of caloric imports accounting for 44 percent of the total (compared to 38 percent of total import value), followed by wheat with a 30 percent share. As far as caloric exports are concerned, rice has the highest

share in the total (32 percent as compared to a 22 percent share in total export value). Whereas the “other agricultural products” sector accounts for 18 percent of the value of total ag-food exports of SAFTA, its share in total exports of calories is insignificant.

Figure 12 Exports and Imports of Calories by Sector (10^3 metric tons)

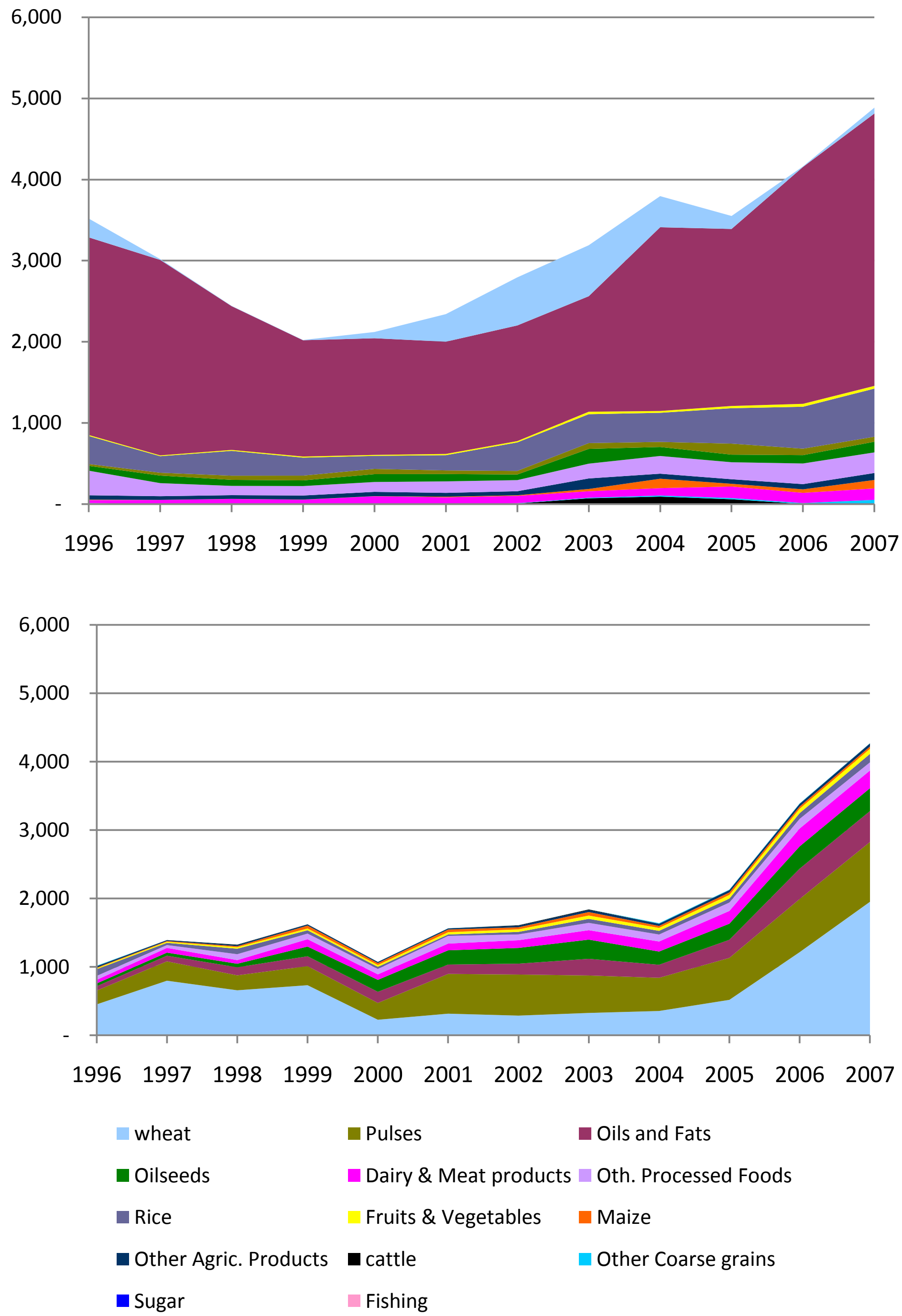


Note: Upper graph is exports, lower graph is imports.

Exports of oils and fats account for the highest share (68 percent - see Figure 13) of total exports of proteins (largely because oilseed meals are included in this sector) but represent only 14 percent of total exports in value terms (and 10 percent of total protein imports because exported oils and fats are higher in protein content that imports). The share of wheat in total protein exports increased between 1998 and 2002 (21 percent of total protein exports in 2002 compared to 1 percent in 1998), an increase commensurate with the increase in value of wheat exports during the same period period. Wheat and pulses are the most important sources of imported proteins, representing respectively 45 percent and 20 percent of total imports of proteins in 2007.

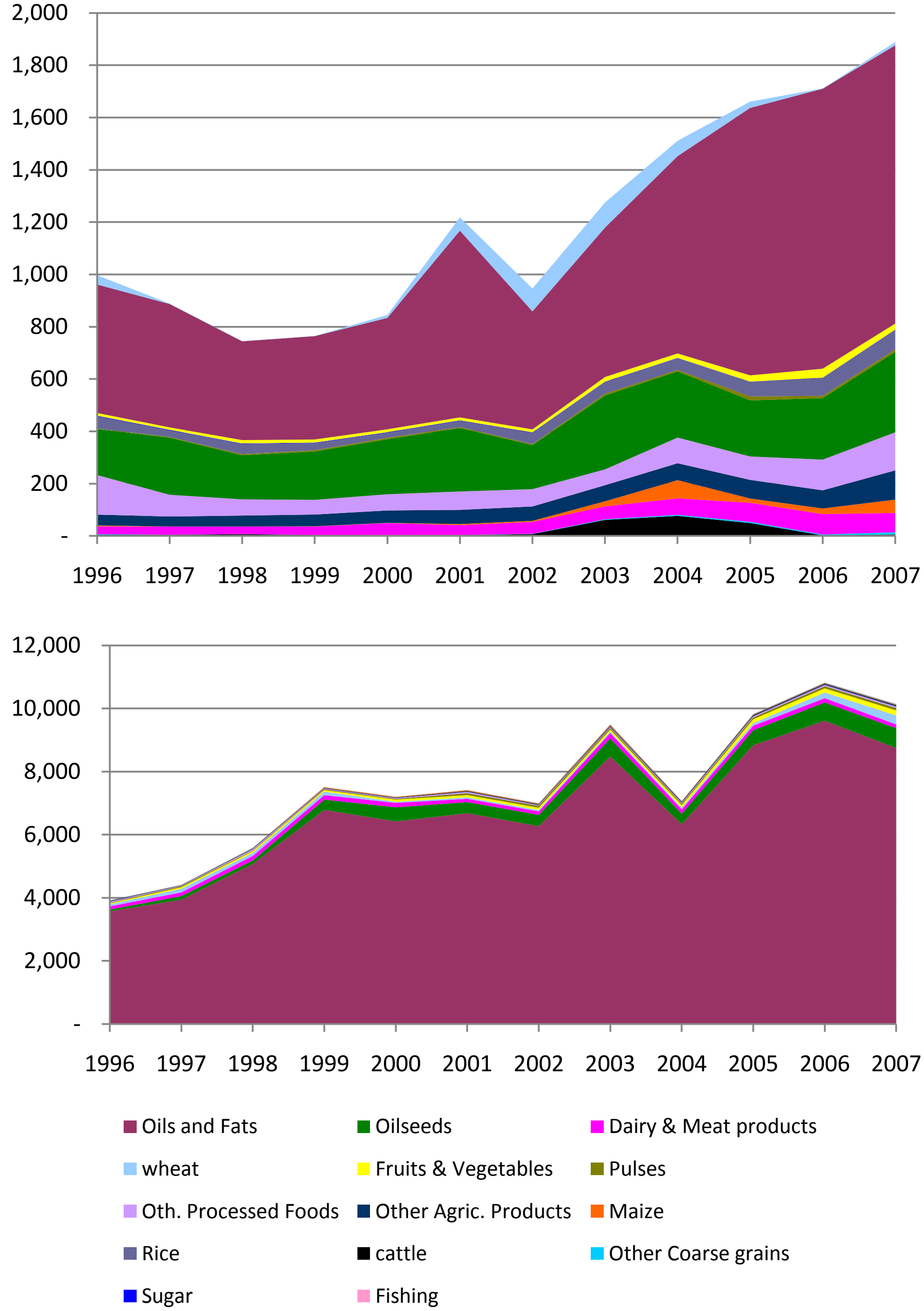
Figure 14 describes the sectoral composition of SAFTA's exports and imports of fats. Oils & fats and oilseeds are clearly the two most important sources of fats in total trade, accounting for respectively 56 percent and 16 percent of total exports of fats in 2007, and respectively 86 percent and 6 percent of total imports of fats.

Figure 13 Exports and Imports of Proteins by Sector (10^3 metric tons)



Note: Upper graph is exports, lower graph is imports.

Figure 14 Exports and Imports of Fats by Sector (10^3 metric tons)



Note: Upper graph is exports, lower graph is imports.

3.2.2 Regional and sectoral decomposition of SAFTA's trade flows

Figure 15-18 display a decomposition of trade flows in terms of value, calories, proteins and fats - this time simultaneously by region and by sector.

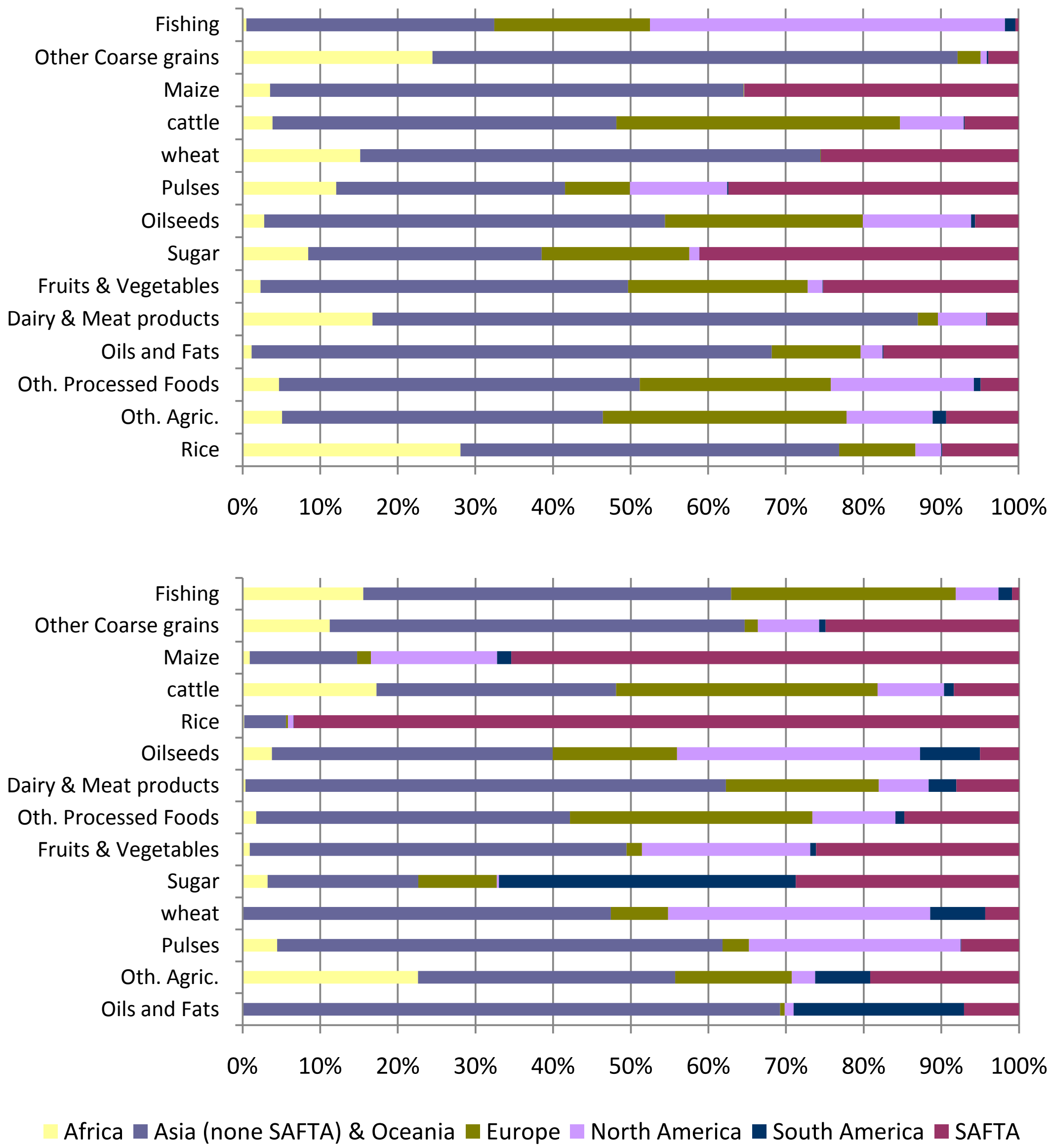
Figure 15 represents exports and imports of ag-food commodities in value terms. Asia & Oceania is SAFTA's most significant trading partner. For example it is the origin of 70 percent of SAFTA's imports of oils and fats, and the destination for 67 percent of SAFTA's exports of other coarse grains. Another significant export and import market is represented by SAFTA's intra-regional market, in particular in the case of sugar (62 percent of total sugar exports) and maize (66 percent of total imports). South America is not a significant market for SAFTA's ag-food exports, even though it is an important source of sugar imports (38 percent of SAFTA's total imports of sugar).

Note: Upper graph is exports, lower graph is imports.

Figure 16 provides an overview of the composition of trade of calories by ag-food sector and trading partners. Again Asia & Oceania comes to bear as an important source and destination for SAFTA's trade in ag-food products. For example and when expressed in calorie terms, Asia & Oceania is the destination of 73 percent of SAFTA's total cattle exports and 69 percent of its oils and fats exports. When expressed in calorie terms, SAFTA sources respectively 90 percent and 84 percent of its rice and maize imports from inside the region.

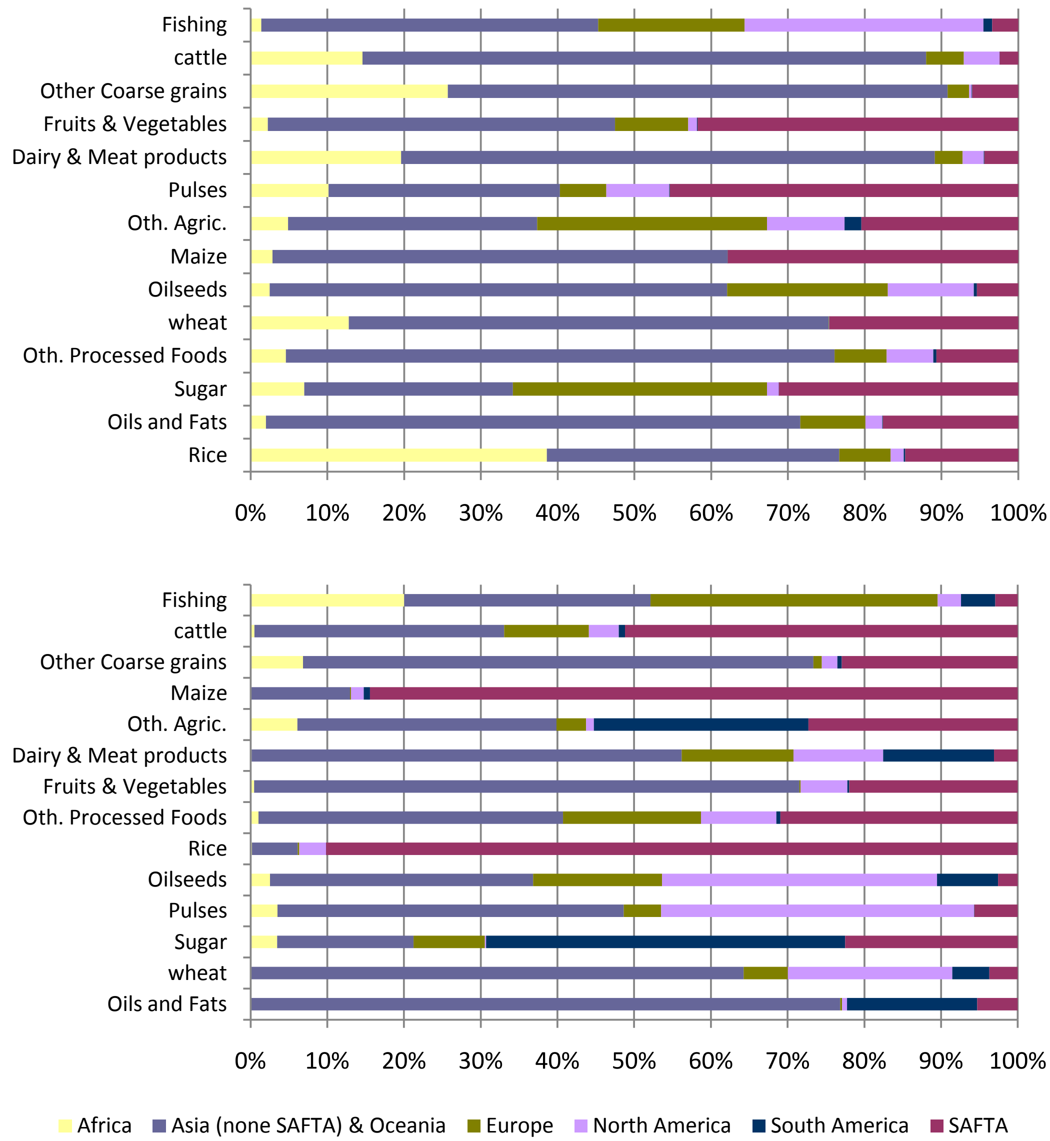
The composition of SAFTA's trade flows by fat and protein content split out by region are presented in respectively Figure 13 and Figure 14.

Figure 15 Composition of Exports and Imports (value)



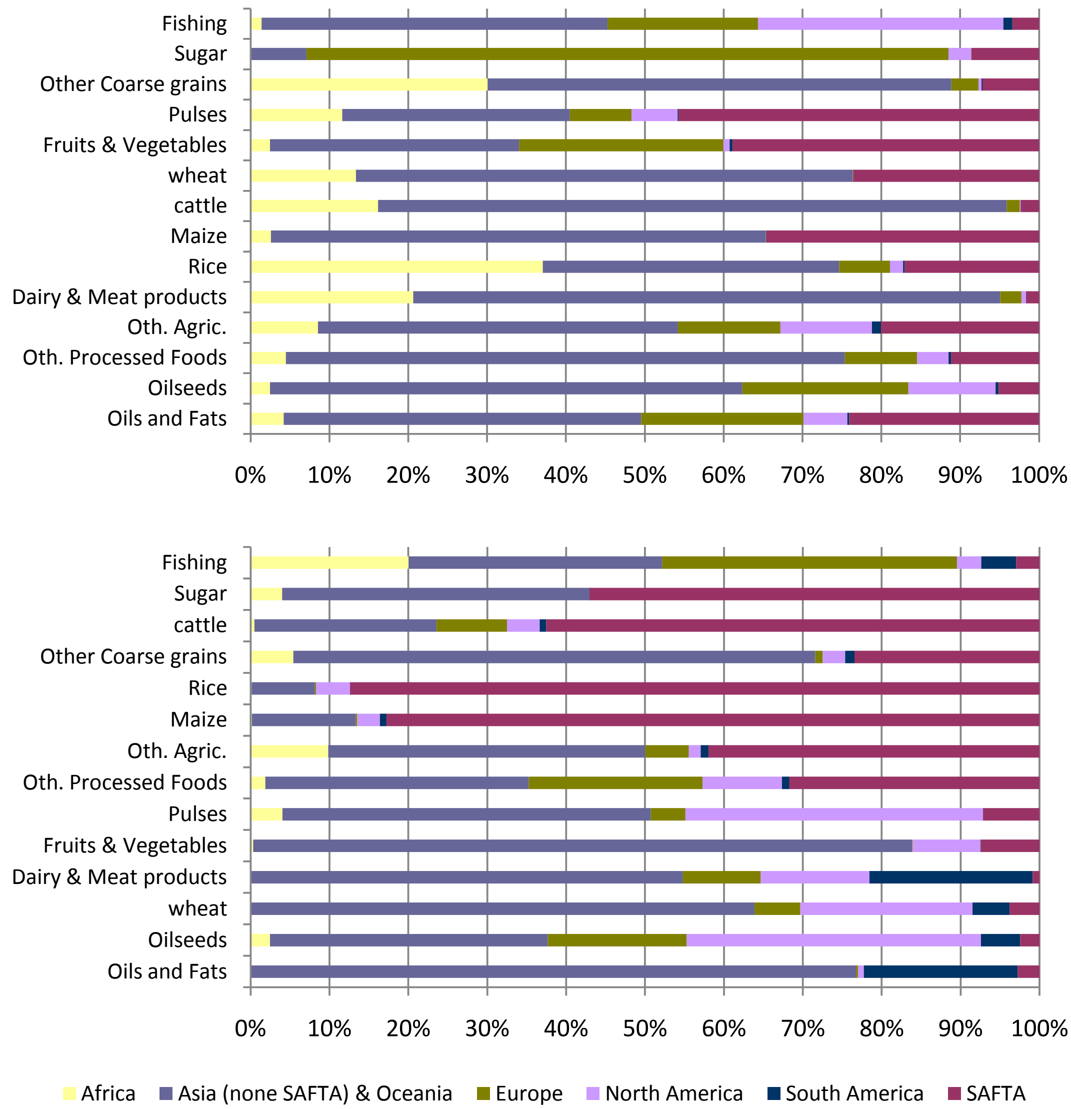
Note: Upper graph is exports, lower graph is imports.

Figure 16 Composition of Exports and Imports of Calories



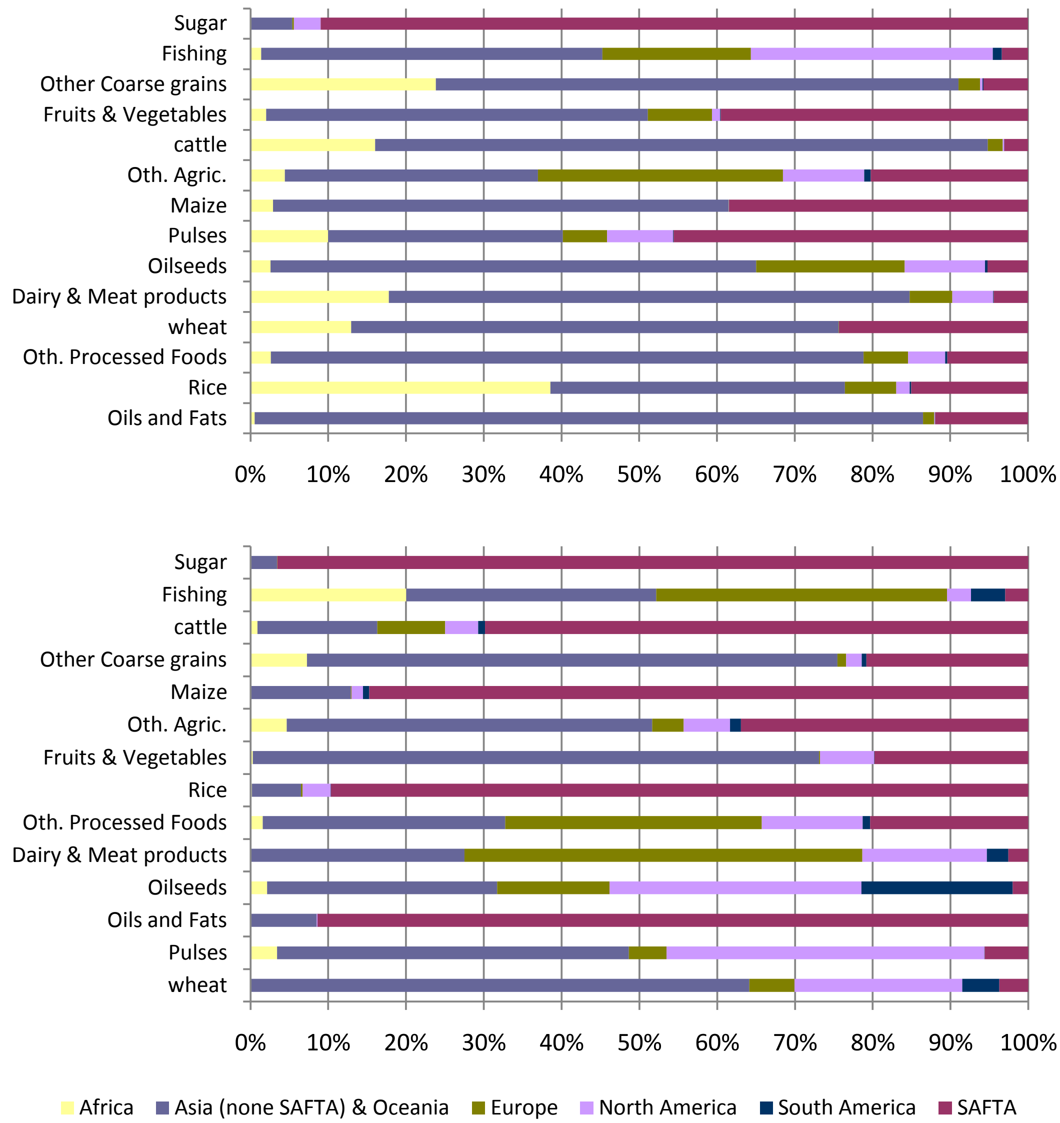
Note: Upper graph is exports, lower graph is imports.

Figure 17 Composition of Exports and Imports of Proteins



Note: Upper graph is exports, lower graph is imports.

Figure 18 Composition of Exports and Imports of Fats



Note: Upper graph is exports, lower graph is imports.

3.2.3 The composition of SAFTA's intra-regional trade

Table 4-6- provide an overview of SAFTA's intra-regional trade weighted by the calorie, protein and fat content of trade respectively. We find that India is by far the most significant trading partner of all other SAFTA countries. Bhutan and Nepal only import from India and Pakistan, while all SAFTA member countries export to Bangladesh, India and Pakistan.

In calorie terms (see Table 4), while India accounts for 78 percent of intra-regional exports of calories, its share of total intra-regional imports is significantly lower at 19 percent. This finding is consistent with the structure of average protection rates described above: the average tariff level applied by India on imports of calories originating from the rest of SAFTA is 9.1 percent, compared to a 4 percent average tariff faced by Indian exports.

India is the destination of 99 percent of Nepal's exports, 93 percent of Bangladesh's and 92 percent of Sri Lanka's. On the other hand, India's most significant regional export markets include Bangladesh (48 percent of total intra-regional caloric exports), Sri Lanka (20 percent) and Pakistan (20 percent). This order changes when it comes to India's imports of calories: Sri Lanka accounts for 40 percent of India's total caloric imports, followed by Nepal (27 percent) and Pakistan (23 percent).

With respect to trade values weighted by the protein content (Table 5) and fat content of trade (Table 6), the composition of trade does not change significantly when compared to that of calories. However, India's imports from Sri Lanka are less intensive in protein content than calorie content - but more intensive in fat content than in both calorie and protein content.

Table 4 Bilateral Exports of Calories (10^6 metric tons)

Importer/ Exporter	Bangladesh	Bhutan	Sri Lanka	Maldives	Nepal	Pakistan	India	Total
Bangladesh			7,569		0	127,935	4,518,449	4,653,954
Bhutan	3,097					0	79,462	82,559
Sri Lanka	1,482			216	0	125,539	1,922,600	2,049,837
Maldives	0		19,512		0	8,087	123,563	151,162
Nepal	17		35			2,169	973,839	976,060
Pakistan	1,985	0	47,765	34	2,792		1,857,128	1,909,705
India	97,960	156,229	931,828	9	627,699	541,181		2,354,905
Total	104,541	156,229	1,006,708	259	630,491	804,913	9,475,041	12,178,182

Table 5 Bilateral Exports of Proteins (10^6 metric tons)

Importer/Exporter	Bangladesh	Bhutan	Sri Lanka	Maldives	Nepal	Pakistan	India	Total
Bangladesh			20		0	4,034	167,335	171,389
Bhutan	5					0	1,597	1,602
Sri Lanka	32			13	0	2,964	71,608	74,618
Maldives	0		670		0	153	1,969	2,792
Nepal	1		0			48	37,075	37,124
Pakistan	42	0	543	2	50		112,486	113,123
India	1,758	177	6,304	0	16,934	11,882		37,055
Total	1,839	177	7,537	15	16,984	19,082	392,070	437,704

Table 6 Bilateral Exports of Fats (10^6 metric tons)

Importer/Exporter	Bangladesh	Bhutan	Sri Lanka	Maldives	Nepal	Pakistan	India	Total
Bangladesh			829		0	1,058	27,344	29,231
Bhutan	354					0	938	1,292
Sri Lanka	16			3	0	1,415	19,987	21,420
Maldives	0		335		0	71	879	1,285
Nepal	1		3			120	11,606	11,730
Pakistan	60	0	4,224	0	117		9,750	14,152
India	8,114	16,886	99,761	0	47,841	3,663		176,266
Total	8,546	16,886	105,151	3	47,959	6,326	70,505	255,376

3.3 The evolution of production, yields, and consumption of agricultural commodities

After reviewing trade policies and trade patterns, it is useful to look at the production and consumption structure of the South Asian agricultural economies. In particular, it is interesting to see how technological progress and changes in yield have impacted the trade position and capacity of these economies to cope with quick increases in demand.

3.3.1 Current situation

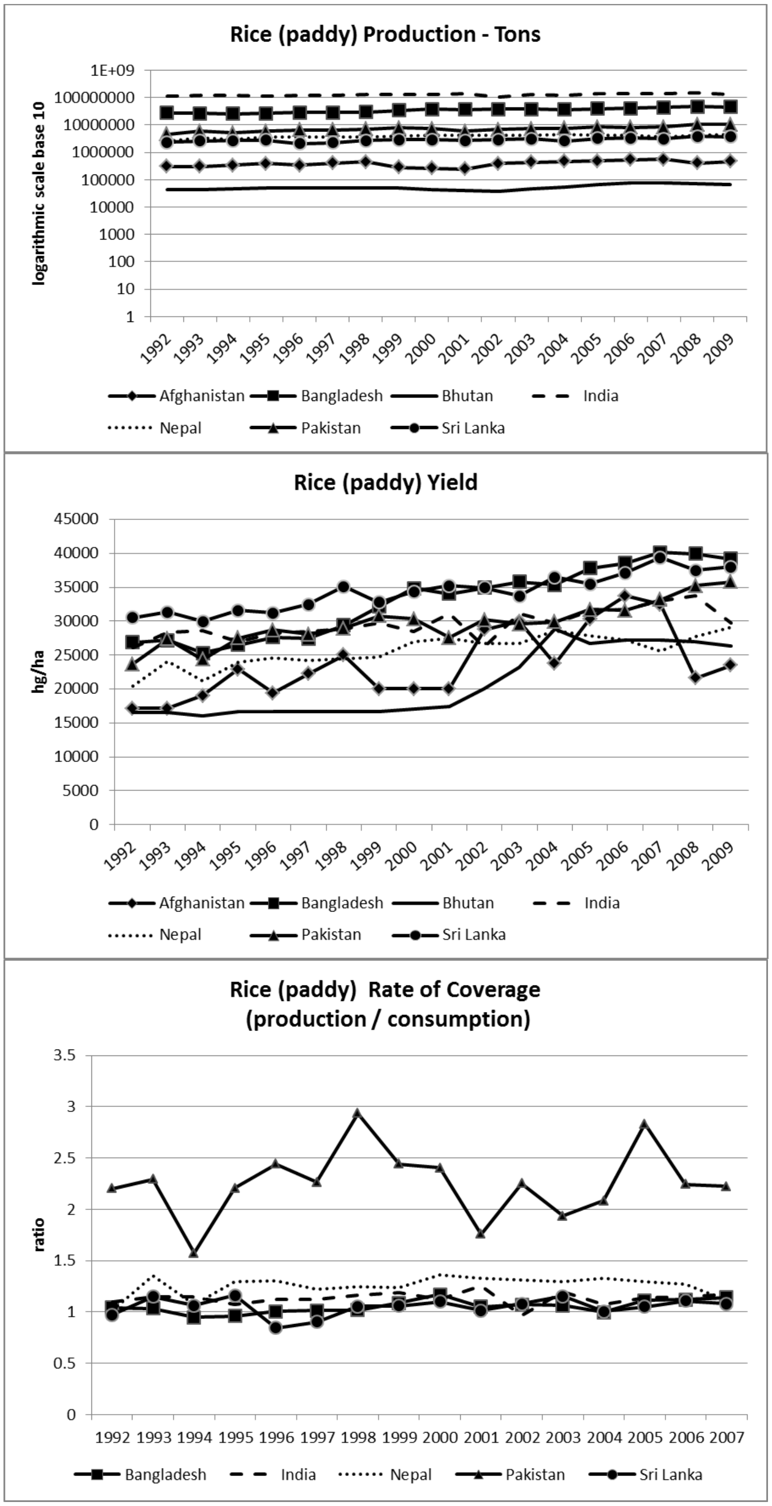
Except in Afghanistan and the Maldives, rice (paddy) ranks first or second in agricultural production in all other South Asian countries. India and Bangladesh dominate regional rice production, together accounting for more than 90 percent of the total. While India is by far the largest rice producer in South Asia (131 million metric tons (t) of paddy in 2009) and second in the world only after China, its share in regional production has been decreasing over the last fifteen years. Bangladesh ranks fourth in the world in rice production and has been increasing its share of regional production from17 to 23 percent in the past fifteen years - reaching 45 million t by 2009. Yields of paddy rice, ranging in 2009 from 2.35 t/ha in Afghanistan to 3.92 t/ha in Bangladesh have improved slightly but have remained below the world average of 4.20 t/ha (FAOSTAT 2010). Annual yield growth rates vary between 2.66 percent for countries with low paddy yield (Bhutan, Afghanistan) to 1.7 percent for the initially most productive country (Sri Lanka). The SAFTA region has been successful at satisfying domestic demand with domestic production. While Bangladesh, India and Sri Lanka have seen coverage ratios (measured by the ratio of domestic production over domestic consumption) hovering around 1, Pakistan has managed to sustain a coverage ratio exceeding 2 and nearly 3 in 1998 and 2005 for most of the past fifteen years (see Figure 19 below).

South Asia produces only 3 percent of the world's maize production (817 million t in 2009). All South Asian countries historically are net maize importers - with the notable exception of India which accounts for nearly 75 percent of total SAFTA production (FAOSTAT 2010). Pakistan is a distant second with a share in total regional production of just under 15 percent. Maize yields in South Asia have historically been low by world standards. With the exception of Bangladesh where yields reached nearly 6 t/ha in 2009, yields have remained below 3.7 t/ha in all other countries in South Asia. On the other hand, yield growth has been substantial with an annual average growth rate of more than 5 percent over the past 17 years. Improvement in yields in Bangladesh were particularly impressive - during the period 2000-2003 yields grew by 50

percent (8.5 percent per year on average since 1992) and even after 2005 the growth of maize yields in Bangladesh remained above the world average.[5] In spite of this success in improving yield performance, Bangladesh has fallen short in covering domestic maize consumption with domestic production – even though the situation is gradually improving. Similarly the ratio domestic production/domestic consumption in Sri Lanka has also remained below unity. On the other hand, India has maintained a ratio that exceeds 2.5 since 2000 and Pakistan has seen the ratio fluctuating between below 1 in 2002 to nearly 3 in 2007 (Figure 20). Overall, most SAFTA countries have managed to improve their surplus or reduce their deficit in maize.

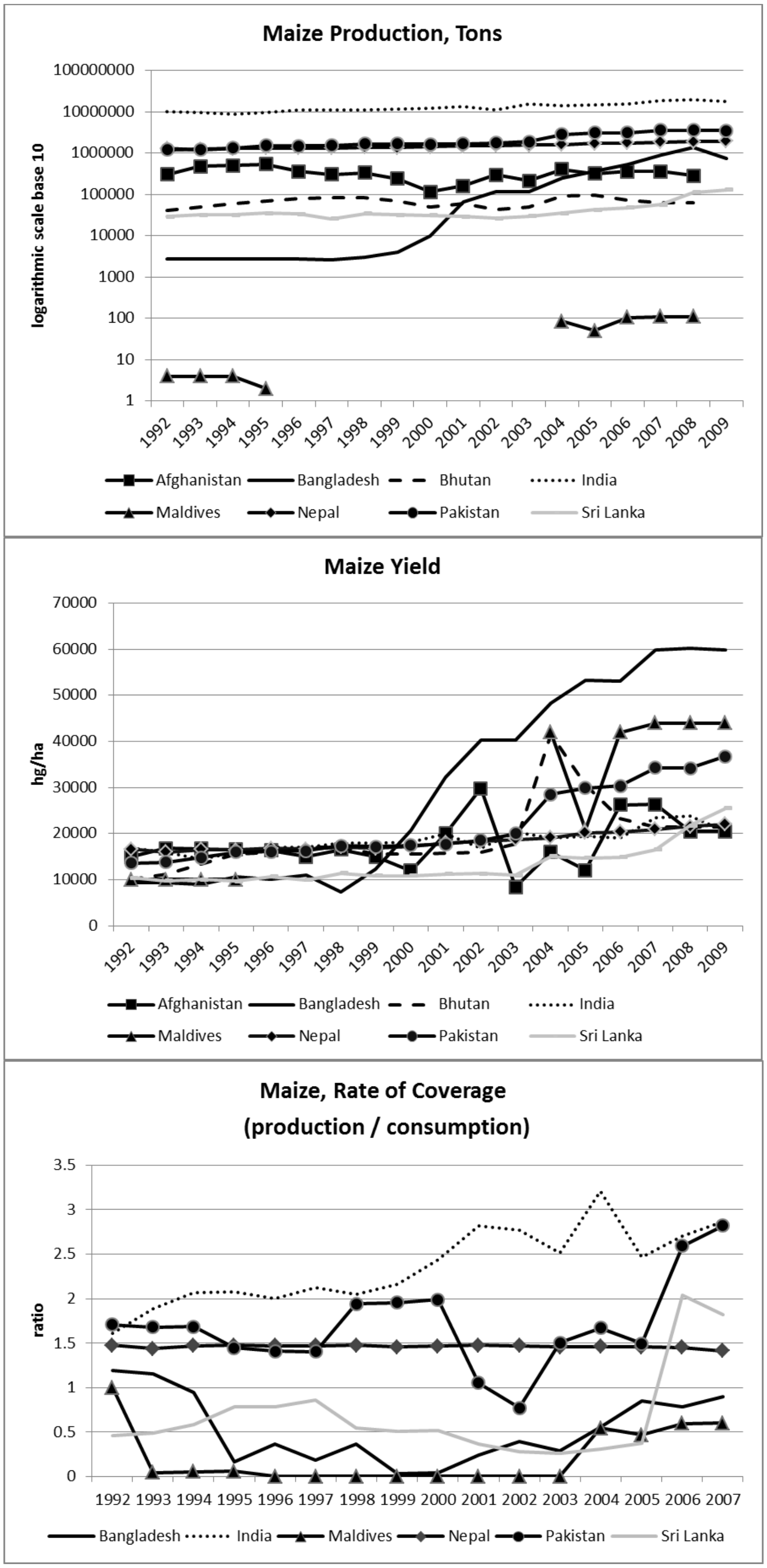
[5] During this period in Bangladesh, seed companies imported and marketed hybrid maize in order to promote production to respond to higher demand from a rapidly expanding domestic poultry sector. In 2001 Bangladesh was generating its own maize hybrids (Ali et al., 2008).

Figure 19 Production, yields and coverage of consumption: Paddy rice



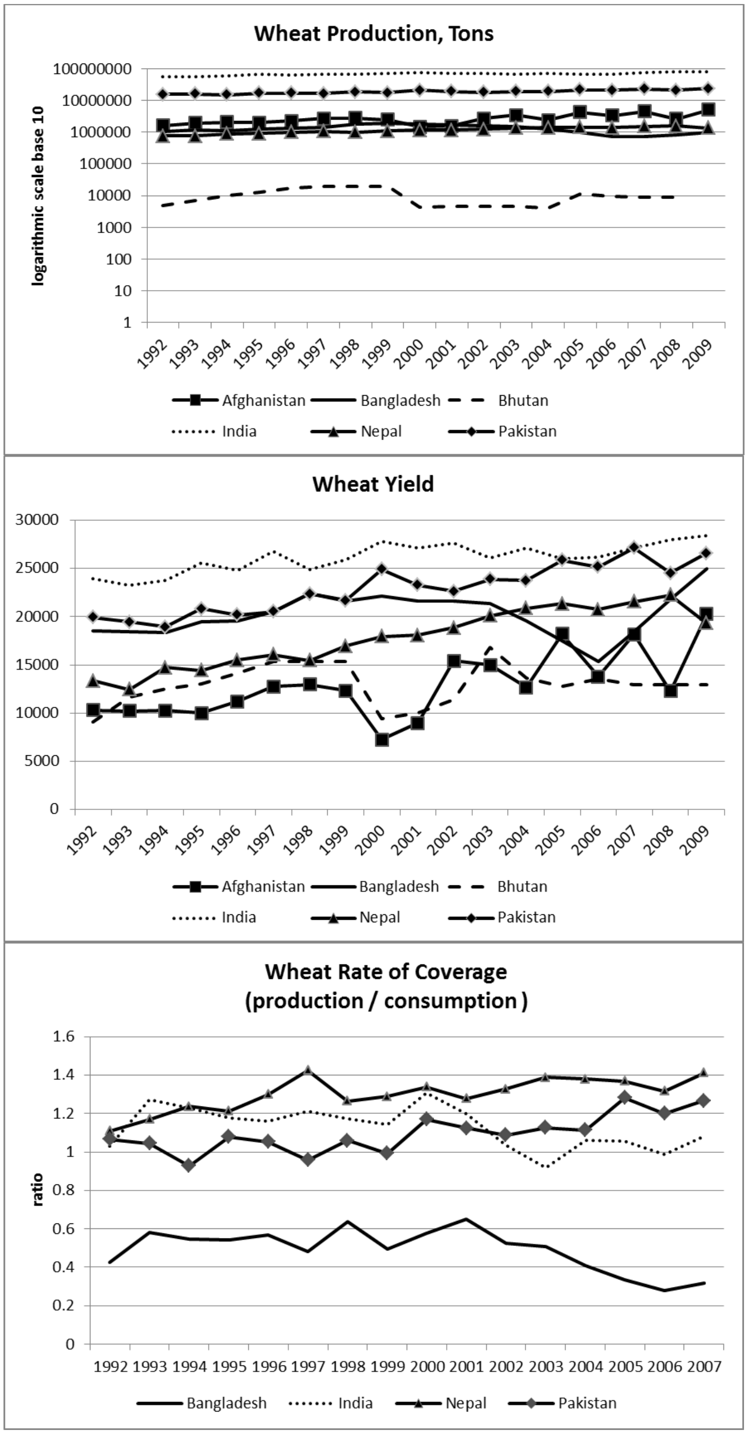
Source: Authors' computation based on FAOSTAT 2010.
Note: No coverage data available for Afghanistan and Bhutan.

Figure 20 Production, yields and coverage of consumption: Maize



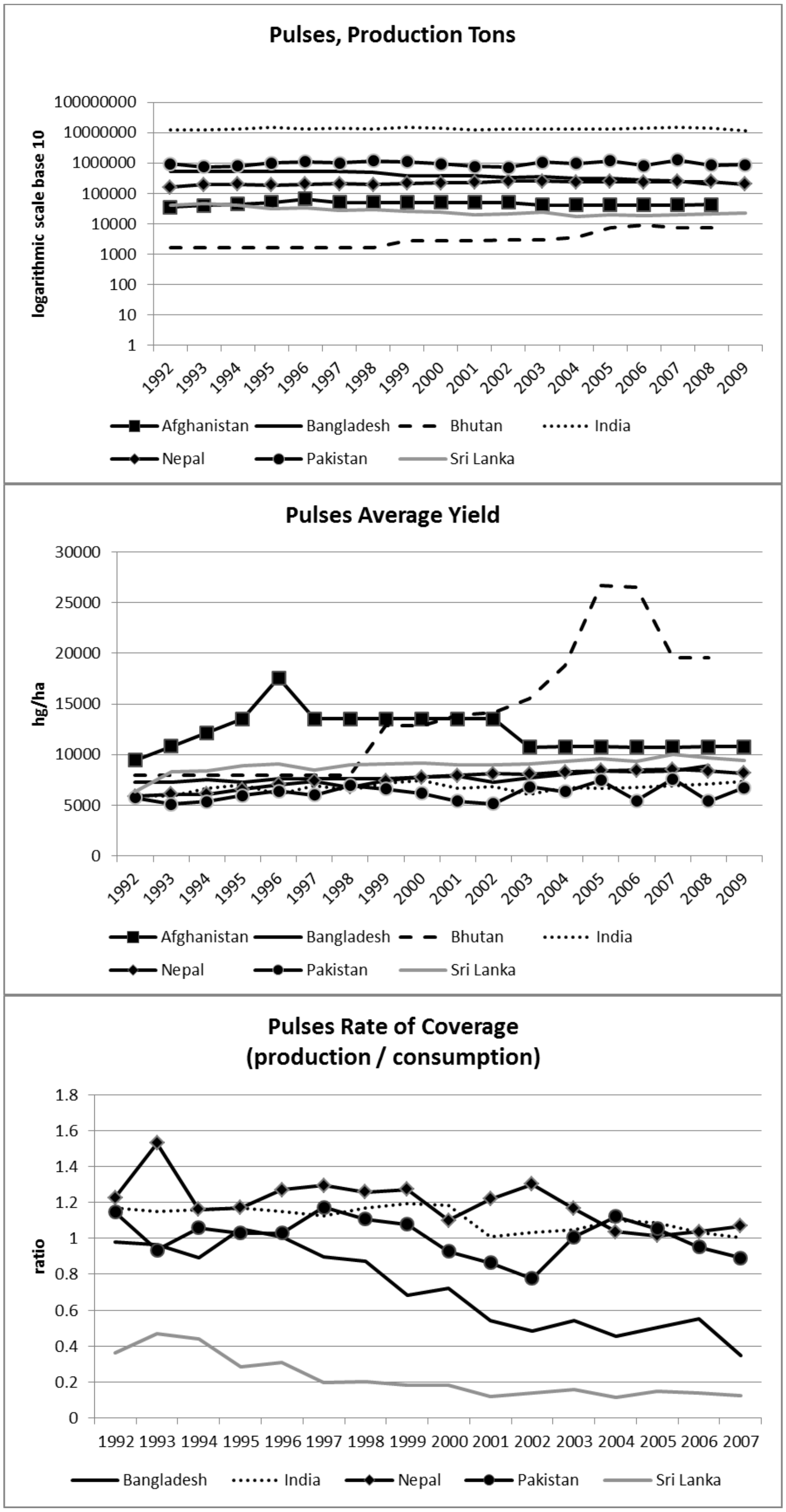
Source: Authors' computation based on FAOSTAT 2010.
Note: No coverage data available for Afghanistan and Bhutan.

Figure 21 Production, yields and coverage of consumption: Wheat



Source: Authors' computation based on FAOSTAT 2010.
Note: No coverage data available for Afghanistan and Bhutan.

Figure 22 Production, yields and coverage of consumption: Pulses



Source: Authors' computation based on FAOSTAT 2010.
Note: No coverage data available for Afghanistan and Bhutan.

Between 15 and 17 percent of the world's total wheat production originates in South Asia. In 2009 India with a production of 80.6 million t and Pakistan with 24 million t accounted for 95 percent of regional production (FAOSTAT 2010). Wheat is the second most important grain after rice in the region but production has stagnated in the period 1992-2009 - both at the regional and country level (Figure 21). Yields have improved only very gradually, especially in the case of India[6] and Pakistan (average yearly growth rate in the order of 1.5 percent). Recently wheat yields in Bangladesh have gone up substantially. But wheat yields in all three countries remain below the world average. Yields in other SAFTA countries are lower but catching up (e.g. the average yearly growth rate for wheat in Nepal is in the order of 5.5 percent). Coverage of domestic consumption is good for most producing countries – with the exception of Bangladesh where the wheat coverage ratio has remained below 0.7 and is decreasing (Figure 21); and Sri Lanka and the Maldives which rely totally on imports (mostly from India) to meet their domestic demand.

South Asia accounts for about 25 percent of total world pulse production. During the period 1992-2009 regional production varied relatively little - ranging between 14 and 17 million t (FAOSTAT 2010). Individual countries' production reflects economic size hierarchy between countries (Figure 22). Chick pea, beans and pigeon pea account for 80 percent of total pulse production in the region. India expectedly dominates the market, followed by Pakistan and Bangladesh. With the exception of Bhutan, Pakistan and Sri Lanka, average pulse yields have largely stagnated, ranging between 0.5 and 1.0 t/ha. In India no significant yield increases have been achieved in nearly 20 years. Coverage of domestic demand for pulses has historically been a challenge: ratios are particularly low in the Maldives and Sri Lanka, they have been decreasing in Bangladesh and barely reach unity in India, Nepal and Pakistan (Figure 4). Nepal was the only net exporter of pulses in the region until 2005 when became a net importer - just like the other South Asian countries (FAOSTAT 2010).

In summary, the region is an important player at the world level in terms of production and consumption for key cereals and pulses. It has managed to cope with increased demand by improving yields for most crops - but has not developed significant export surpluses. While the

[6] Limited yield increases in India appear to be mainly the result of reduced and imbalanced input usage of fertilizers in the Indo-Gangetic plain (Nagarajan, 2005).

situation regarding rice remains satisfactory, the wheat balance is more precarious and the deficit in pulses has deepened. Yield gains in rice have allowed all SAFTA countries to maintain or improve self-sufficiency ratios. The wheat situation paints a different and more variable picture: while Nepal and Pakistan have increased yields and improved their production capacity, other countries have seen their dependence on international trade grow. Regional equilibrium still depends on the yearly fluctuations in Indian production and policies – e.g. export restrictions aimed at stabilizing the Indian domestic market potentially involve large negative externalities for the smaller countries - as became evident in 2008 during the food crisis. Regarding maize, Bangladesh has managed to increase yields and production and reduce its deficit. Other countries have followed this trend by reducing their imports or increasing their export potential. While the overall situation for cereals remains satisfactory, this is not the case for pulses where the relatively marginal or even zero yield increases have increased SAFTA's dependency on imports.[7]

While the poorest economies of the SAFTA region have performed a partial catch up in terms of agricultural productivity with the main regional producers, yields in the region as a whole are still lagging those in many other areas of the world (and not only developed but also some developing countries e.g. South East and East Asia) . Yield increases are increasingly critical for maintaining an adequate coverage ratio and that any perturbation coming from climate change can lead to a quick deterioration in the regional food balance.

3.3.2 Yield fluctuation and domestic demand coverage

The production capacity in South Asia affects the region's trade requirements. To identify this relationship, a two step analysis was performed: first investigating whether changes in yields generate changes in self sufficiency ratios, i.e. determining if short term yield fluctuations involve a widening or a reduction in the gap between domestic supply and domestic demand. Indeed, for a given planted area, production is directly proportional to yields so changes in the self sufficiency ratio can be expected to be correlated with changes in yields if consumption remains constant. Figure 23 illustrates this correlation for each country and commodity.[8]

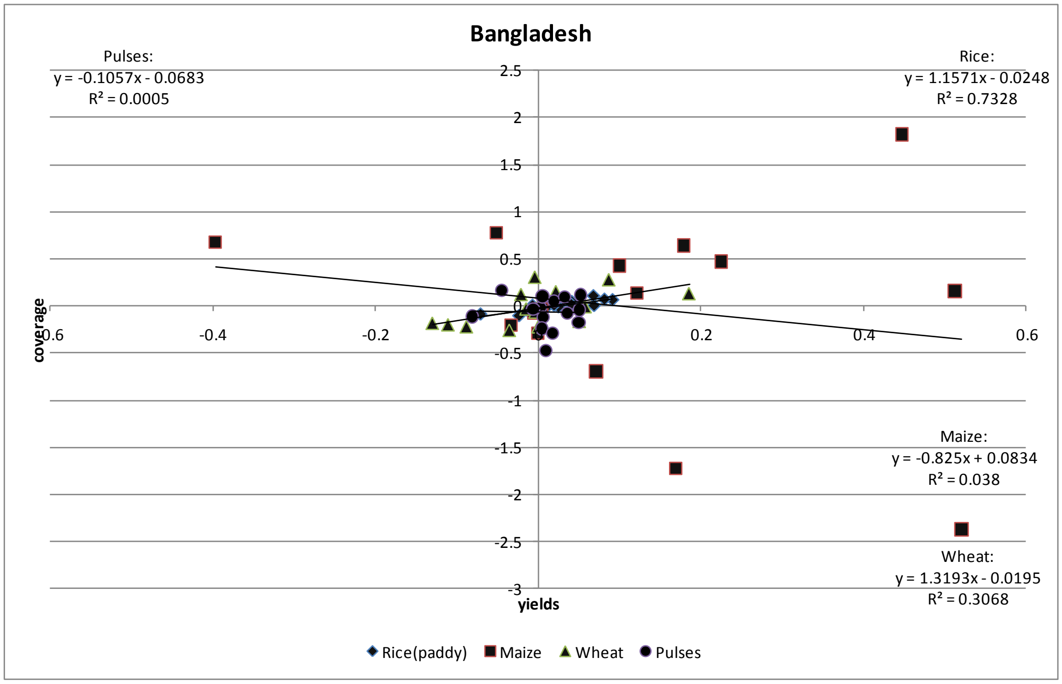
---

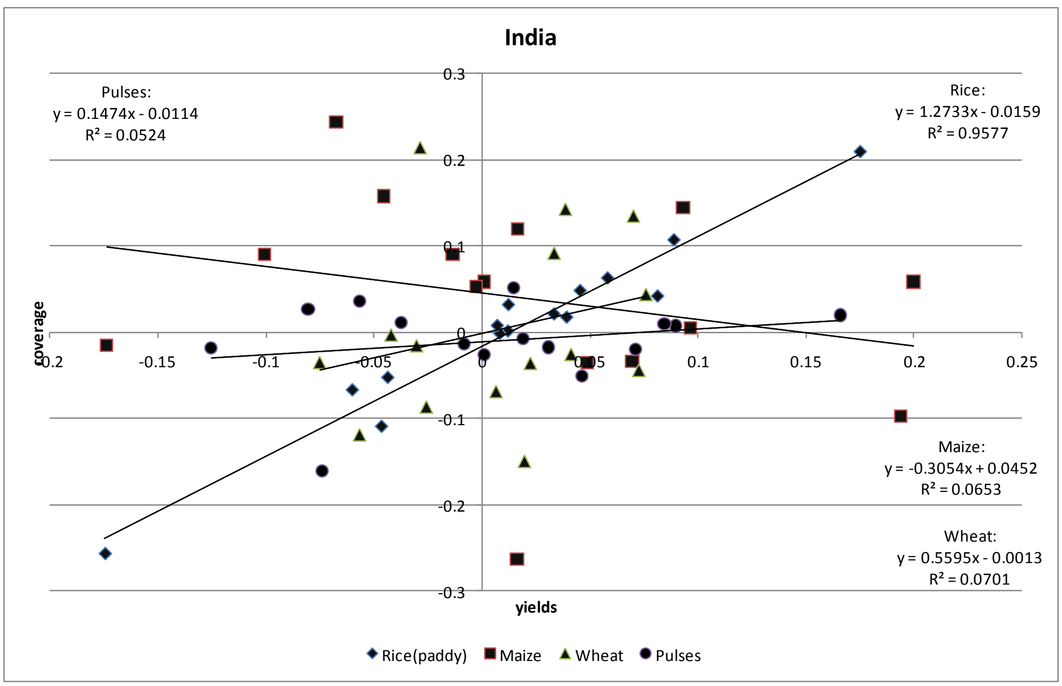
[7] This reflects the lack of R&D for these commodities but also the large gap for these traditional crops between recommended best agronomic practices and currently prevailing farm practices.

[8] Indicators for coverage and yields are expressed by the difference in the natural logarithms of their respective annual values for the period 1992-2007.

The relationship between changes in self sufficiency ratio and changes in yield is strongest in the case of rice for India, Nepal and Bangladesh (R^2 values of 0.96, 0.93 and 0.73 respectively). For these countries the expected results are obtained: short term yield variations explain the gap between consumption and production - and therefore this gap has to be managed through inventory changes or trade. For Sri Lanka however, this relation does not appear and production and consumption remain closely correlated: in other words changes in yields induce adjustments in consumption. As shown in Figure 1923, Sri Lanka maintains a high and rather stable self-sufficiency ratio in rice (except for the 1996-1997 period).

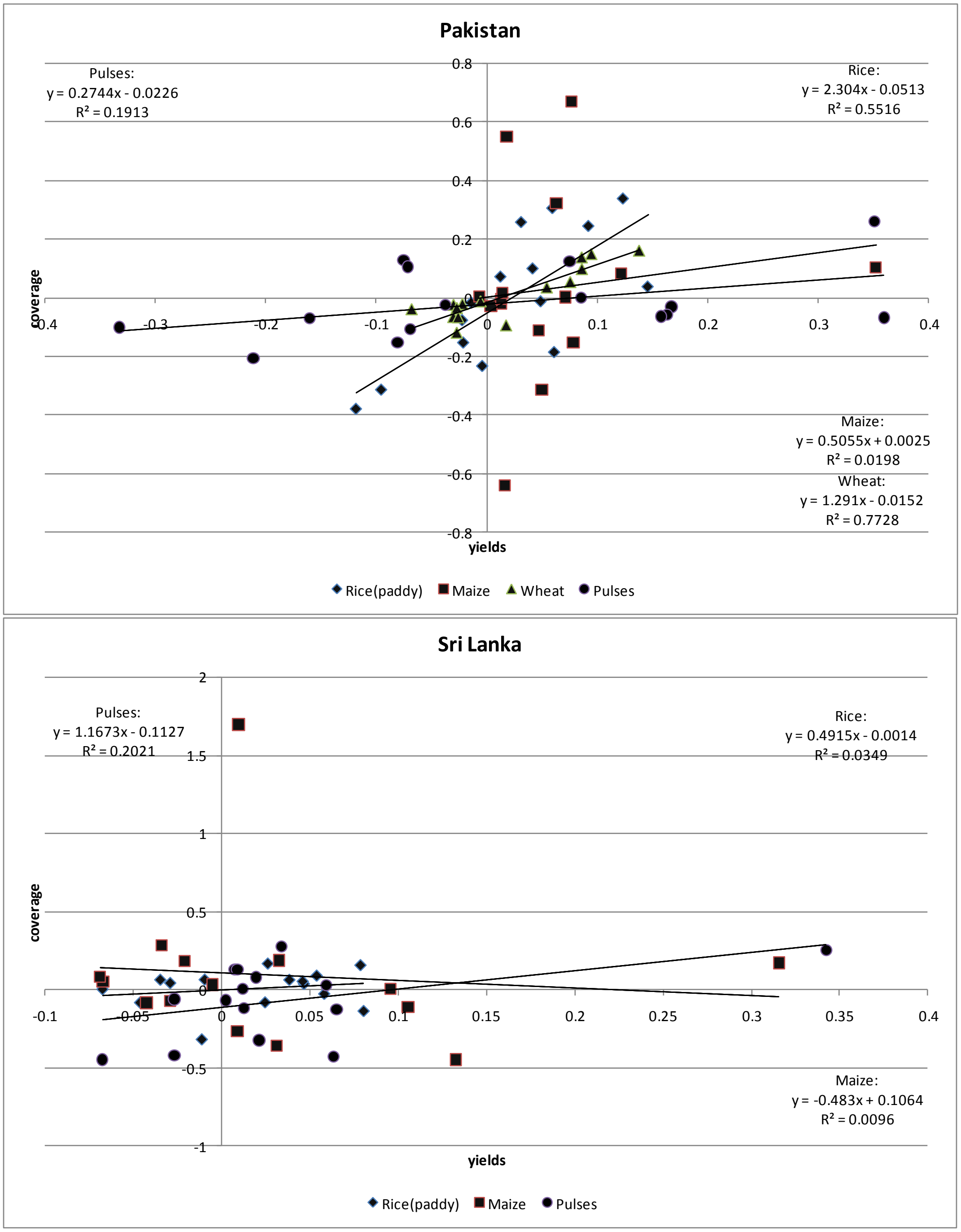
Figure 23 Correlation between variations in coverage and yield - by country





Source: Authors' computation based on FAOSTAT 2010.
Note: Graphs represent the relationship between coverage and yields as a linear function:
$Ln(coverage_t) - Ln(coverage_{t-1}) = f(Ln(yield_t) - Ln(yield_{t-1}))$. t = 1992-2007.

Figure 23 (continued)



Source: authors' computation based on FAOSTAT 2010.

Note: Graphs represent coverage and yields in the a linear function: Ln(coverage t) - Ln (coverage t-1) = f(Ln(yield t) - Ln (yield t-1)). t = 1992-2007.

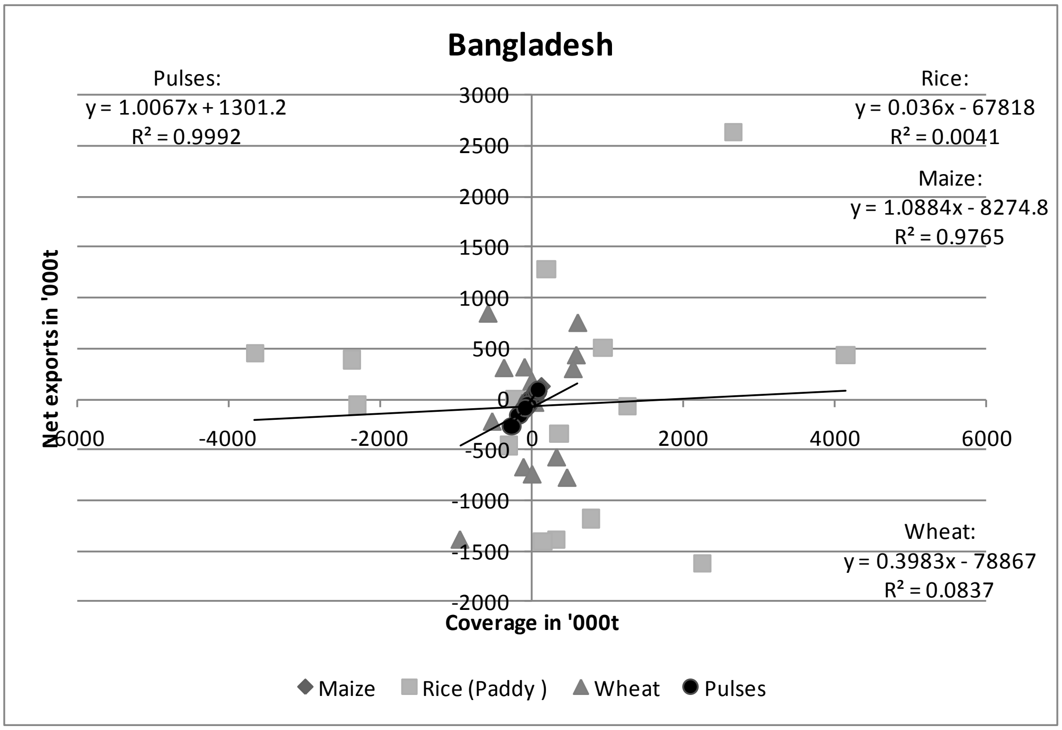
In the case of wheat, only Pakistan displays a strong correlation between coverage and yields, with the expected sign and a R^2 of 0.77. No strong relationship is found in the cases of maize and pulses for any of the SAFTA countries. In these cases changes in area planted and fluctuations in food demand seem to contribute more than changes in yields to the variations in coverage. For example in Bangladesh, the decline in wheat production between 2003 and 2007 is driven by the reduction in area harvested while maize production peaked in 2001 due to a threefold increase in area harvested (FAOSTAT 2010). In India, changes in harvested wheat area has fluctuated between -5 and +5 percent and changes in harvested maize area varied between 0 and 10 percent for the period 1992-2007 (FAOSTAT 2010). Depending on the situation, these land use changes were correlated positively or negatively to yield changes. For example in the case of maize production in Bangladesh, new technologies (e.g. hybrid seed) have permitted large gains in yields and increased the profitability of this crop leading to large production increases. On the other hand in India, area expansion takes place primarily in less favorable regions where yields are lower - leading to increased production but lower average yields. In addition, demand behavior can be also a dominant factor responsible for changes in the coverage ratio. In India for example, the annual variation in total demand for wheat has varied between -10 percent to +20 percent while production changes were much more limited. Changes in consumption where driven by price fluctuations during the late nineties, a period during which the price elasticity and cross price elasticities for wheat were larger than they are now (mainly due to higher proportions of low income consumers) and the public food distribution system underwent reform. More generally, an important factor responsible for the large variations in production and consumption are the grain policies in South Asia which have been strongly interventionist in nature in production, marketing as well as distribution (Ganesh-Kumar, Roy, and Gulati 2010).

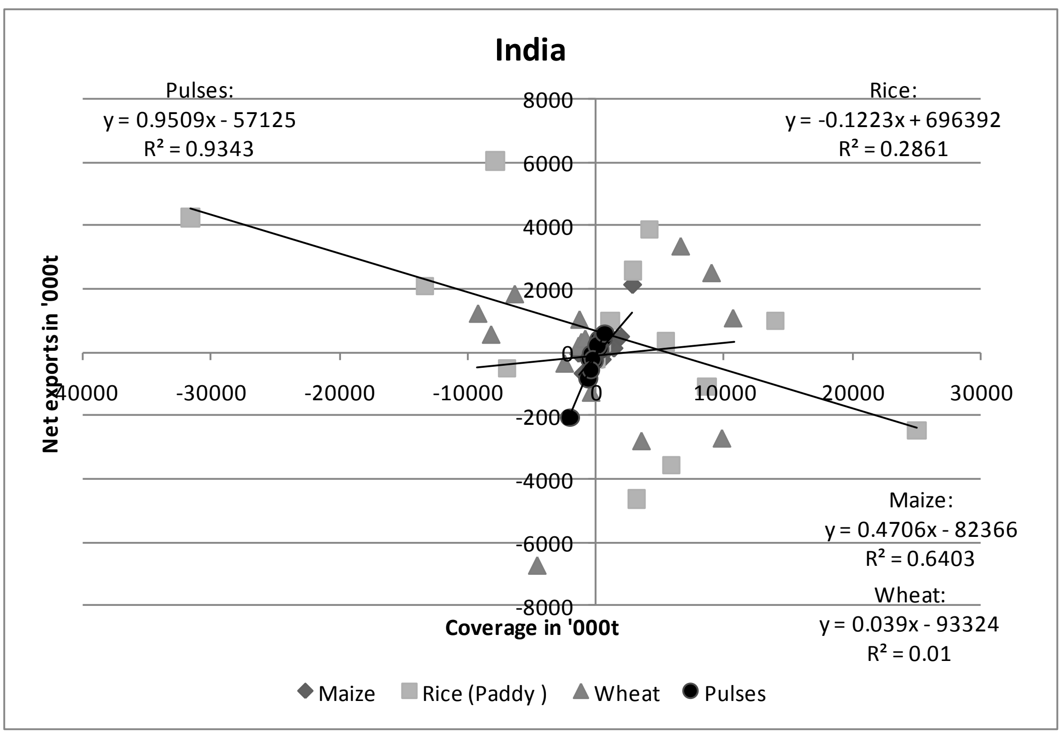
The above analysis has shown that changes in yields may lead to improvements or deteriorations in domestic self sufficiency ratios - but also that this link is not systematic. Indeed the correlation appears robust only in the case of rice. This relation is not analyzed further but it is obvious that the origins of the change in yields (climatic event, technological change etc) affect this relation through the correlation with changes in land use. These results are important to anticipate the effects of climate change where one deals with long term yield shifts that affect farmers' cropping strategies and land allocation decisions. On the other hand, focusing on self sufficiency ratios could lead to erroneous interpretations since price increases

will translate in demand reductions and may maintain production and consumption strongly correlated even when yields are negatively affected (though at an important nutritional cost for the poor). In this context, trade liberalization may help mitigating price increases and protecting poor consumers.

To conclude this chapter, it is important to analyze how the largest countries in South Asia use trade to make up for shortfalls in domestic production or dispose of production surpluses - while also keeping in mind that in South Asia changes in self sufficiency rates are often handled through public stock management. This relation is examined by correlating changes in production surplus against changes in net exports. The results (see Figure 24) show that countries are most likely to use trade to balance changes in the self sufficiency rate in the case of pulses. This is demonstrated by R^2 values of nearly one in the case of Bangladesh, 0.93 for India, 0.77 for Pakistan, 0.68 for Nepal, and 0.64 in the case of Sri Lanka. These results can be explained by a lack of large inventories for pulse crops combined with relatively low tariffs levels (in particular in Pakistan and India where import tariffs on pulses are half or less of those applied on wheat, rice and maize). On the other hand, trade seems to play a minor role in supplementing shortfalls or surpluses in coverage of domestic rice and wheat consumption: for these two commodities significant public intervention in domestic markets combined with trade barriers largely disconnect national markets from international markets. In the case of maize trade is used in some SAFTA countries in an effort to maintain coverage - for example in Bangladesh and to a lesser extent in India.

Figure 24 Correlation between variations in coverage and net exports

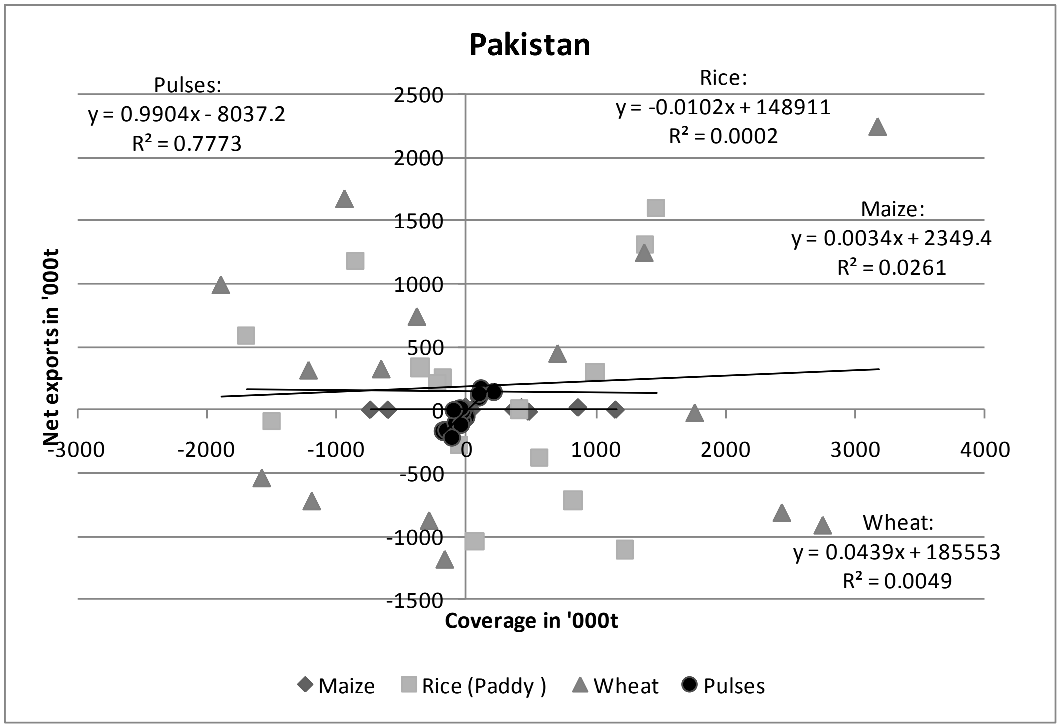


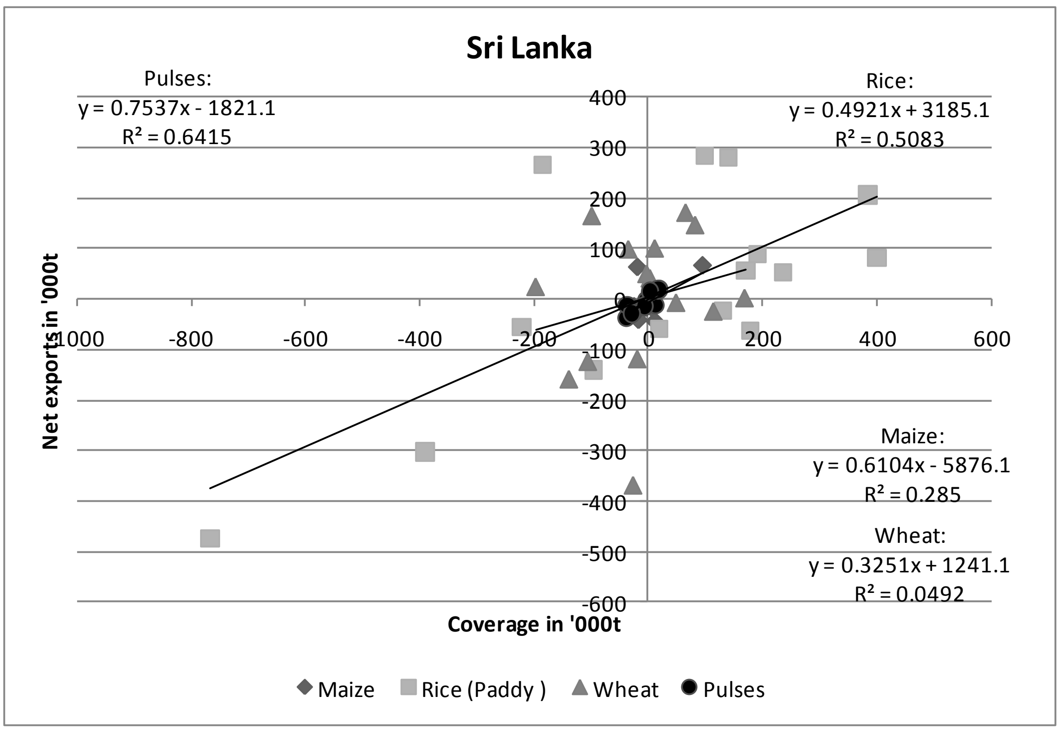


Source: authors' computation based on FAOSTAT 2010.

Note: Graphs represent changes coverage and net exports in the a linear function: $(Y_t - C_t - (Y_{t-1} - C_{t-1})) = f(X_t - M_t - (X_{t-1} - M_{t-1}))$ *where Y, C, X, M represent production, consumption, exports, and imports respectively.* t *= 1992-2007.*

Figure 24 (continued)





Source: authors' computation based on FAOSTAT 2010.

Note: Graphs represent relationship between coverage and net exports as a linear function: $(Y_t - C_t - (Y_{t-1} - C_{t-1})) = f(X_t - M_t - (X_{t-1} - M_{t-1}))$ *where Y, C, X, M represent production, consumption, exports, and imports respectively. t = 1992-2007.*

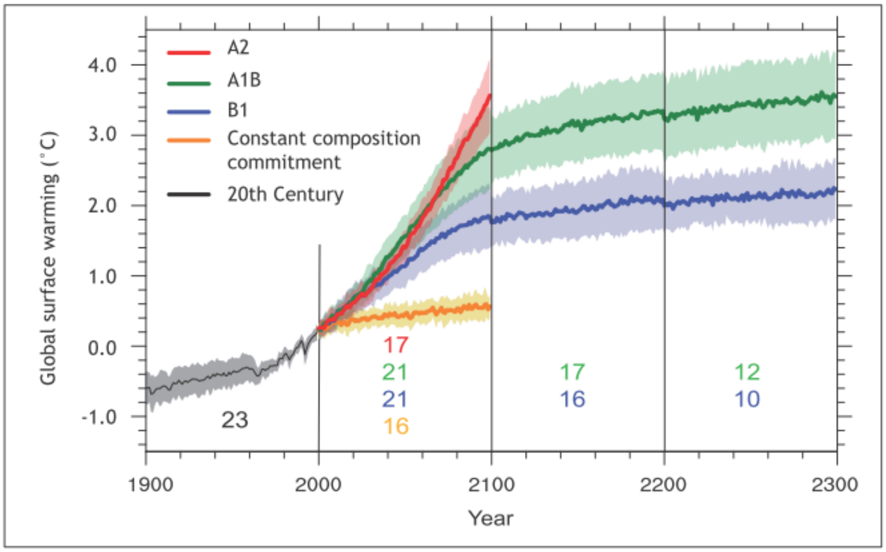
4 Climate change scenarios

Introducing the effects of different climate change scenarios into the overall food and agriculture scenarios presents a particular challenge – in particular, how to take into account the range of plausible pathways for greenhouse gas (GHG) emissions. The available global circulation models (GCMs) translate those emission scenarios into varying temperature and precipitation outcomes. While the general consequences of increasing atmospheric concentrations of GHGs are increasingly well known, great uncertainty remains about how climate change effects will play out in specific locations. Therefore this paper relies on 12 alternative climate change scenarios that will help provide the range of potential outcomes from climate change for South Asia. These 12 SRES[9] scenarios are the result of the combination of GHG paths and alternative GCM models.

Figure 25 shows the range of average surface temperature outcomes for the GHG pathways in the SRES scenarios of the IPCC. By 2050, global surface warming projections in the A1B, A2, and B1 scenarios are approximately identical, at about 1°C above the reference period of the late 20th century. Temperature increases diverge significantly after 2050 however, with the A2 scenario resulting in the highest increase (about 3.5 °C) by the end of the 20th century. Because the analysis in this paper stops in 2050, it does not capture the effects of the large increases expected in the second half of the 21st century.

[9] Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC).

Figure 25 Emissions scenarios: change in temperature



Source: Reprinted with permission from the Intergovernmental Panel on Climate Change (2007).

Table 7 displays the consequences of different emission paths (GHG pathways) in terms of precipitation and temperature. First, as average temperatures rise, so does annual precipitation. A 1°C increase in average temperature typically results in less than a 1 percent increase in average annual precipitation. Temperature increases of over 2°C result in 2–5 percent increases in precipitation. Second, with identical GHG emissions, the different GCM differ substantially in their climate change predictions. The most extreme comparison is with the outcomes of the B1 scenario. The CSIRO GCM has almost no increase in average annual precipitation and the smallest temperature increase of any of the GCM/GHG scenario combinations. The MIROC GCM has the second largest increase in precipitation (within the B1 scenario) and one of the largest increases in average temperature. So, it appears that the CSIRO scenarios are relatively dryer and cooler while the MIROC results describe a warmer and more humid future. The ECH and CNR models display intermediate pictures where the ECH GCM appears to forecast a less wet future than the CNR models.[10]

[10] See www.ipcc.ch/publications_and_data/ar4/wg1/en/suppl/chapter10/Ch10_indiv-maps.html for detailed results and maps.

Table 7 Alternative GCM model results in terms of changes in temperature and precipitation

GCM	SRES scenario	Change between 2000 and 2050 in the annual averages			
		Precipitation (percent)	Precipitation (mm)	Minimum temperature (°C)	Maximum temperature (°C)
CSIRO	**B1**	**0.0**	**0.1**	**1.2**	**1.0**
CSIRO	**A1B**	**0.7**	**4.8**	**1.6**	**1.4**
CSIRO	A2	0.9	6.5	1.9	1.8
ECH	B1	1.6	11.6	2.1	1.9
CNR	B1	1.9	14.0	1.9	1.7
ECH	A2	2.1	15.0	2.4	2.2
CNR	A2	2.7	19.5	2.5	2.2
ECH	A1B	3.2	23.4	2.7	2.5
MIROC	A2	3.2	23.4	2.8	2.6
CNR	A1B	3.3	23.8	2.6	2.3
MIROC	**B1**	**3.6**	**25.7**	**2.4**	**2.3**
MIROC	**A1B**	**4.7**	**33.8**	**3.0**	**2.8**
Multi-model ensemble mean					
	A1B	1.51		1.75	
	A2	1.33		1.65	
	B1	1.65		1.29	

Source: From Nelson et al., 2010.
Note: For an exhaustive discussion on the GCMs, see appendix II of Nelson et al., 2010.
Model acronyms are explained in Chapter 2.

In the following sections, each scenario will be named by the three first letters of the GCM followed by the two first letter of the SRES scenario (e.g. *mir_a1* will stand for MIROC GCM, SRES A1B).

4.1 Yield impact of Climate Change

This section discusses the impact of the different climate change scenarios on the yields of maize, wheat, rice, soybeans and groundnuts as estimated by the DSSAT model.

4.1.1 Impact of climate change on global yields

The DSSAT simulations in Figure 26 show the change in yields driven by climate change for different scenarios at the global level. Simple averages across scenarios are also displayed.

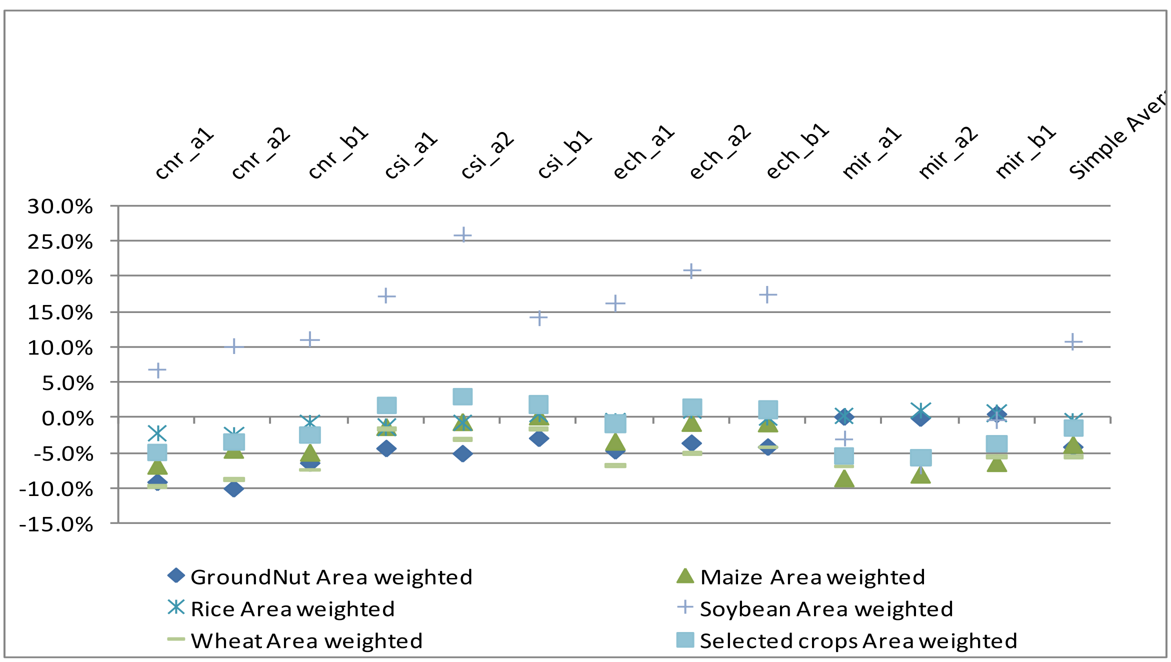
First, all scenarios show a decline in average yields (weighted by initial production) from -0.6 percent (*csi_b1* scenario) to -11 percent (*mir_a1* scenario). These extreme values match the

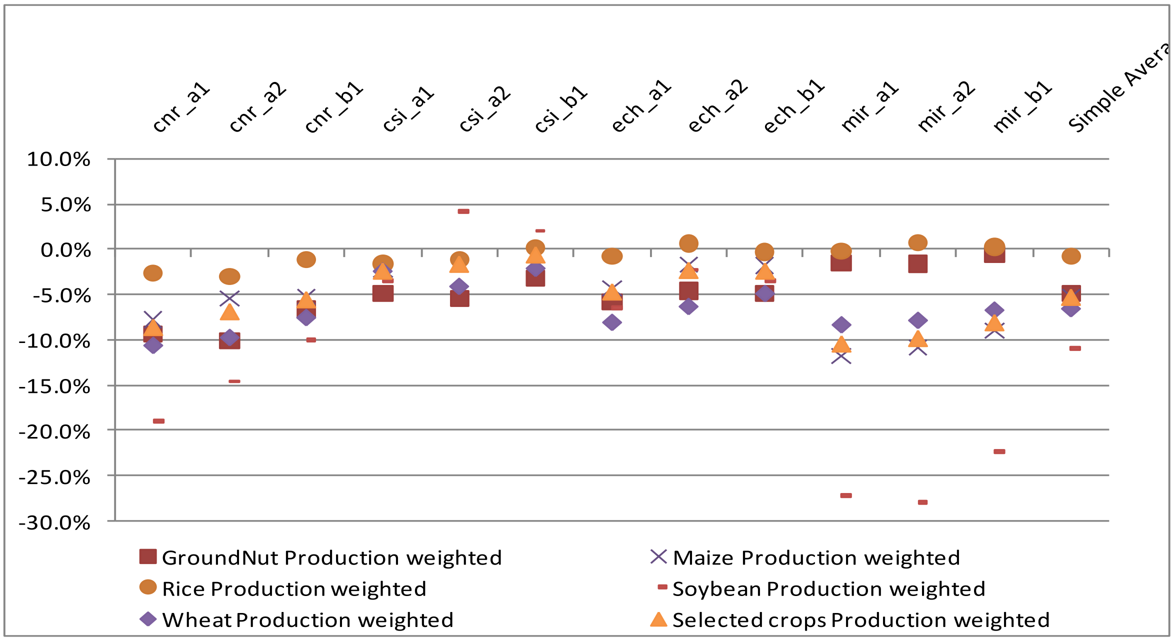
extreme temperature and precipitation scenarios discussed in Table 7 – with the wetter and warmer scenario (*mir_a1*) having the most adverse effects.

The most affected crops are wheat and maize – and both show a yield decline of 5 percent or more based on a simple average across scenarios. Heterogeneity among scenarios at the world level is high – as expressed in coefficients of variation across scenarios of 45 percent and 75 percent for wheat and maize, respectively. Rice (rainfed) and soybeans are less affected on average but the variance across scenarios are also higher (160 percent for rice).The extremes (yield declines of 10 percent or more) are found for groundnut and wheat respectively in scenarios *cnr_a1* and *cnr_a2I*; and for maize and soybeans in scenarios *mir_a1* and *mir_a2*, respectively.

Second, a broad hierarchy can be defined across scenarios from the most adverse to the more moderate: *mir_a1, mir_a2, cnr_a1, mir_b1, cnr_a2, cnr_b1, ech_a1, csi_a1, ech_b1, ech_a2, csi_a2, csi_b1*. Of course, some crops display some special behavior: for example, groundnut production is less affected by the *mir* scenarios than by other scenarios, even though the former are on average more adverse.

Figure 26 Changes in world yields (rainfed) due to climate change for different scenarios and selected crops. Weighted by initial area and production.

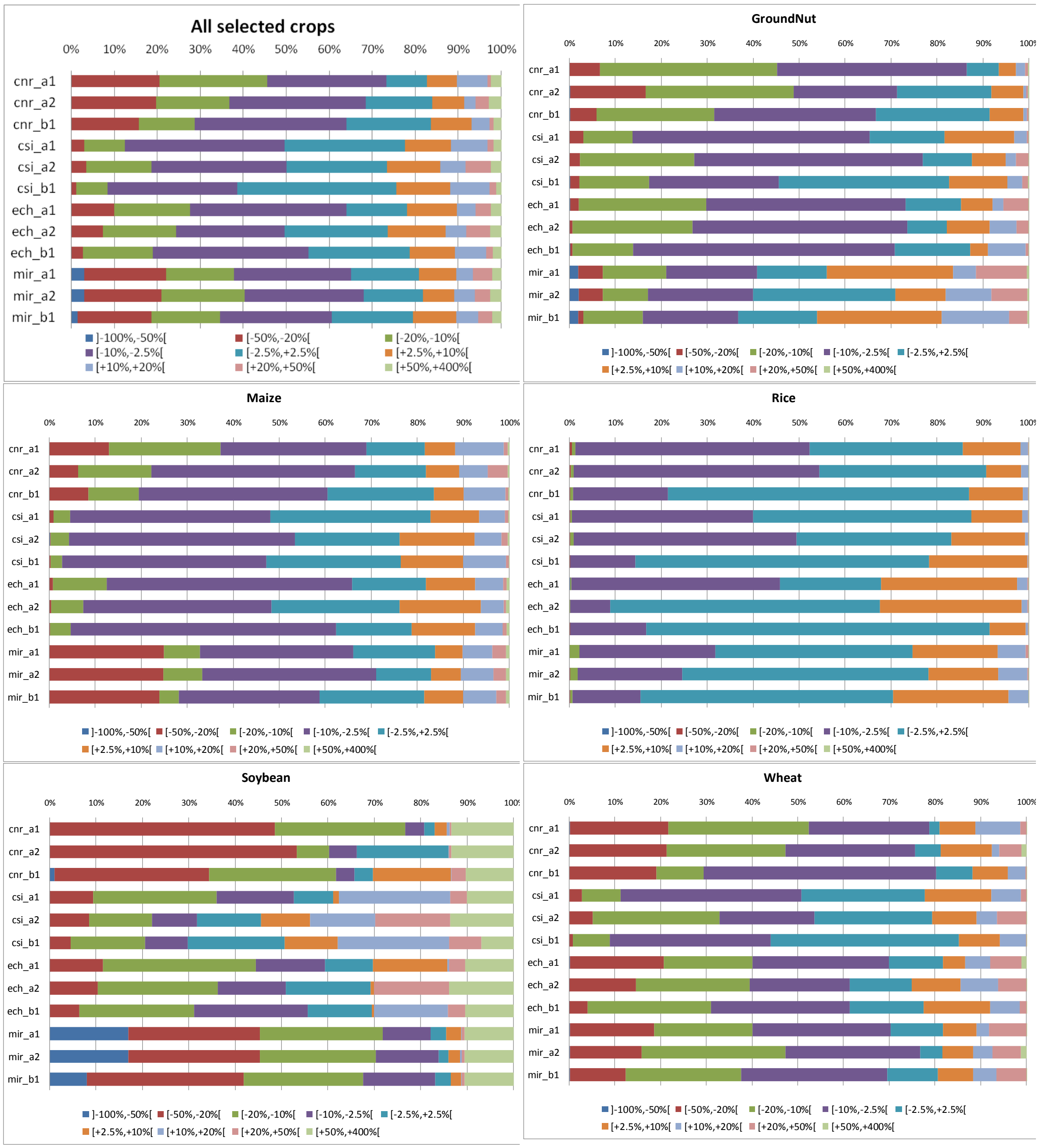




Source: DSSAT model simulations.
Note: Upper graph is weighed by area, lower graph is weighed by production.

A comparison of the lower and upper panels of Figure 26 shows that the average changes in yields weighted by initial production are more pessimistic than the average changes weighted by area (e.g. in scenario *cnr_a1* the increase in average soybean yield is 6.7 percent whereas yield is projected to decreases by 18 percent when weighted by production). This pattern is found for all crops and all scenarios. The explanation is simple: the regions with the highest yield are going to be relatively more affected by climate change than initially low productivity regions. This may involve significant changes in trade patterns to the extent that high yield regions are the source of traditional exports.

Figure 27 Distribution of yield changes under alternative climate change scenarios. Weighted by area (Rainfed).



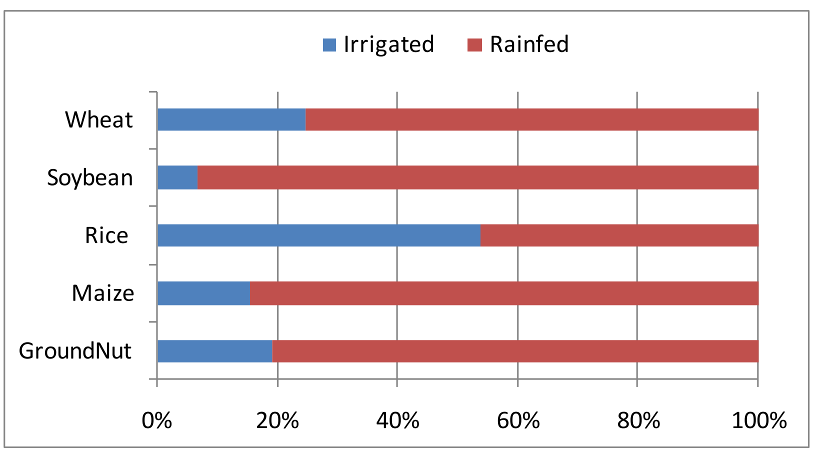
Source: DSSAT model simulations.

Figure 27 displays the yield change distribution on rainfed land. Except for soybean and rice, most areas will experience relatively moderate yield decreases (-10 percent to -2.5 percent). Except for (rainfed) rice all other distributions exhibit relatively flat tails on the right. Soybean exhibits the highest variation across regions and scenarios – and also has relatively large areas with either substantial yield decreases (exceeding 20 percent) or large yield increases (above 20

percent). In several scenarios (*cnr* and *mir* types), maize and wheat have large areas where a yield decrease of more than 20 percent is predicted.

The previous discussion was focused on rainfed agriculture which, at least for the crops considered in this paper, represents more than 80 percent of cultivated area (see Figure 28). In the DSSAT simulations, irrigated crops are only affected by changes in temperature – in other words water availability is considered to be sufficient to maintain optimal level. However, changes in yields are more important for irrigated than rainfed agriculture (between -6 percent and -11 percent for the production weighted average for selected crops across all scenarios). Compared to rainfed cultivation, yield decreases in irrigated agriculture are larger but less variable across scenarios (standard deviation about 20 percent for most crops). Indeed, only temperature variability across scenarios plays a role here. Among irrigated crops, changes in temperature affect wheat yields most, with yield decreases of between 10 percent and 16 percent at the world level (versus less than 10 percent for rainfed wheat). As noted earlier, this implies that the impact of climate change will be larger in regions with initially better yields (driven by better conditions under rainfed management or by irrigation).[11]

Figure 28 Share of rainfed agriculture at the world level for selected crops



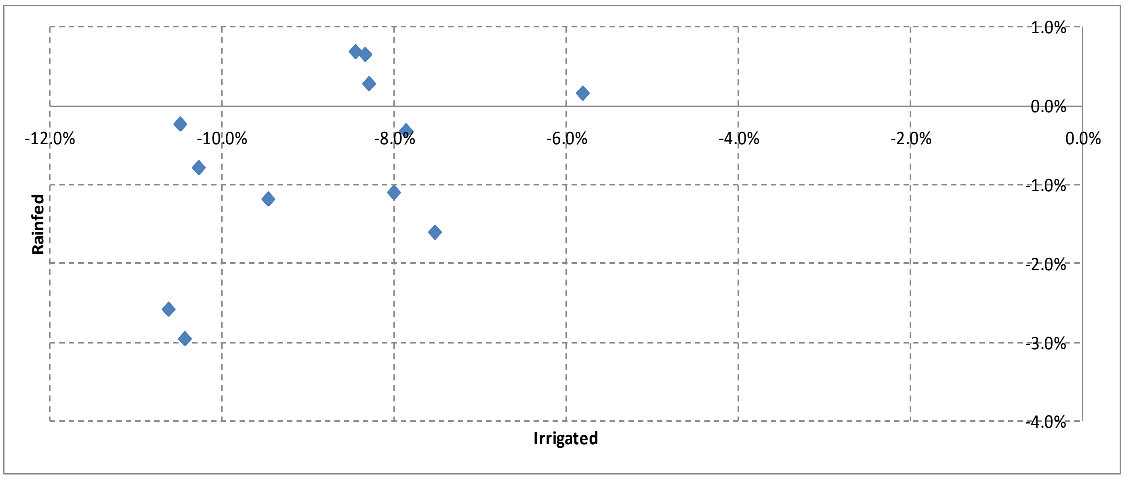
Source: IMPACT model database

The specific case of rice warrants separate discussion. As shown in Figure 26 and Figure 27, rainfed rice is relatively little affected by climate change (yield changes of between +1 percent and -3 percent). Figure 29 displays the average change in yields for rainfed and irrigated rice,

[11] This also implies that in some regions the adverse effects of higher temperatures are compensated by additional water for rainfed crops.

showing that the effects on irrigated rice will be substantially larger (two to three times) than for rainfed case. Therefore, the optimistic picture for rainfed rice changes when considering overall rice production since most rice comes from irrigated land. More precisely, rice yields will decrease by 6.6 percent on average when calculated over all scenarios (with production as weights).

Figure 29 Distribution of change in global yield of rice (weighted by production) for rainfed and irrigated cultivation.



Source: IMPACT model database and DSSAT simulations.

4.1.2 Impact on yields in South Asia

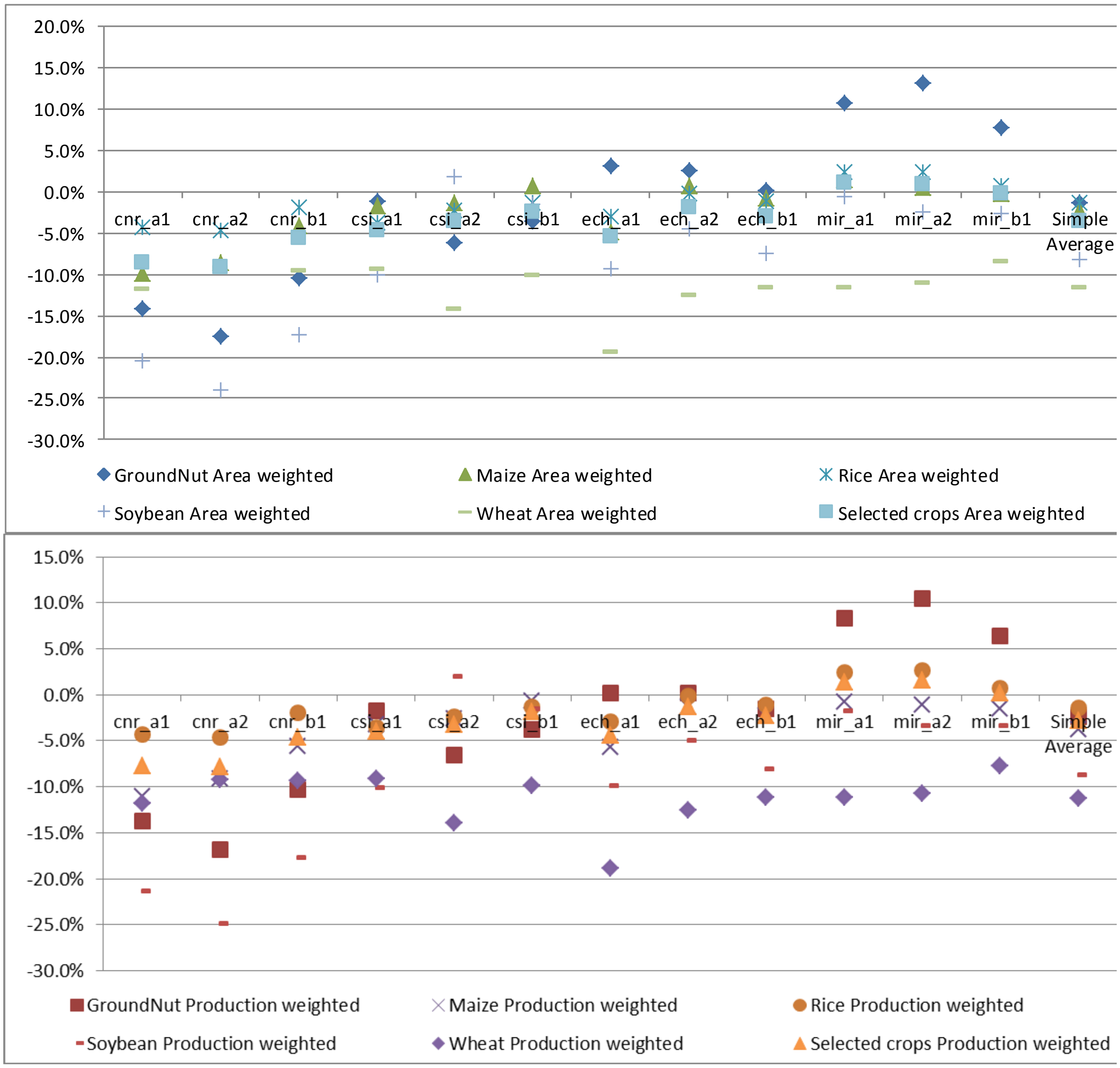
While the previous section discussed the impact of different climate change scenarios on yields on a global level, this section provides further details for the SAFTA region and the four SAFTA countries that are explicitly represented in the model.

Figure 30 depicts changes in yields in South Asia for selected crops (rainfed) under different climate change scenarios. Considering simple averages across crops and scenarios reveals that contrary to earlier findings on the global level, the results weighted by area are slightly more pessimistic (-3.5 percent decrease in yields on average) than those weighted by production (-2.8 percent decrease in yields on average). Across scenarios, scenarios *cnr_a1* and *cnr_a2* have prominent negative effects on average yields (-8.6 percent and -9.1 percent area weighted decline in yields, respectively) while scenarios *mir_a1* and *mir_a2* lead to slight increases in average yields. The results weighted by area are relatively close to those weighted by production, indicative of relatively similar productivity across SAFTA counties for the crops under consideration. These results differ from those on the global level where heterogeneity in

productivity across countries led to a more pronounced gap between the production and area weighted results.

Average yield changes across different scenarios are negative for all crops irrespective of the type of weights used (i.e. production or area). Wheat and soybeans are the most severely impacted crops as their yields (weighted by area) are expected to decline by -11.5 percent and -8.2 percent, respectively. On the other hand, groundnuts and rice are the least affected crops. Nevertheless, a closer look at average yield change for groundnuts for different scenarios shows very high coefficients of variation (779 percent using area weights and 352 percent using production weights). More specifically, scenarios *cnr_a1, cnr_a2* and *cnr_b1* result in significant decreases in groundnut yields, while *mir_a1, mir_a2* and *mir_b1* lead to significant yield increases. With respect to wheat, all climate change scenarios lead to a decline in yields in SAFTA countries, and are more pronounced in the *ech_a1* and *csi_a2* scenarios (-19.4 percent and -14.2 percent using area weights, respectively).

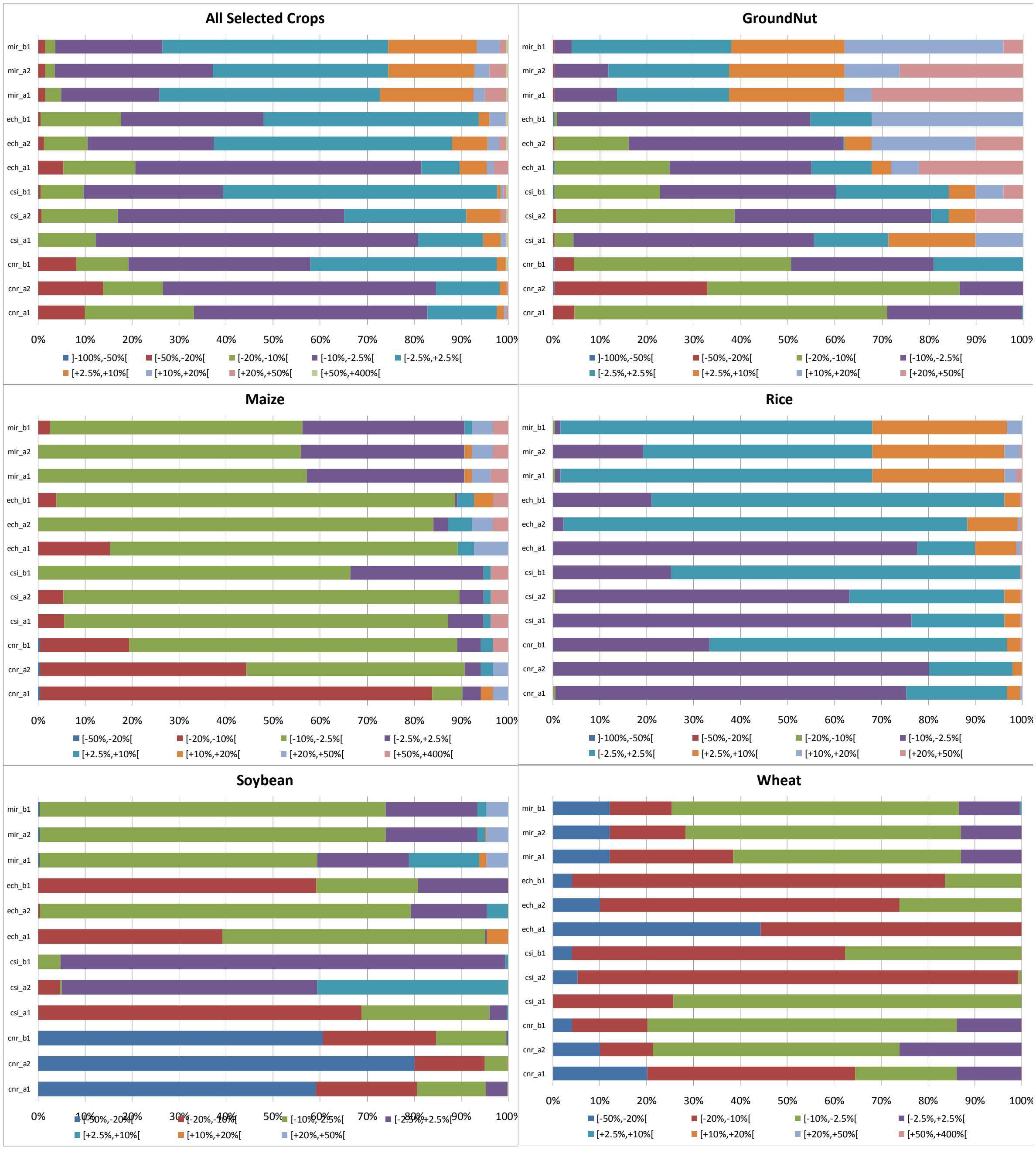
Figure 30 Changes in crop yields in South Asia (rainfed) due to climate change for different scenarios and selected crops. Weighted by initial area and production.



Source: DSSAT model simulations.

The overall distribution of yield changes on rainfed land in SAFTA countries is presented Figure 31 - and turns out to be quite similar to the corresponding distribution on the global level. A moderate (-10 percent to -2.5 percent) decrease in yields affects large areas across all scenarios. Notable exceptions to this case are wheat and soybeans which exhibit a more pronounced negative yield change (-20 percent to -10 percent). With respect to groundnuts there are large areas with large yield increases (20 percent to 50 percent), while in the case of wheat more than half of rainfed areas are impacted by significant yield decreases ranging from -50 percent to -10 percent.

Figure 31 Distribution of yield changes under alternative climate change scenarios. Weighted by area (Rainfed).



Source: DSSAT model simulations.

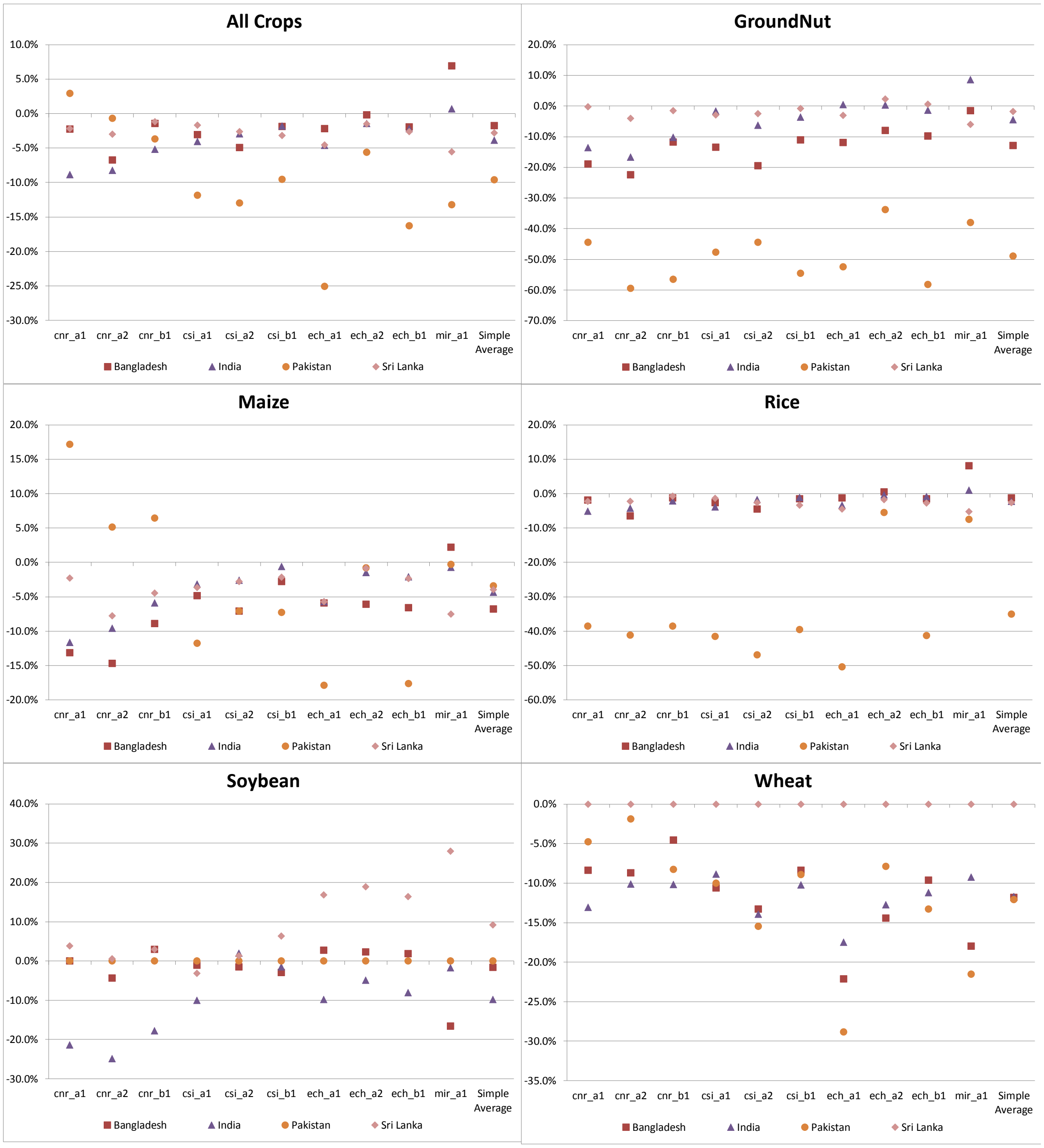
Figure 32 further decomposes yield changes in Bangladesh, India, Pakistan and Sri Lanka. Considering average yield changes across all crops and scenarios, all four countries suffer from decreasing yields, with Pakistan and India being affected most (suffering average yield decreases of respectively 9.6 percent and -3.9 percent when weighted by production). In the case of

Pakistan there are particularly large decreases in average yields for scenarios *ech_a1* (-25.1 percent) and *ech_b1* (-16.3 percent).

The 9.6 percent decrease in average crop yield in Pakistan is mainly driven by significant drops in rice productivity (-35.1 percent) and groundnut yield (-49 percent) – for these crops all scenarios exhibiting yield decreases. Other crops in Pakistan including maize and wheat are less affected, suffering average yield decreases of respectively -3.4 percent and -12.1 percent. In some scenarios (*cnr_a1, cnr_a2* and *cnr_b1*) maize yields in Pakistan even increase.

Average groundnuts yields decrease most significantly in Bangladesh (-12.8 percent). On the other hand, groundnut productivity in India increases by 8.6 percent under scenario *mir_a1*. On average across scenarios, rice yields in SAFTA suffer only moderately (except the case of Pakistan discussed previously). Wheat yields decrease across all countries and scenarios, most significantly so in scenario *ech_a1.* Finally, average soybean yields in Sri Lanka increase (by 9.2 percent).

Figure 32 Distribution of yield changes across countries under alternative climate change scenarios. Weighted by production (rainfed).

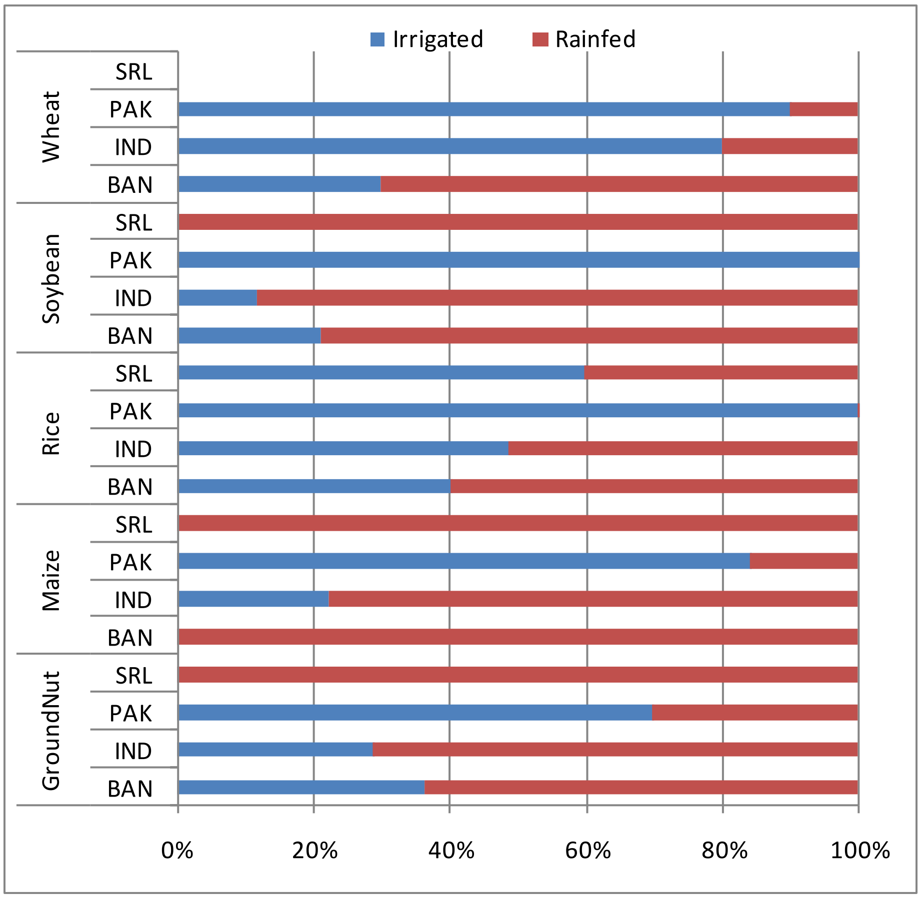


Source: DSSAT model simulations

The results discussed above concern only the impact of climate change scenarios on yields of selected crops under rainfed conditions. However, the share of irrigated crops is significant in SAFTA countries (see Figure 33). For example, Pakistan is one of the leading countries in the world as far as irrigated agriculture is concerned. Irrigated land accounts for about 80 percent of total cropland in that country - and about 90 percent of wheat and 100 percent of the rice

and soybean crops receive irrigation. Furthermore, irrigation plays an important role in Indian agriculture as well - 80 percent of wheat and 50 percent of rice is cultivated under irrigated conditions. On the other hand, in Sri Lanka irrigated land is mostly used for rice with maize and groundnuts completely rainfed.

Figure 33 Share of rainfed agriculture at the world level for selected crops

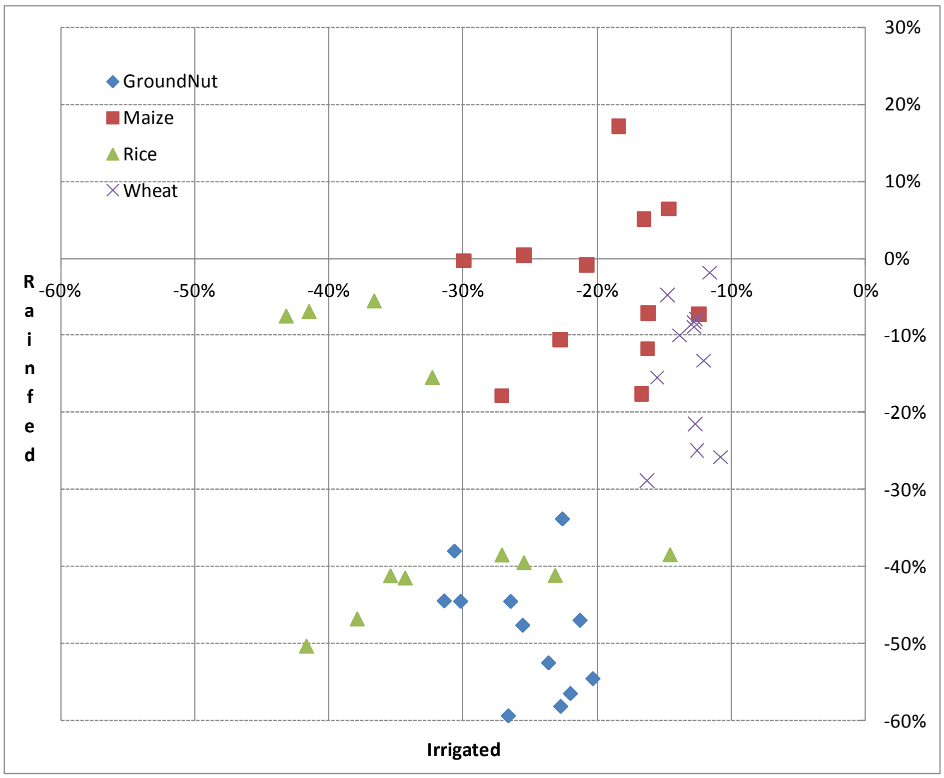


Source: IMPACT model database

Given the importance of irrigation in Pakistan, Figure 34 compares yield distributions for selected crops under rainfed and irrigated conditions. Since in the case of irrigated crops climate change does not change water availability (i.e. water is assumed to be sufficient and maintained at an optimal level), the only driver of yield change in irrigated crops is changes in temperature (as opposed to rainfed crops where both temperature and precipitation changes are also considered). For groundnuts the results show similar patterns across all scenarios: averega irrigated yield decreases (-25.3 percent) are smaller than average rainfed yield decreases (-48.4 percent). The results are more variable in the cases of rice and wheat: in some scenarios rainfed yields decrease more than irrigated yields while in other scenarios the

opposite holds. In the relatively cooler and drier climate change scenarios rainfed rice yields decrease more than yields of irrigated rice, while in the relatively more humid and warm scenarios irrigated wheat yields suffer more than rainfed wheat yields. In the case of maize irrigated yields decline more than rainfed yields. In scenarios *cnr_a1, cnr_a2* and *cnr_b1* climate change leads to an increase in yields of rainfed maize and a decrease in irrigated maize yields.

Figure 34 Distribution of yield of selected crops in Pakistan for rainfed and irrigated production (weighted by production)



Source: DSSAT model simulations.

5 Trade Policy Scenarios and Simulations Results

This Chapter presents the different trade policy scenarios considered and discusses the simulation results. Due to the relatively high number of scenarios (124)[12], it is not practical to display detailed results for all simulations.[13] Moreover, the goal in this paper is not to determine what will be the detailed consequences of each potential climate scenario but rather to assess how changes in trade policy might allow South Asia to mitigate the effects of an uncertain future. For this reason, simple averages and their variation across climate scenarios are displayed for each trade policy baseline in order to identify a potentially optimal policy. Indeed, there is no a-priori bias with respect to the occurrence of one scenario or another. In addition, the analysis places special emphasis on presenting the results by individual South Asian countries, given that a single SAFTA aggregate would be dominated by India and give insufficient attention to the other SAFTA countries.

The next section looks at the trade policy alternatives that constitute the different baselines, followed by a discussion of simulation results in section 5.2. All simulation results will be compared against the perfect mitigation case: the latter figures as the equivalent of a 13th SRES scenario in which yields are not affected by climate change.

5.1 Trade policy alternatives as different baselines for climate change scenarios

As discussed earlier in Chapter 2, assumptions regarding trade policies[14] are critical at different levels. Since policy makers exert control over trade policy, this paper considers eight different trade policy scenarios for possible implementation between 2010 and 2024 and which shape the landscape in which climate change will occur. The potential role of trade policies (mainly tariffs in this paper) in further shaping the effects of climate change can be summarized as follows:

- Under the assumption that they are not endogenous to world prices, ad-valorem duties amplify domestic price increases caused by climate change. Therefore, duties magnify

[12] The 124 scenarios were derived as follows: (12 SRESxCGM scenarios + 1 perfect mitigation scenario) x 8 trade policy baselines.

[13] All the results for each scenario are available from the authors upon request.

[14] Other assumptions regarding the baseline are discussed in section 2.2.2.

the cost burden for consumers by applying an additional tax on the exogenous price change. This is a direct effect.

- Duties affect relative prices between sectors of an economy which in turn affects the relative size distribution between sectors. Therefore, the size of the agricultural sector (which is the sector that is directly affected by climate change) compared to the size of other sectors (manufacturing and services) is to an important extent influenced by the type of trade policy:
    a. Since protection rates are higher for the agricultural sector compared to the other sectors in all SAFTA countries, unilateral trade liberalization would lead to a reallocation of production factors from agriculture to other sectors, thus reducing the size of the agricultural sector. Since the impact of climate change (i.e. changes in agricultural productivity) on overall GDP is lower for economies whose GDP is less dependent on agriculture, unilateral trade liberalization may facilitate compensating those in the agricultural sector who stand to lose from climate change.
    b. In case of multilateral trade liberalization, comparative advantages will play out to their maximum. New market opportunities may arise for some sectors - including the agricultural sector (e.g. for rice exports to Japan). The impact of multilateral trade liberalization on the consequences of climate change (i.e. on agricultural production and incomes) would depend on how climate change affects the productivity of agricultural commodities in which South Asian countries have a comparative advantage.
    c. If some agricultural sub-sectors (commodities) are excluded from trade liberalization, it will be important for the region to assess the extent to which these sub-sectors are affected by climate change (relative to other less protected sub-sectors). If the sub-sectors that continue to be protected are also those which are affected most by climate change, then protectionist policies will maintain artificial specialization (in contrast to comparative advantage resulting from free trade) in activities that will face severe productivity losses.
- Trade liberalization changes the extent to which countries depend on world markets, their degree of openness, and how they are exposed to different price shocks in world

markets through the terms of trade effect. Depending on the exposure to world prices and the structure of trade, the cost to the domestic economy of a relative price shock will vary. Relative prices exert their influence through two channels: i.e. relative prices between domestic and foreign producers within a given sector, and relative prices between exports and imports, across sectors. If trade liberalization leads to higher imports of a commodity that increases in price as a result of climate change, the cost for the importing economy will increase as well.

- Discriminatory trade policies (e.g. preferential trade agreements) can play an important role by shifting regional trade patterns into a particular direction. Assuming that policy makers can correctly predict which countries will be more negatively affected by climate change, it will be important that they get market access for their own exports to these markets and that they develop trade relations with other regions to satisfy their own demand. In other words, it may be optimal to use trade policy to diversify trading partners in order to reinforce trade relations with regions for which climate shocks will be negatively correlated with the domestic economy, as in a portfolio management strategy. This can act as an incentive to pursue a non regional integration strategy if the region does not provide enough diversification opportunities.

The previous explanations have made it clear that there is a need to analyze alternative trade policy scenarios combining different mixes of sectoral and geographical trade liberalization.

5.1.1 Description of trade policy alternatives

A total of eight trade policy alternatives were considered, each involving a different mix of potential tariff reductions compared to their starting levels in 2007 (see Table 8):

1. Baseline tariffs (*BASE*): In this alternative, tariffs are frozen at their 2007 levels.
2. SAFTA implementation (*SAFTA*): This alternative describes the full implementation of SAFTA including sensitive products (see the SAFTA scenario description in Bouet and Corong 2009).
3. SAFTA-plus alternative (*SAFTAFULL*): This alternative involves the full elimination of all tariffs between South Asian countries.
4. Unilateral liberalization (*UNISEN*): SAFTA countries unilaterally liberalize trade in all sectors (agriculture and non-agriculture) except for sensitive products. For each SAFTA

economy the list of sensitive products is identical to the one used in the SAFTA agreement. This alternative involves keeping tariffs on most key agricultural imports.

5. Unilateral elimination of all tariffs in agriculture (*UNIAGR*): This alternative leads to a sharp decline in agricultural prices relative to manufacturing prices and a reallocation of resources towards the latter sector.
6. Full liberalization of SAFTA economies towards all partners for all sectors (*UNIALL*): This alternative involves a complete unilateral liberalization of SAFTA economies. The liberalization of the manufacturing sector dampens the shock on relative prices compared to the *UNIAGR* alternative.
7. Free trade among all countries in Asia and Oceania (*FTA*): This alternative involves strong regional integration alternative by abolishing any remaining tariff restrictions between the South Asian countries and Central Asia, China, developed East Asian economies, ASEAN countries, and Australia and New Zealand (ANZCERTA). For South Asia this alternative creates both new market opportunities (e.g. in the initially highly protected South Korea and Japanese markets) and increased competition in domestic markets from other participating countries.
8. Complete trade liberalization (MULTI): This alternative involves tariff elimination at the global level. This very ambitious alternative provides a benchmark for all other (less ambitious) alternatives.

Table 8 Summary of trade policy alternatives

Label	Description	Sensitive Products in Agriculture for SAARC	Manufacturing Liberalization for SAARC	Unilateral/ Regional policy for SAARC	Market access gains in other regions
BASE	Status quo in 2007	n.a.	n.a.	n.a.	n.a.
SAFTA	Implementation of the post 2007 SAFTA commitments	yes	partial	yes	no
SAFTAFull	SAFTA + elimination of all remaining tariffs on sensitive products	no	yes	yes	no
UNISEN	SAFTAFull + unilateral liberalization with all partners for non-sensitive products in SAFTA	yes	partial	yes	no
UNIAGR	SAFTAFull + unilateral liberalization in agriculture	no	no	yes	no
UNIALL	Full unilateral liberalization of all SAFTA countries	no	yes	yes	no
FTA	Full FTA in Asia and Oceania	no	yes	no	in Asia
MULTI	Full multilateral liberalization	no	yes	no	in world

5.1.2 Baseline results

Simulations are carried out up to the year 2050 and the economic structure of different countries, especially those in South Asia, can be expected to change significantly between now and then. This makes it important to discuss the evolution of key indicators in the baseline. Detailed information regarding the assumptions used in the baseline is given in Chapter 2. In this sub-section we focus on the two extreme trade policy alternatives: the status quo (BASE) and full trade liberalization (MULTI).

The projected population figures in Table 9 are consistent with the latest UN projections. Annual growth rates in per capita GDP are virtually identical in the BASE alternative (continuation of status quo) and the MULTI alternative (full multilateral trade liberalization). This result is not surprising. In models with full employment, trade policy effects are nearly always below 1 percent of real income. Average per capita GDP growth is highest in India (6.2 percent), followed by Bangladesh (4.6 percent) and Pakistan (4.5 percent). Due to the shift in demand and activity, the industrial sector growth dominates agricultural growth, except for specific cases. However and given the significant trade barriers in agriculture, multilateral trade liberalization will boost agricultural exports and imports – especially in India where in any case the increase in trade flows in percentage change terms for both the BASE and the MULTI

alternatives is highest. A notable exception is formed by exports of staples where the percentage growth in India's trade flows is exceeded by those in Bangladesh, Pakistan and Sri Lanka. Not surprisingly, trade growth under full multilateral trade liberalization is systematically higher than that in the base trade policy scenario for all South Asian countries.

Table 9 Baseline trade policy alternative: evolution of selected indicators

		Bangladesh	India	Pakistan	Sri Lanka	Rest of South Asia	World
Population in 2050 (Mil. inhabitants)		222	1,611	332	22	123	9,058
Annual growth rate (Base trade policy)	GDP per Capita	4.6%	6.2%	4.5%	4.1%	3.8%	3.9%
	Imports (staple)	4.4%	9.8%	7.2%	4.5%	6.6%	5.4%
	Imports (agrifood)	5.0%	7.0%	4.8%	3.0%	5.7%	4.5%
	Imports (industrial)	5.9%	10.3%	8.4%	5.3%	7.0%	5.1%
	Exports (staple)	7.9%	7.0%	7.4%	7.7%	7.0%	5.4%
	Exports (agrifood)	5.3%	10.5%	9.9%	4.7%	3.7%	4.5%
	Exports (industrial)	5.0%	11.1%	8.7%	6.1%	9.1%	5.1%
Annual growth rate (Multilateral full liberalization)	GDP per Capita	4.6%	6.2%	4.5%	4.1%	3.8%	3.9%
	Imports (staple)	4.6%	11.6%	7.7%	5.5%	7.4%	5.9%
	Imports (agrifood)	5.5%	8.4%	6.1%	3.9%	6.1%	5.4%
	Imports (industrial)	6.6%	10.8%	8.9%	5.5%	7.5%	5.3%
	Exports (staple)	9.4%	7.8%	8.1%	9.1%	9.0%	5.9%
	Exports (agrifood)	6.0%	12.6%	10.4%	5.2%	4.2%	5.4%
	Exports (industrial)	5.7%	11.5%	9.3%	6.5%	9.7%	5.3%

Source: Simulations with MIRAGE.

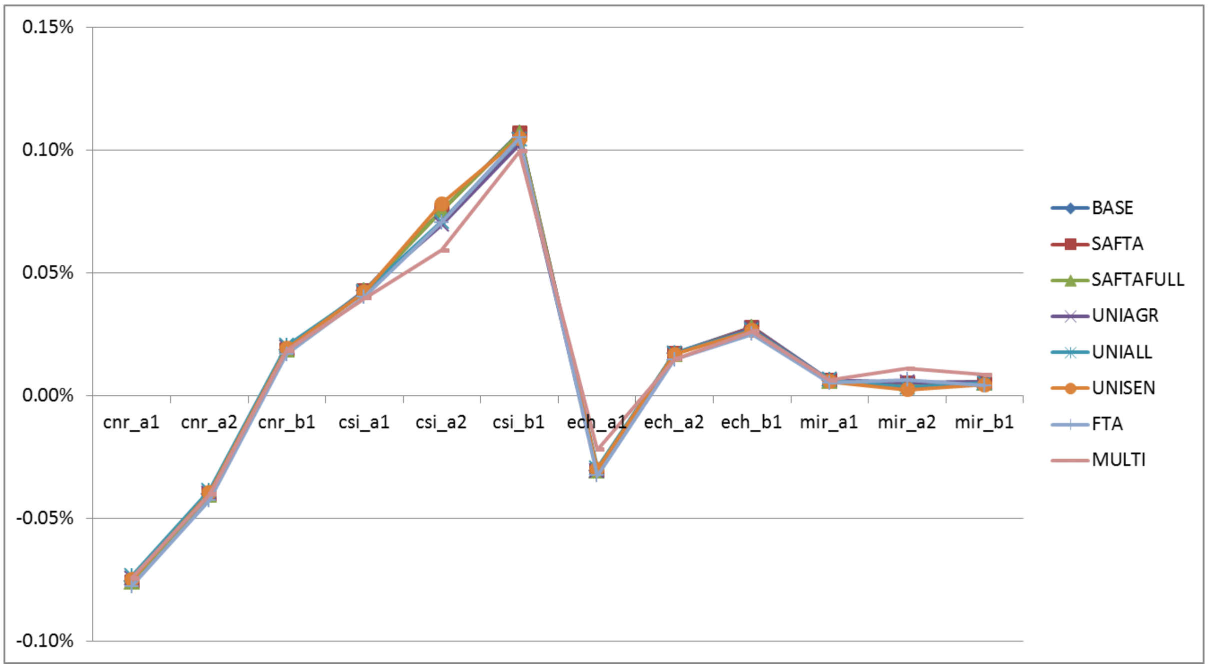
5.2 Simulation Results

5.2.1 Impact of climate change and trade policy on real income

Figure 35 displays the evolution of changes in real income by 2050 for the world across trade policy alternatives and climate change scenarios. The impact of climate change on world GDP is relatively small which is not unexpected given the steady decline in the share of agriculture in GDP. However, even the small relative change in world GDP still represents between -$740 billion and +$1,015 billion (in 2004 constant USD). More interesting is the fact that there are relatively large variations across climate change scenarios - with the largest increase seen in scenario *csi_b1* and the largest decrease obtained in scenario *cnr_a* (see Table 7 on page 76 for climate change scenario definitions). Furthermore, trade policy options have only limited effects on real world income. Full multilateral trade liberalization (the MULTI trade policy alternative) leads to an increase in real income compared to the status quo (the BASE trade

policy alternative) only in 5 out of the 12 climate change scenarios – a testimony to the complexity of the mechanisms at play. Nevertheless, trade liberalization does play a more important role in certain specific cases: for example, full multilateral trade liberalization has minimal effects on real income in the *csi* climate change scenarios but maximizes income gains in the *mir* climate scenarios while limiting losses significantly in the *ech_a1* scenario. The *csi* climate scenarios, which will be discussed in greater detail in subsection 5.2.5 below, are the most sensitive to trade policy. The full multilateral liberalization trade policy alternative (MULTI) results in a relatively large expansion of trade in the baseline leads to more limited readjustment and therefore, less important real income gains from trade.

Figure 35 Annual changes in world real income by 2050 - by climate change scenario and trade policy alternative

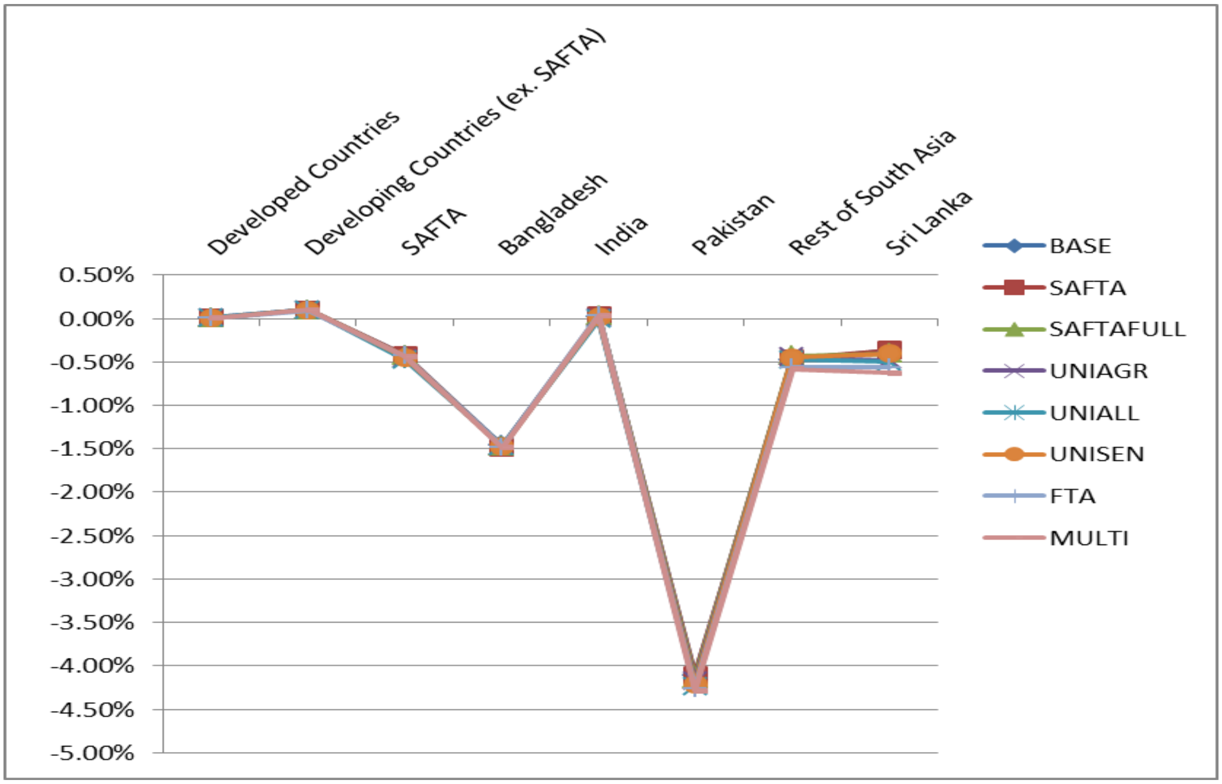


Source: Simulations with MIRAGE

SAFTA is one of the regions that are most negatively affected by climate change in terms of income (see Figure 36), especially Pakistan (up to 4 percent income loss) followed by Bangladesh and Sri Lanka. On the other hand, India benefits from a slight increase in real income and acts as a stabilizer in the region. A decomposition by trade policy scenario across climate change scenarios (Figure 37) illustrates that there is relatively high dispersion among countries with respect to the impact of trade policy on real income. There is a clear negative correlation between country size and the degree of dispersion, i.e. the impact of different trade liberalization alternatives varies more significantly in the case of Sri Lanka than in that of India.

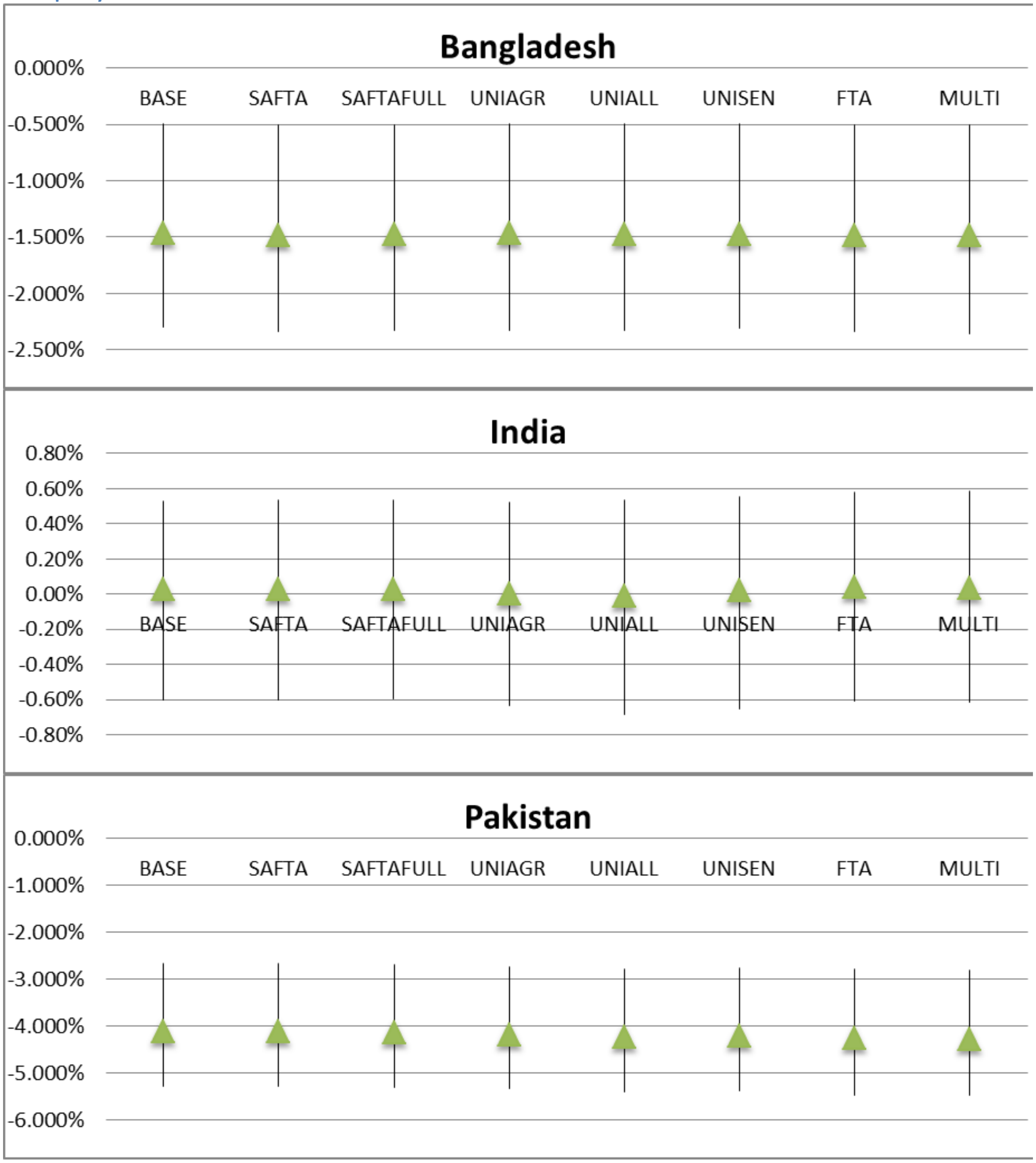
In addition, Sri Lanka and the Rest of South Asia experience bigger proportional declines in real income as the degree of liberalization increases. Detailed results for each climate change scenario and trade liberalization policy are presented in Table 19 in the Appendix.

Figure 36 Changes in real incomes in SAFTA countries compared to other regions and countries (simple averages across climate change scenarios)

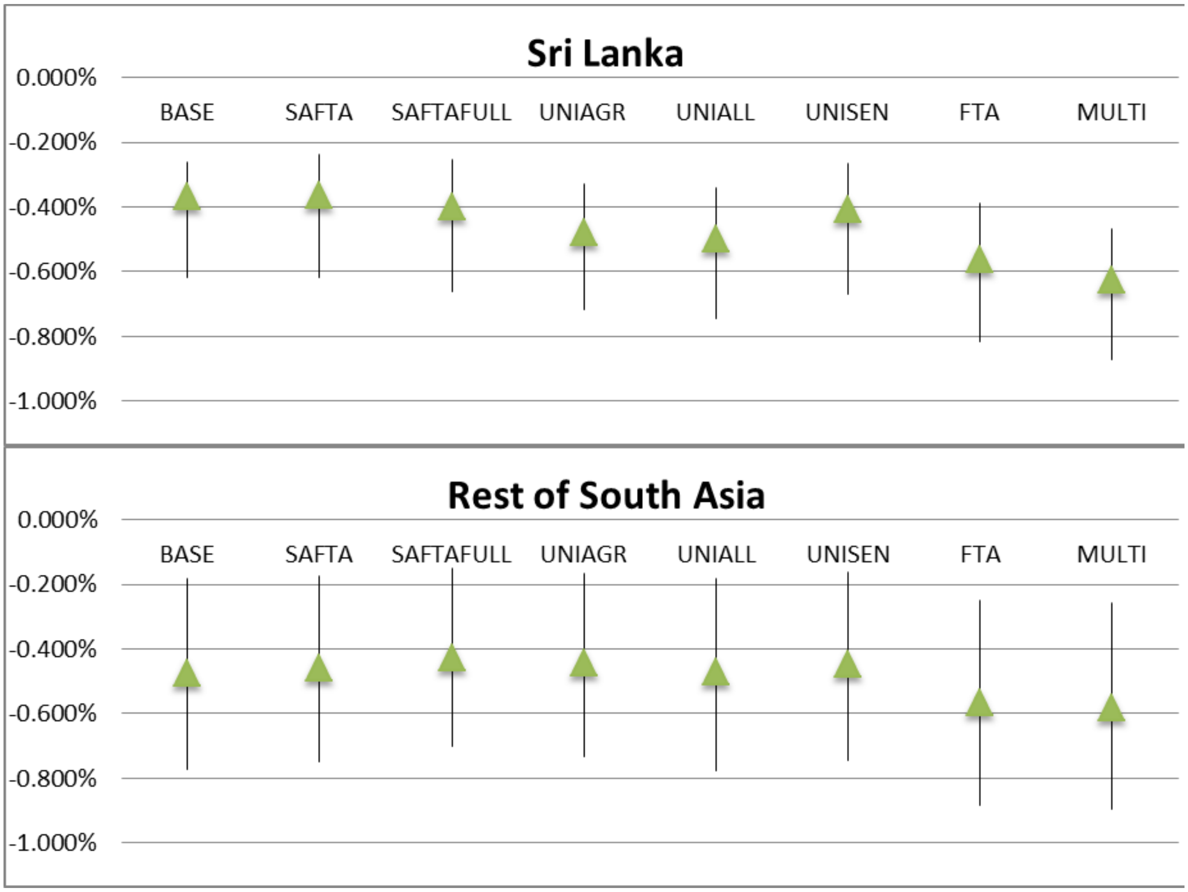


Source: Simulations with MIRAGE.

Figure 37 Real Income effects (simple averages and extreme values) of climate change in SAFTA countries – by trade policy alternative



(continued on next page)



Note: Length of bars represent minima and maxima across climate scenarios.
Source: Simulations with MIRAGE.

Table 10 is an attempt at summarizing the ranking (based on the real income criteria) of different trade policy alternatives for SAFTA countries. *Optimistic* describes the highest real income increase across climate scenarios, *average* the average change and *pessimistic* the most adverse real income change. The results show that all countries except India would favor more conservative trade liberalization scenarios. For India, full trade liberalization maximizes the increase in real income, while a full FTA in Asia and Oceania leads to the average real income change. On the other hand, Pakistan and Sri Lanka would favor the SAFTA trade policy alternative while Bangladesh is best off with the UNIAGR alternative.

Table 10 Summary table of best options for trade policies. Real Income criteria

	Bangladesh	India	Sri Lanka	Pakistan	Rest of South Asia
BASE	*Pessimistic, Average*		*Average*	*Pessimistic*	
SAFTA		*Pessimistic*	*Pessimistic, Optimistic*	*Average, Optimistic*	
SAFTAFULL				*Pessimistic*	*All cases*
UNIAGR	*Optimistic*				
UNIALL					
UNISEN					
FTA		*Average*			
MULTI		*Optimistic*			

Given that agriculture will represent a small share of world GDP by 2050, as well as for a booming economy like India, our previous results on real income were not surprising. However, it is important to keep in mind that we model only a small part of the consequences of climate change, that is only the direct changes in crop yield due to water and temperature modifications. We do not consider the possibility of new pest and diseases related to variation in climatic conditions, the shift in cattle productivity due to temperature changes or more generally any negative productivity shocks associated to warmer climate. Last but not least, extreme events (flooding) or loss of agricultural area due to rise in the sea level are not taken into account although may represent a key issue for the region.

5.2.2 Impact of climate change and trade policies on Agricultural Production

Beyond the macroeconomic consequences of changes in crop yields, it is important to focus on the first order sectoral effects, i.e. changes in agricultural production. Table 11 describes changes in production volumes of both staples (i.e. primary crops) and agro-foods (processed food) across trade liberalization alternatives - and highlighting the extreme values and averages across climate change scenarios. In order to better understand these changes it is useful to refer back to the discussion on yield changes in section 4.1. As expected, the substantial yield changes in Pakistan result in similar changes in production - on average ranging from -8.7 percent to -8.4 percent in the case of staple production and from -6.5 percent to -5.4 percent for ag-foods, across the different liberalization scenarios. Bangladesh is the second most adversely affected country in the SAFTA region – showing decreases of -5.1 percent and -4.1 percent in respectively staple production and agro-food production. In general, production in the agri -food sectors is less affected by climate change than production of primary crops. In

India and Sri Lanka the expansion of the food processing sector can be explained by a shift to higher value added goods (including exports).

Among SAFTA countries India seems the most resilient to climate change. Due to its high economic growth rate and substantial expected productivity gains, India is expected to be able to generate a large flow of savings and therefore investment capacity during the next forty years or so. Sustained high agricultural prices will induce significant investment in agriculture and the resulting productivity increases will be able to mitigate the exogenous yield decreases caused by climate change. It is important to keep in mind that since the model closure used in this paper does not allow for foreign direct investments and foreign aid is not taken into account, countries only depend on their own income and savings for investment. Moreover and due to its size and a large number of river basins/FPUs, India can reallocate production across crops and regions more efficiently. For example when wheat production declines, the model indicates an increase in production of maize corn and other coarse grains. These kinds of shifts in allocation of production factors from one crop to the other will partially mitigate the overall shock of climate change. Finally, from the point of view of policy makers it is important to ensure flexible domestic markets and equitable social consequences of production relocation.

Last, note that the type of trade policy does matter in key cases: in Pakistan for example, a higher degree of trade liberalization reduces the decline in agro-food production. Compared to the BASE trade policy alternative, full SAFTA integration also reduces the negative effects on staple food production by creating a larger (but still protected) regional market.

Table 11 Impact of climate change on agro-food and stale production (% changes in 2050 relative to the baseline in each trade policy alternative)

	BASE	SAFTA	SAFTAFULL	UNIAGR	UNIALL	UNISEN	FTA	MULTI
Bangladesh								
Agro-food								
Average	-3.8%	-3.9%	-4.0%	-4.0%	-4.1%	-4.1%	-4.3%	-4.0%
Maximum	-1.3%	-1.3%	-1.4%	-1.5%	-1.6%	-1.5%	-1.7%	-1.5%
Minimum	-6.3%	-6.4%	-6.4%	-6.5%	-6.6%	-6.5%	-7.1%	-6.7%
Staple								
Average	-5.1%	-5.1%	-5.0%	-5.1%	-5.0%	-5.0%	-5.1%	-5.1%
Maximum	-0.8%	-0.8%	-0.7%	-0.7%	-0.7%	-0.7%	-0.8%	-0.8%
Minimum	-8.9%	-8.9%	-8.8%	-8.8%	-8.8%	-8.8%	-9.0%	-8.9%
India								
Agro-food								
Average	4.6%	4.6%	4.6%	4.6%	4.3%	4.3%	4.6%	3.7%
Maximum	5.8%	5.7%	5.7%	5.3%	5.1%	5.5%	5.4%	4.2%
Minimum	4.0%	3.9%	4.0%	4.1%	3.8%	3.7%	4.2%	3.3%
Staple								
Average	-1.2%	-1.2%	-1.2%	-1.3%	-1.3%	-1.2%	-1.2%	-1.3%
Maximum	0.3%	0.3%	0.3%	0.2%	0.2%	0.3%	0.2%	0.1%
Minimum	-3.0%	-3.0%	-3.0%	-3.0%	-3.0%	-3.0%	-3.0%	-3.0%
Pakistan								
Agro-food								
Average	-6.5%	-6.1%	-6.0%	-6.2%	-6.1%	-6.1%	-5.4%	-5.4%
Maximum	-4.6%	-4.3%	-4.4%	-4.4%	-4.3%	-4.5%	-4.0%	-3.9%
Minimum	-9.4%	-8.9%	-8.7%	-9.0%	-8.9%	-8.8%	-7.6%	-8.0%
Staple								
Average	-8.5%	-8.4%	-8.6%	-8.5%	-8.6%	-8.6%	-8.7%	-8.7%
Maximum	-5.3%	-5.2%	-5.3%	-5.3%	-5.3%	-5.3%	-5.4%	-5.4%
Minimum	-10.6%	-10.6%	-10.7%	-10.6%	-10.7%	-10.7%	-10.9%	-10.9%
Sri Lanka								
Agro-food								
Average	1.4%	1.4%	2.7%	1.6%	1.7%	2.9%	2.7%	1.0%
Maximum	2.7%	2.6%	4.5%	2.7%	2.8%	4.8%	3.8%	2.2%
Minimum	-0.2%	-0.2%	0.8%	0.5%	0.5%	0.8%	1.5%	-0.3%
Staple								
Average	-3.9%	-3.8%	-3.9%	-4.2%	-4.2%	-3.9%	-4.6%	-4.4%
Maximum	-2.6%	-2.6%	-2.6%	-2.8%	-2.8%	-2.6%	-3.1%	-3.1%
Minimum	-5.1%	-5.1%	-5.1%	-5.4%	-5.4%	-5.1%	-5.9%	-5.6%
Rest of South Asia								
Agro-food								
Average	-2.5%	-2.5%	-2.6%	-2.7%	-2.7%	-2.5%	-2.6%	-2.4%
Maximum	-1.9%	-2.0%	-1.7%	-2.2%	-2.2%	-1.6%	-2.1%	-1.8%
Minimum	-3.2%	-3.3%	-3.6%	-3.4%	-3.4%	-3.6%	-3.3%	-3.1%
Staple								
Average	-1.7%	-1.7%	-1.6%	-1.7%	-1.7%	-1.6%	-2.1%	-2.1%
Maximum	0.5%	0.6%	0.7%	0.6%	0.5%	0.6%	0.5%	0.6%
Minimum	-3.3%	-3.2%	-3.1%	-3.2%	-3.3%	-3.2%	-3.8%	-3.9%

Source: Simulations with MIRAGE.

Table 12 displays the five agricultural products whose domestic production is most negatively affected in the South Asian countries analyzed in this paper. The results show that the largest decreases in maize production occur in Bangladesh (ranging from -17.6 percent to -18.8 percent across trade liberalization alternatives) followed by Sri Lanka (from -8.8 percent to -23.6

percent) and the Rest of South Asia (from -11.4 percent to -13.3 percent). These production decreases are the result of not only the direct effect of yield declines in these countries but also yield increases in India which put downward pressure on maize prices and crowd out other producers. In India climate change affects wheat and vegetable oilseed production most, while in Pakistan oilseeds and rice are most affected.

Simulated changes in crop production are the result of the combined impact of yield shocks, trade relocation effects, inelastic demand, and competition for land between crops. To illustrate this with a specific example, consider Indian wheat yields which will decrease as a result of climate change. As a result Indian wheat production will decrease but Pakistan's will not (wheat is not among the five agricultural products whose supply is most negatively affected in Pakistan). The wheat sector in Pakistan will start attracting resources (land) from other agricultural sectors (rice, cotton, pulses). Meanwhile India increases its production of maize (+89 percent on average, not shown in Table 12 that focuses only on crops that suffer production losses) as well as that of other coarse grains – and starts serving other countries' demand for maize as well (note the decline in maize production in other SAFTA countries). Furthermore, intersectoral linkages come into play as well: the decline in oilseed yield (mainly groundnut) in India leads to a (more than proportional) decline in vegetable oil production. Commodities with higher demand elasticities such as cotton that can be easily substituted with other fibers may decrease their land use and free up land for food production.

Table 12 Five most negatively affected agricultural commodities by country (% changes in 2050 relative to the baseline in each trade policy alternative)

	BASE	SAFTA	SAFTAFULL	UNIAGR	UNIALL	UNISEN	FTA	MULTI
Bangladesh								
Maize	-18.8%	-18.5%	-18.3%	-18.2%	-17.9%	-18.2%	-17.6%	-17.3%
Other Coarse Grains	-17.6%	-18.0%	-17.9%	-17.5%	-17.3%	-17.4%	-18.0%	-17.0%
Cotton	-13.7%	-13.6%	-13.5%	-13.4%	-13.5%	-13.5%	-13.4%	-13.5%
Oilseeds	-13.1%	-13.0%	-12.9%	-13.0%	-12.8%	-12.9%	-12.9%	-12.9%
Wheat	-12.5%	-12.5%	-12.3%	-12.3%	-12.3%	-12.3%	-12.4%	-12.5%
India								
Wheat	-7.2%	-7.2%	-7.2%	-7.3%	-7.3%	-7.2%	-7.4%	-7.5%
Vegetal Oils	-4.6%	-4.7%	-5.0%	-6.3%	-6.6%	-5.2%	-7.2%	-4.8%
Rice	-4.8%	-4.8%	-4.8%	-4.8%	-4.9%	-4.8%	-4.9%	-5.3%
Cotton	-3.5%	-3.5%	-3.5%	-3.6%	-3.6%	-3.5%	-3.6%	-3.6%
Oilseeds	-2.0%	-2.0%	-2.0%	-2.1%	-2.1%	-2.1%	-2.0%	-2.1%
Pakistan								
Oilseeds	-35.1%	-35.1%	-35.0%	-34.8%	-34.8%	-35.1%	-34.7%	-34.6%
Rice	-32.7%	-32.6%	-32.6%	-32.6%	-32.6%	-32.6%	-33.2%	-33.5%
Cotton	-27.6%	-27.6%	-27.6%	-27.6%	-27.7%	-27.7%	-27.6%	-27.6%
Pulses	-27.2%	-27.1%	-27.4%	-27.4%	-27.3%	-27.3%	-27.4%	-27.3%
Vegetables and Fruits	-22.2%	-22.2%	-22.2%	-22.3%	-22.3%	-22.2%	-22.6%	-22.6%
Sri Lanka								
Maize	-23.6%	-23.3%	-23.6%	-23.4%	-22.9%	-23.3%	-8.8%	-12.3%
Other Coarse Grains	-14.6%	-14.5%	-16.4%	-15.0%	-14.9%	-16.2%	-16.5%	-15.4%
Sugar	-11.4%	-11.4%	-16.7%	-11.5%	-11.4%	-16.5%	-14.4%	-8.1%
Rice	-8.4%	-8.5%	-10.5%	-11.4%	-11.6%	-10.8%	-13.5%	-12.4%
Cotton	-11.2%	-10.6%	-10.4%	-10.3%	-10.3%	-10.4%	-10.5%	-10.6%
Rest of South Asia								
Maize	-12.9%	-13.1%	-13.3%	-13.1%	-12.8%	-13.1%	-12.0%	-11.4%
Sugar	-11.4%	-11.7%	-12.3%	-11.8%	-11.4%	-11.9%	-10.8%	-9.5%
Other Coarse Grains	-10.1%	-10.2%	-10.3%	-9.9%	-9.7%	-10.0%	-9.2%	-9.3%
Wheat	-6.3%	-6.3%	-5.6%	-5.7%	-5.6%	-5.6%	-5.3%	-5.2%
Vegetables and Fruits	-4.1%	-4.1%	-4.0%	-4.3%	-4.2%	-4.0%	-3.8%	-4.0%

Source: Simulations with MIRAGE.

5.2.3 Impact of climate change and trade policies on Poor People's Income

Poor people's income is approximated by the real rate of return to unskilled labor. To convert nominal rates of return into real ones, country specific price indices were used, i.e. the fact that poor people spend relatively larger proportions of their income on food was not considered. Given the relatively long term time horizon of the analysis (up to 2050) and the possibility of urban-rural migration, the focus is on the average unskilled labor wage in the economy. The evolution of the unskilled labor wage thus reflects the combined impact of productivity shocks in agriculture (a relatively large user of unskilled labor), the overall price index in the economy, and the mobility of unskilled labor across sectors.

The results show that average real wages of unskilled labor decline in all SAFTA countries except India. This decline is most significant in Pakistan (from -5.2 percent to -5.9 percent across trade

policy alternatives) followed by Sri Lanka and Bangladesh (each between -1.9 percent and -2.3 percent). On the other hand, real unskilled labor wages in India increase (between 0.4 percent and 1.6 percent) across trade policy alternatives.

A comparison between changes in real income (discussed in section 5.2.1) and changes in the real wage of unskilled labor yields interesting insights about the inequalities that result from the impacts of climate change and/or trade liberalization. Indeed the results show that the negative impact of climate change on unskilled labor wages systematically exceeds that on real incomes across all trade liberalization alternatives in all countries. The only exception is India where the increases in unskilled labor wages exceed real income gains. But even in India despite the increases in unskilled labor wages, minimum wages show a significant decline (between -4.7 percent and -9.1 percent) – leading to a higher coefficient of variation in the wage of real unskilled labor across climate change scenarios that any other SAFTA country.

The type of trade liberalization policy matters for the evolution of the unskilled labor wage, even if the variation across trade policies is significantly lower than the variation across climate change scenarios. Except for unskilled laborers in India, unilateral liberalization appear to be attractive for unskilled workers. And interestingly, unilateral trade liberalization in SAFTA seems to provide the best insurance for the worst case scenario, even for unskilled workers in India.

Table 13 Changes in real Unskilled labor Wages (% changes in 2050 relative to the baseline in each trade policy alternative)

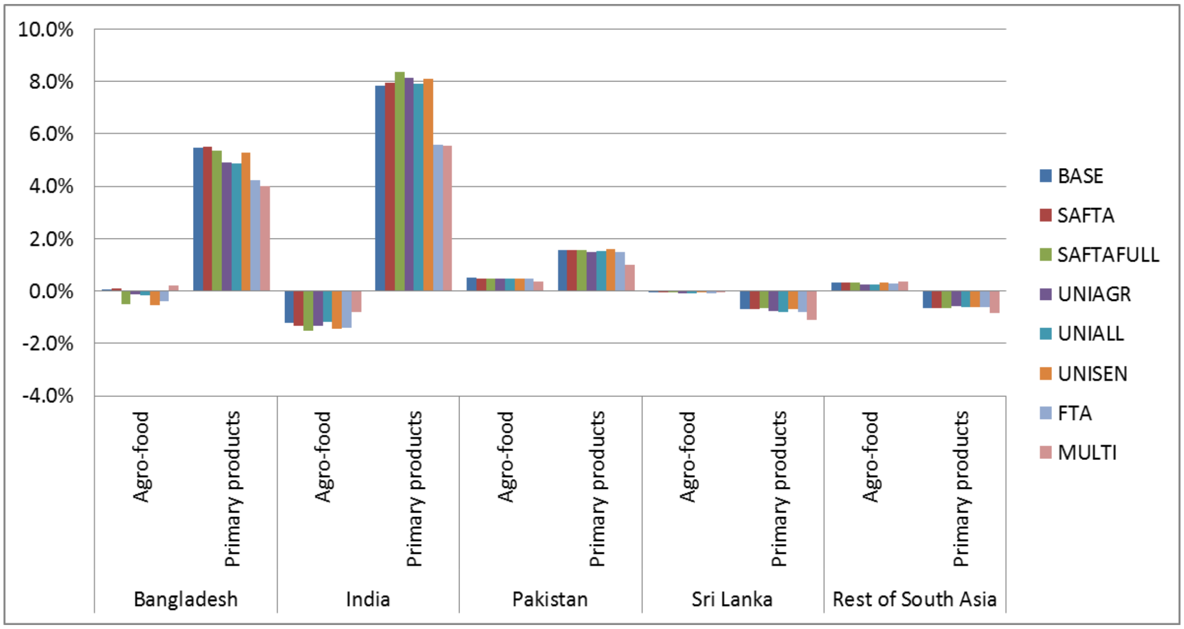
	BASE	SAFTA	SAFTAFULL	UNIAGR	UNIALL	UNISEN	FTA	MULTI
Bangladesh								
Average	-2.1%	-2.1%	-2.0%	-2.0%	-1.9%	-2.0%	-1.9%	-1.9%
Maximum	-0.4%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
Minimum	-3.6%	-3.5%	-3.4%	-3.3%	-3.3%	-3.3%	-3.3%	-3.3%
India								
Average	1.6%	1.5%	1.4%	0.8%	0.4%	0.8%	1.0%	0.8%
Maximum	8.2%	8.1%	8.0%	6.1%	3.9%	4.9%	5.4%	4.3%
Minimum	-9.1%	-9.1%	-9.1%	-7.8%	-5.4%	-6.0%	-6.0%	-4.7%
Pakistan								
Average	-5.9%	-5.8%	-5.7%	-5.7%	-5.3%	-5.3%	-5.4%	-5.2%
Maximum	-3.3%	-3.2%	-3.1%	-3.3%	-2.8%	-2.8%	-2.8%	-2.7%
Minimum	-8.2%	-8.1%	-8.0%	-7.9%	-7.4%	-7.5%	-7.5%	-7.3%
Sri Lanka								
Average	-1.9%	-1.9%	-1.9%	-2.0%	-2.1%	-1.9%	-2.3%	-2.3%
Maximum	-1.2%	-1.2%	-1.2%	-1.3%	-1.4%	-1.2%	-1.6%	-1.6%
Minimum	-2.4%	-2.4%	-2.4%	-2.5%	-2.6%	-2.4%	-2.9%	-2.8%
Rest of South Asia								
Average	-0.9%	-0.9%	-0.8%	-0.9%	-0.9%	-0.8%	-0.7%	-0.7%
Maximum	-0.1%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	0.1%	0.0%
Minimum	-1.5%	-1.4%	-1.4%	-1.4%	-1.5%	-1.5%	-1.2%	-1.2%

Source: Simulations with MIRAGE.

5.2.4 Impact of climate change and trade policies on Food consumption and Food prices

The impacts of climate change on final consumers for each trade policy alternative are analyzed with emphasis on average food prices and food consumption per capita (Figure 38).

Figure 38 Average changes in food prices (% changes in 2050 relative to the baseline in each trade policy alternative)



Source: Simulations with MIRAGE.

In Bangladesh, India and Pakistan the average prices of primary (food staple) products are more affected than prices of agro-food (processed food) products. The increase in average food staple prices is highest in India where the relatively small decreases in real incomes (or even income increases) keep up demand. Figure 38 shows the important role of trade liberalization in mitigating food price increase, in particular regional free trade (FTA) and multilateral trade liberalization - markets need to be able to operate freely in order to absorb the climate change shock. Unilateral trade liberalization in SAFTA countries will not be able to play a similar role in mitigating food prices. It is important to keep in mind that these results compare the impact of climate change on food prices under the different trade policy baselines – the results do *not* represent the combined effects of trade liberalization and climate change relative to a full status quo baseline. In other words, the price reduction effect of trade liberalization is the consequence of less distorted markets and not the consequence of tariff reductions. The latter are already included in the baseline of each trade policy alternative.

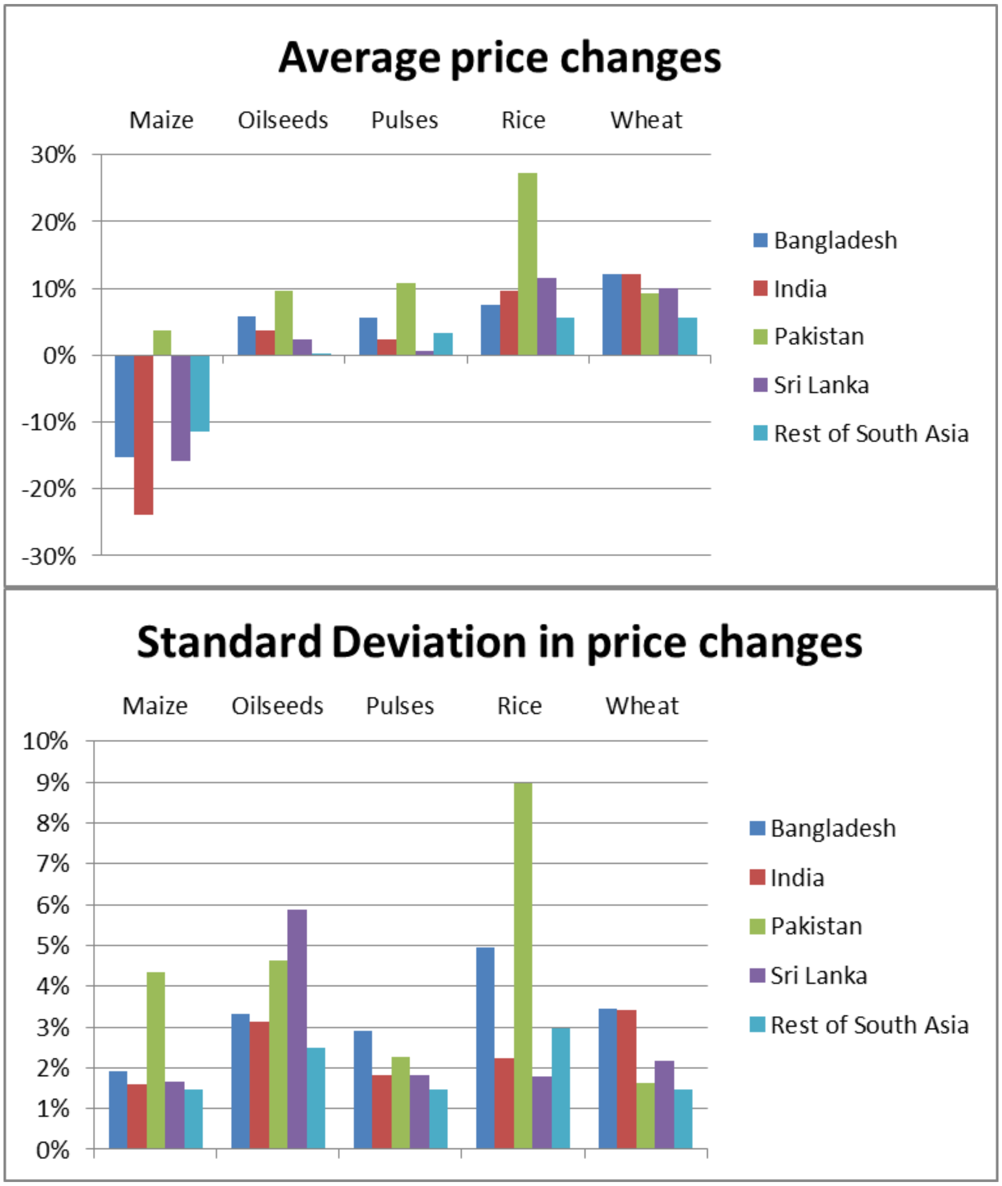
Depending on the country, the average price of agro-food (processed food) products either decreases or increases only moderately. This result is obtained because this average price represents a Fisher price index (the "true" price index on food products would pose computational difficulties given the CES LES demand framework). In the computation of the

Fisher price index weights change and consequently product shares evolve. The only commodities whose prices decrease include maize and other coarse grains (driven by area and yield increases) and sugar. The effects of these price decreases on the Fisher price index is through the direct price decrease and substitution effects with other crops. The result is nearly perfect mitigation (in Bangladesh's case through the sugar channel) or even a slight overall price decrease.

In order to complete the price picture, Figure 39 depicts changes in domestic market prices and their variability for local varieties of selected commodities – as averages across all climate change scenarios and trade policy options. Average prices of all commodities (except maize in all countries but Pakistan) increase. Price increases are highest for rice, particularly in Pakistan (27 percent). Wheat also increases significantly in price (10 percent). Pakistan is the country most affected by price increases. The decrease in the price of maize is driven by large production increases in India due to significant increases in both yield and area in that country.

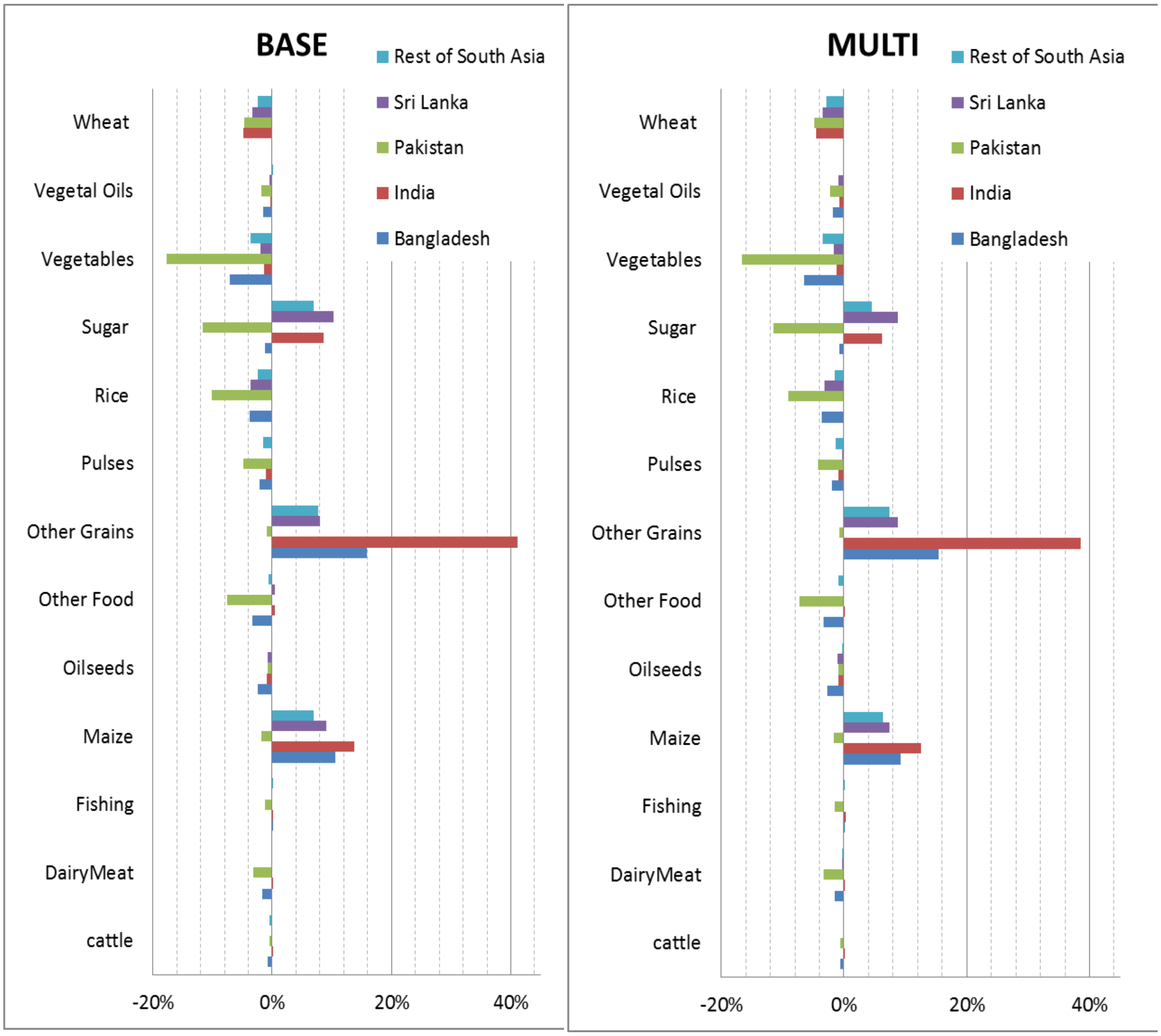
In terms of variability in price changes across climate change scenarios and trade policy alternatives, Sri Lanka and Pakistan show large uncertainties. Poor consumers will be most adversely affected by these price changes given the large share of food in their total expenditure.

Figure 39 Changes in domestic prices for local varieties of key commodities – averages across climate change scenarios and trade policy alternatives (% changes relative to the Status quo trade policy baseline in 2050)



Source: Simulations with MIRAGE.

Figure 40 Changes in average per capita consumption (% changes relative to the baseline in 2050, simple average across climate change scenarios) for the BASE (status quo) and MULTI (multilateral trade liberalization) trade policy alternatives



Source: Simulations with MIRAGE.

Per capita food consumption is calculated as an average that is determined by the combined effects of changes in real income at the country level and changes in food prices. Only averages across households are considered, i.e. household heterogeneity is ignored.

Since different trade policy alternatives lead to changes in income that are very similar across climate change scenarios, Figure 40 depicts only the impact of the two 'extreme' trade liberalization alternatives (status quo and full multilateral trade liberalization). Changes due to price differences (discussed above) are therefore the main driver that differentiates per capita consumption across sectors.

Considering the full liberalization trade policy alternative, the results show that average consumption per capita of most food products declines across all countries. Notable exceptions are maize and other coarse grains for which household demand increases in all countries except Pakistan – the increase is most significant in India (39 percent) as a result of lower prices and low initial consumption levels). As expected, consumption in Pakistan is severely (negatively) affected, also because the average food basket in Pakistan is less diversified. Comparing the two trade policy alternatives, some interesting new consumption patterns come to bear – e.g. the increase in consumption of maize in Bangladesh and of other coarse grains in India.

Table 14 Standard deviation in the % change of per capita food consumption across climate change scenarios in 2050

	Bangladesh	India	Pakistan	Sri Lanka	Rest of South Asia
Cattle	0.5%	0.2%	0.2%	0.2%	0.3%
Dairy & Meat	0.7%	0.2%	0.7%	0.1%	0.2%
Fishing	0.1%	0.2%	0.4%	0.1%	0.1%
Maize	1.1%	1.3%	1.5%	0.8%	0.8%
Oilseeds	1.3%	0.8%	1.3%	1.9%	0.9%
Other Food	0.7%	1.0%	1.2%	0.2%	0.4%
Other Grains	1.2%	1.0%	1.4%	0.6%	0.8%
Pulses	1.1%	0.9%	0.9%	0.6%	0.6%
Rice	2.1%	0.1%	2.5%	0.5%	1.1%
Sugar	2.8%	0.2%	3.7%	0.4%	0.8%
Vegetables	2.5%	1.7%	2.7%	0.6%	0.8%
Vegetal Oils	1.3%	0.9%	0.8%	1.0%	0.7%
Wheat		1.2%	0.7%	0.6%	0.5%

Source: Simulations with MIRAGE.

Instead of using minima and maxima across climate change scenarios, Table 14 represents the variation of results expressed by the standard deviation in the percentage change of per capita food consumption. Countries with the highest variation include Pakistan and Bangladesh – and standard deviations are highest for rice, sugar and vegetables.

As discussed before, the adverse impact of climate change shocks will be particularly significant for poor households given the decreases in unskilled labor wages combined with the relatively high share of food in total expenditure. To take a concrete example, in Pakistan real income falls on average by -4.25 percent while food prices increase by nearly 2 percent and the real wage of unskilled labor falls by 5.6 percent.

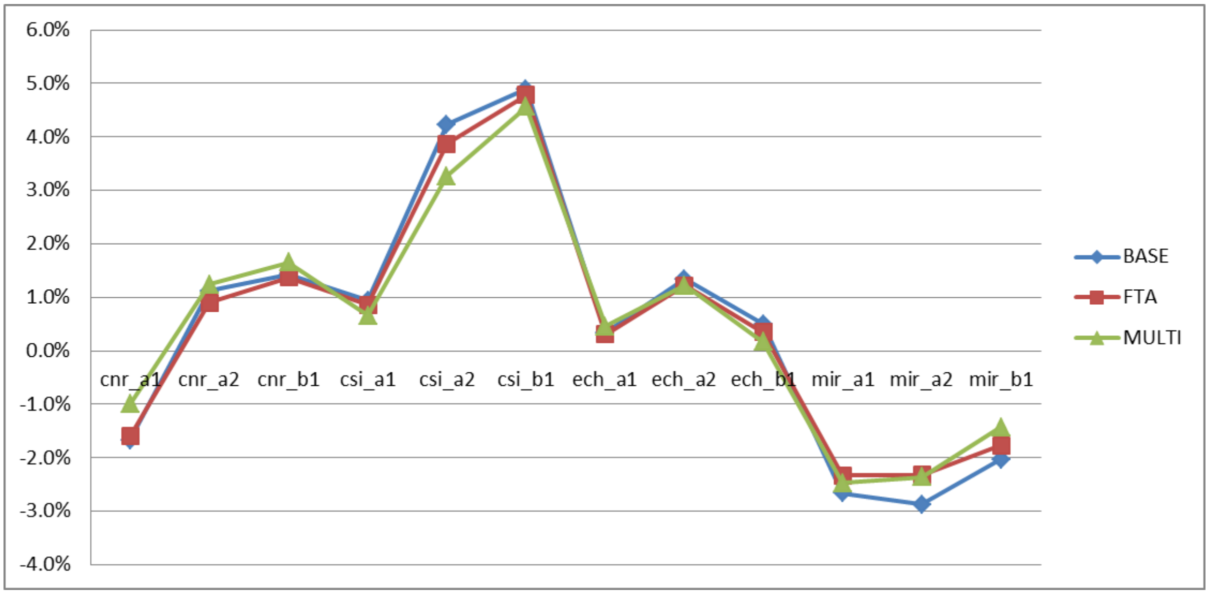
Self sufficiency ratios (domestic production divided by domestic consumption) remain relatively stable mainly due reductions in consumption following the production shocks. For example in Pakistan, the self sufficiency ratio of staple commodities (whose production is most negatively affected by climate change) deteriorates by a maximum of 0.5 percentage points. Beyond the range of changes directly resulting from climate change, trade policy can significantly influence the self sufficiency ratio: in Sri Lanka for example, the Asia-wide FTA trade policy option[15] will enhance the negative effects of climate change (by -0.3 percentage points in terms of coverage) compared to the status quo (-0.1 percentage points). The stability of the self sufficiency ratio is associated with relatively large decreases in production and consumption occurring simultaneously (via price and income effects). At the individual commodity level, the self sufficiency ratio for rice and pulses decreases by more than 5 percentage points in Pakistan.

5.2.5 Impact of climate change and trade policies on Trade

There are a number of factors that can explain the expansion or contraction of trade. First, income and trade are generally positively correlated - lower income results in less trade and vice versa. Second, substitution effects vary either positively or negatively with trade, depending on who is impacted. For example, if climate change affects yields of traditional large scale farmers that produce for export (as is the case for South American producers in the *mir* climate change scenarios), traditional export flows will decrease and domestic production may replace previous imports.

[15] In the most pessimistic scenario, the decline in coverage ratio can reach 1.1 percentage points for staple foods and 2.6 percentage points for agro-food commodities.

Figure 41 Changes in world trade of staple crops (% changes in volume relative to baselines of trade policy alternatives by 2050)



Source: Simulations with MIRAGE.

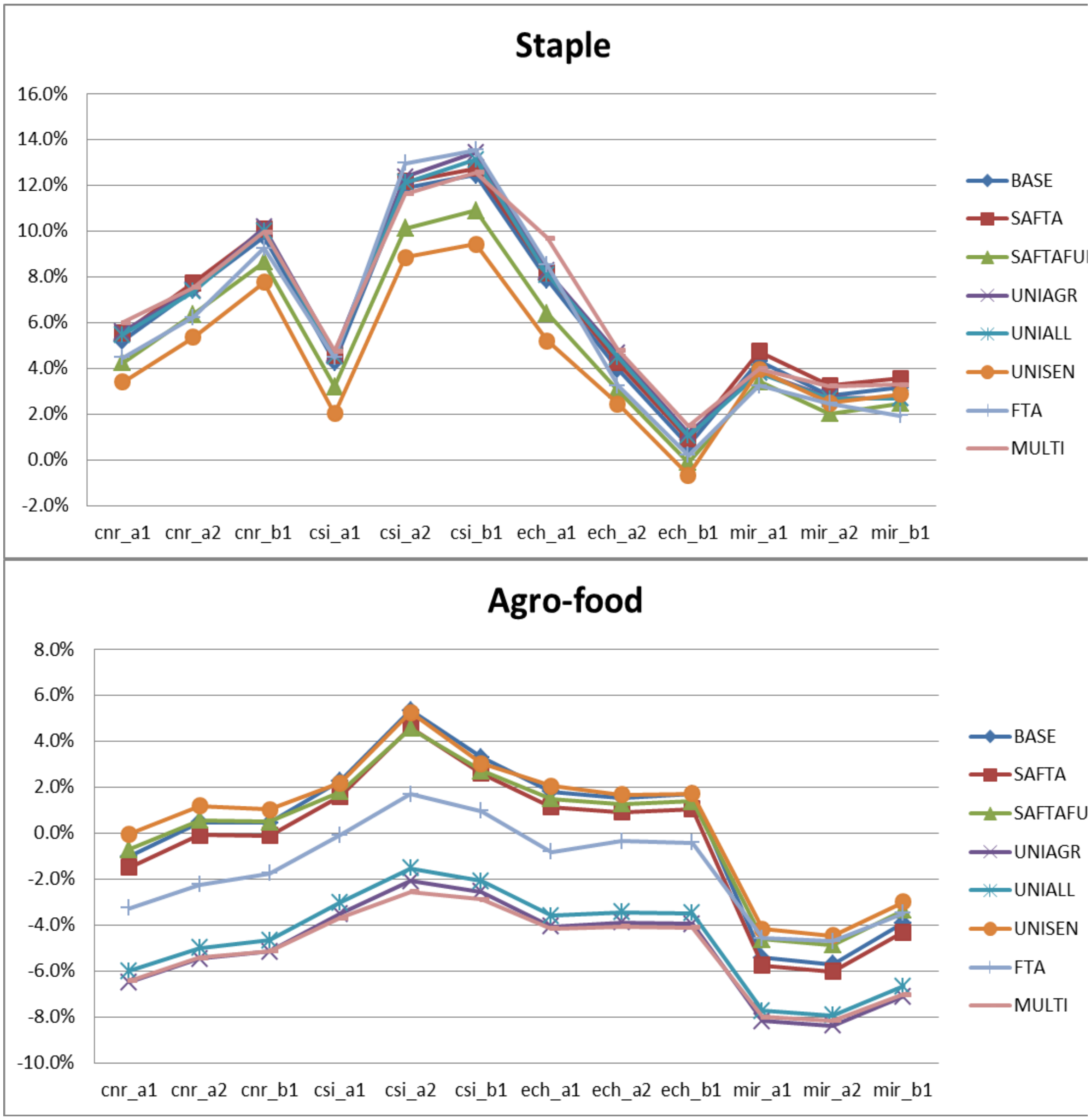
Figure 41 depicts changes in overall world trade of staple crops in volume terms in 2050 relative to the baseline for selected trade liberalization alternatives. The results show significant changes in world trade of staples (ranging from -3 percent +5 percent), implying a large variation across different climate change scenarios. Indeed the simple average of world staple trade growth is 0.5 percent with a coefficient of variation of 500 percent. Developed countries' imports will rise when imports in the developing world decrease for both staples and processed food products.

Once again the type of trade policy option has a far smaller impact on the trade volumes than does the type of climate change scenario. On the other hand and compared to the status quo trade policy option, the full liberalization option may reduce the impact of climate change on trade volumes by up to one-third, especially when world trade decreases. Therefore, global trade liberalization seems to provide a framework that provides increased stability to world trade whatever the climate change scenario may be. Interestingly, this result holds for both developed and developing country imports for both staple and processed food trade: the standard deviation across climate scenarios is always lower for the MULTI baseline than for the status quo trade policy option (BASE).

The impact of climate change on trade volumes in South Asia are depicted in Figure 42 and are a magnitude larger than the impact at the global level (Figure 41) – even though the extreme scenarios differ a bit. South Asian imports of food staples show a consistent increase across virtually all trade liberalization and climate change scenarios. The impact differs significantly between the various trade policy options. Adopting a trade policy characterized by higher distortions such as unilateral liberalization but with sensitive products included (the UNISEN trade policy option which involves product discrimination) or a full FTA within SAFTA (the UNIALL trade policy option which involves sub regional discrimination) will limit the imports of the region, especially by discouraging imports from the rest of the world or/and for needed products. On the other hand, the largest increases in imports are linked to more liberal trade policies: from USD 40 to 250 billion with MULTI to USD 27 to190 billion with the full Asia FTA.

With respect to agro-food commodities and for a given climate change shock, trade policies that imply lower distortions such as full liberalization (MULTI) or unilateral liberalization (UNIAGR orUNIALL) lead to relatively larger import reductions than is the case under more protectionist trade policy regimes – even though it should be realized that the baseline values in these trade policy alternatives were also higher. In this sense climate change will "claim back" part of the market share given to outsiders during the liberalization process under either of these two trade policy options.

Figure 42 Food imports in South Asia (% changes in volumes relative to the baseline for each trade policy option by 2050)

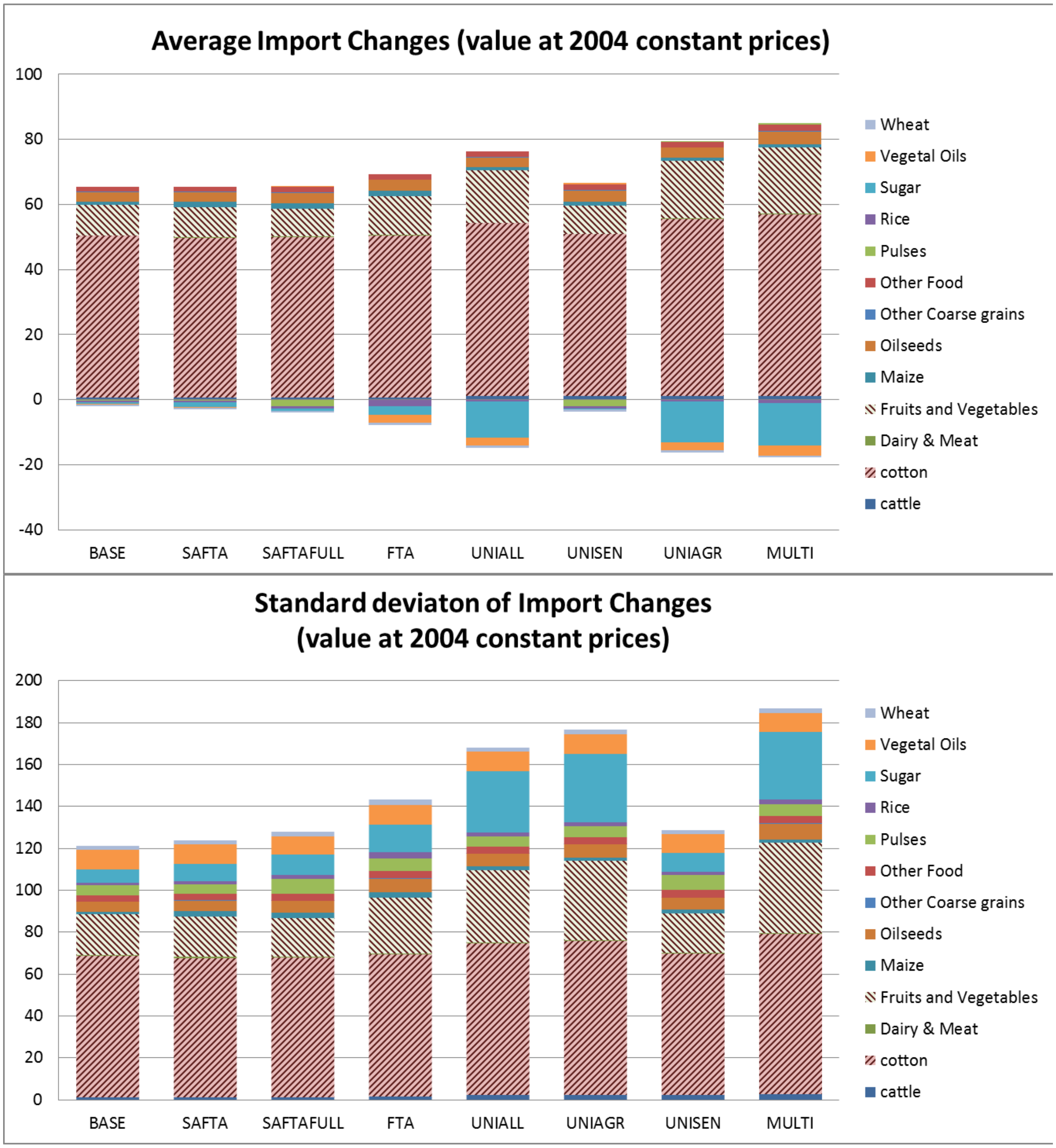


Source: Simulations with MIRAGE.

The sectoral composition of changes in South Asian imports resulting from climate change in is depicted in Figure 43. Imports may displace significant portions of domestic production of fruits and vegetables, oilseeds and (especially) cotton. Imports of pulses may decrease. Imports of sugar and oilseeds also decrease but only if liberalized in the baseline. Trade liberalization policies such as SAFTAFULL andUNISEN that maintain sensitive products (among which cotton) limit the extent changes in imports. The lower part of Figure 43 shows the standard deviation of these flows across climate change scenarios. For many trade policy options the coefficient of

variation of changes in import values exceeds 100 percent, implying that different climate change scenarios have widely diverging effects given a particular trade policy.

Figure 43 Sectoral composition of import changes for South Asia by trade policy alternative (simple averages across climate change scenarios – constant 2004 US$ 10^9)



Source: Simulations with MIRAGE.

Table 15 further decomposes the overall changes caused by climate change in SAFTA's imports of food staples and processed food by country. Not surprisingly, Pakistan is most affected. The type of trade policy option matters most in Sri Lanka and India. In general the more liberal trade

policy options (UNIALL, MULTI) reduce the need to increase imports. While for these more open trade policies the base is larger in percentage terms, the market is already more open and reallocation of production factors can take place more easily.

Table 15 Changes in imports of staple and processed foods by country (% change in volumes relative to the each trade policy option's baseline by 2050)

	Agro-food			Staple		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Bangladesh						
BASE	7%	12%	-1%	3%	12%	-1%
SAFTA	6%	10%	-1%	3%	12%	-1%
SAFTAFULL	8%	13%	1%	2%	11%	-2%
UNIAGR	7%	11%	0%	3%	11%	-2%
UNIALL	7%	11%	0%	2%	11%	-2%
UNISEN	8%	13%	2%	2%	11%	-2%
FTA	7%	11%	0%	1%	10%	-3%
MULTI	6%	10%	-1%	3%	12%	-2%
India						
BASE	-2%	4%	-8%	5%	12%	-2%
SAFTA	-3%	3%	-8%	5%	12%	-2%
SAFTAFULL	-3%	2%	-8%	3%	10%	-3%
UNIAGR	-8%	-5%	-10%	6%	14%	0%
UNIALL	-7%	-4%	-10%	6%	13%	0%
UNISEN	-2%	3%	-7%	3%	9%	-3%
FTA	-3%	0%	-6%	5%	15%	-2%
MULTI	-8%	-5%	-10%	6%	13%	0%
Pakistan						
BASE	6%	12%	2%	14%	23%	7%
SAFTA	6%	11%	2%	17%	25%	10%
SAFTAFULL	7%	12%	3%	17%	25%	11%
UNIAGR	2%	8%	-3%	14%	23%	8%
UNIALL	3%	8%	-3%	14%	22%	7%
UNISEN	7%	11%	4%	15%	22%	10%
FTA	2%	7%	-3%	13%	20%	8%
MULTI	2%	6%	-2%	15%	22%	10%
Sri Lanka						
BASE	5%	6%	5%	-1%	1%	-4%
SAFTA	5%	5%	4%	-1%	1%	-3%
SAFTAFULL	11%	11%	10%	-2%	0%	-5%
UNIAGR	6%	6%	5%	-2%	0%	-4%
UNIALL	5%	6%	5%	-2%	0%	-5%
UNISEN	11%	11%	10%	-2%	1%	-5%
FTA	9%	9%	8%	-6%	-4%	-8%
MULTI	4%	4%	3%	-3%	-1%	-6%
Rest of South Asia						
BASE	7%	7%	6%	-12%	-9%	-17%
SAFTA	7%	7%	6%	-12%	-9%	-17%
SAFTAFULL	7%	8%	6%	-12%	-9%	-18%
UNIAGR	6%	7%	5%	-12%	-9%	-17%
UNIALL	6%	7%	5%	-12%	-9%	-17%
UNISEN	7%	7%	6%	-11%	-9%	-17%
FTA	6%	6%	5%	-16%	-13%	-20%
MULTI	4%	5%	3%	-14%	-11%	-18%

Source: Simulations with MIRAGE.

Table 16 depicts percentage changes in bilateral agricultural trade in volumes while Table 17 does the same in constant 2004 billion USD. A number of import categories show significant increases (in percentage terms) including ag-food imports from other SAFTA countries, and

some staples from other developing countries. In absolute terms these changes are different. SAFTA's exports of agro-food go to all destinations and despite very large percentage changes remain limited in absolute terms. SAFTA can benefit strongly in terms of agro-food exports once the developed countries have opened their markets (as in the MULTI trade policy option).

Table 16 Changes in bilateral agricultural trade flows (% changes in volumes by 2050 compared to the baseline of each trade policy option)

	BASE	SAFTA	SAFTAFULL	UNIAGR	UNIALL	UNISEN	FTA	MULTI
SAFTA importers								
SAFTA exporters								
Staple	-5%	-1%	-6%	-5%	-4%	-8%	-4%	-6%
Agro-food	87%	4%	16%	99%	95%	19%	35%	55%
Non Food Agricultural products	-13%	-13%	-11%	-12%	-12%	-11%	-11%	-12%
Developed Countries exporters								
Staple	5%	5%	5%	6%	5%	5%	3%	6%
Agro-food	-51%	-52%	-65%	-66%	-66%	-64%	-71%	-55%
Non Food Agricultural products	20%	20%	20%	15%	15%	19%	17%	14%
Developing Countries exporters (excl. SAFTA)								
Staple	11%	11%	11%	10%	10%	9%	12%	10%
Agro-food	-47%	-47%	-54%	-71%	-70%	-53%	-53%	-65%
Non Food Agricultural products	13%	13%	13%	7%	7%	13%	12%	10%
Developed Countries importers								
SAFTA exporters								
Staple	-23%	-23%	-23%	-22%	-22%	-22%	-25%	-24%
Agro-food	122%	122%	121%	110%	109%	124%	109%	364%
Non Food Agricultural products	-8%	-7%	-7%	-7%	-8%	-7%	-8%	-6%
Developing Countries importers (excl. SAFTA)								
SAFTA exporters								
Staple	0%	-1%	0%	-1%	-1%	-1%	-2%	-5%
Agro-food	772%	786%	790%	621%	594%	761%	655%	371%
Non Food Agricultural products	-15%	-15%	-15%	-13%	-13%	-15%	-11%	-13%

Source: Simulations with MIRAGE.

The choice of trade policy is important from both the point of view of regional integration and climate change. When regional markets are relatively open, climate shocks lead to a moderate reduction in intra-regional SAFTA trade in staples. But the effect of climate change is much stronger (and positive) on intra-regional SAFTA trade in agro-food commodities. Once markets have been liberalized on a unilateral (without exceptions, i.e. UNIAGR or UNIALL) or on a multilateral basis (MULTI), there is strong growth of intra-regional SAFTA trade since regional producers (India) capture market share held by developed and other developing countries in the baseline. In the case of the MULTI trade policy option where global liberalization increases

SAFTA's exports to other developing economies, the (negative) shock to potential exports of staples of SAFTA to the rest of developing countries is stronger: global market liberalization allows SAFTA to expand its production and when adverse climate change occurs, SAFTA will increase production for domestic consumption and reduce exports (see cells highlighted in green). This also illustrates the difference between levels and percentages.

Table 17 Changes in bilateral agricultural trade flows (in constant 10^9 2004 dollars by 2050 compared to the baseline of each trade policy option)

	BASE	SAFTA	SAFTAFULL	UNIAGR	UNIALL	UNISEN	FTA	MULTI
SAFTA importers	***2.5***	***2.4***	***2.3***	***2.7***	***2.5***	***2.3***	***2.5***	***3.1***
SAFTA exporters	**-0.7**	**-0.8**	**-1.2**	**-0.8**	**-0.7**	**-1.2**	**-0.9**	**-1.0**
Staple	-0.7	-0.1	-1.5	-1.1	-0.9	-1.7	-0.9	-1.3
Agro-food	0.7	0.1	0.3	1.1	1.1	0.4	0.7	0.7
Non Food Agricultural products	-2.1	-2.5	-2.4	-2.3	-2.3	-2.3	-2.3	-2.4
Developed Countries exporters	**5.9**	**5.9**	**6.0**	**8.0**	**7.6**	**6.1**	**5.4**	**7.9**
Staple	2.4	2.1	2.4	4.3	3.8	2.7	1.7	5.1
Agro-food	-0.3	-0.3	-0.3	-0.8	-0.7	-0.2	-1.0	-0.8
Non Food Agricultural products	15.7	15.7	15.7	20.5	19.6	15.7	15.4	19.5
Developing Countries exporters (excl. SAFTA)	**5.4**	**5.4**	**5.5**	**4.2**	**4.0**	**5.5**	**6.4**	**6.4**
Staple	5.0	5.0	5.0	8.1	7.5	5.1	7.7	9.6
Agro-food	-1.0	-0.9	-1.0	-7.0	-6.3	-0.9	-1.4	-6.7
Non Food Agricultural products	12.1	12.2	12.3	11.3	10.8	12.4	13.1	16.3
Developed Countries importers	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***-0.1***	***6.1***
SAFTA exporters	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**-0.1**	**6.1**
Staple	-1.8	-1.8	-2.0	-2.0	-2.0	-1.9	-2.6	-3.5
Agro-food	2.5	2.6	2.6	2.7	2.7	2.7	2.4	22.0
Non Food Agricultural products	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Developing Countries importers (excl. SAFTA)	***1.0***	***1.0***	***1.0***	***1.0***	***0.9***	***1.0***	***1.7***	***-0.9***
SAFTA exporters	**1.0**	**1.0**	**1.0**	**1.0**	**0.9**	**1.0**	**1.7**	**-0.9**
Staple	-0.4	-0.7	-0.4	-0.7	-1.5	-0.8	-3.1	-6.3
Agro-food	4.8	4.8	4.7	5.2	5.5	5.2	9.6	5.2
Non Food Agricultural products	-1.3	-1.2	-1.2	-1.4	-1.5	-1.3	-1.5	-1.6

Source: Simulations with MIRAGE

In terms of standard deviations within climate change scenarios (not displayed here), there exist substantial variations for non-food agricultural products (e.g. cotton) and high variations regarding the potential of SAFTA exports of staple foods to other developing countries (can be strongly negative or positive).

5.3 Sensitivity analysis based on alternative economic and population growth

This section focuses on alternative assumptions regarding economic and population growth. The first assumption path consists of weaker growth– i.e. world GDP in 2050 is set at 55 percent of the previous target, driven by an accelerated increase in total factor productivity at the global level. This growth path is inspired by the pessimistic scenario developed by Nelson et al. (2010). India's GDP is the most affected (69 percent decrease) followed by Pakistan (32 percent decrease) and Sri Lanka (5 percent decrease). The second assumption is based on a modification of demographic trends. This assumption uses the upper projections provided by the UN – specifically world population is projected to reach 10.5 billion by 2050 which implies 290 million additional people in South Asia in addition to the standard demographic assumptions. This translates into 13 percent more people in India, 9 percent more in Pakistan, and 22 percent more in Sri Lanka. Since GDP targets are not modified under the second assumption, income per capita will decrease. Table 18 displays the changes for the two extreme tariff baselines with the central and these new assumptions for selected indicators.

Table 18 Sensitivity analysis based on alternative assumptions regarding economic and population growth: selected indicators. Simple averages across climate change scenarios for two trade policy alternatives. Numbers represent percentage devations from each baseline.

	BASE			MULTI		
	Central case	**Reduced GDP**	**Larger Population**	**Central case**	**Reduced GDP**	**Larger Population**
Real Income						
South Asia	-0.4%	-0.5%	-0.5%	-0.4%	-0.5%	-0.5%
Bangladesh	-1.5%	-1.2%	-1.5%	-1.5%	-1.2%	-1.5%
India	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pakistan	-4.1%	-2.6%	-4.4%	-4.3%	-2.6%	-4.6%
Sri Lanka	-0.4%	-0.3%	-0.4%	-0.6%	-0.4%	-0.6%
Rest of South Asia	-0.5%	-0.3%	-0.5%	-0.6%	-0.4%	-0.6%
Unskilled worker real wage						
Bangladesh	-2.1%	-2.0%	-1.9%	-1.9%	-1.9%	-1.8%
India	1.6%	0.1%	-0.3%	0.8%	0.2%	-0.1%
Pakistan	-5.9%	-3.4%	-8.0%	-5.2%	-2.9%	-6.7%
Sri Lanka	-1.9%	-1.5%	-1.5%	-2.3%	-1.7%	-1.8%
Rest of South Asia	-0.9%	-0.6%	-0.8%	-0.7%	-0.6%	-0.7%
Imports (volume)						
South Asia						
Agro-food	0.1%	1.2%	-1.9%	-5.1%	-3.0%	-1.9%
Staple	6.1%	12.6%	6.4%	6.6%	12.3%	6.4%

Source: Simulations with MIRAGE.

5.3.1 Consequences of lower GDP growth

Lower GDP growth limits relative real income losses from climate change – this is because lower growth makes the reduction in yield apply to a lower base (lower productivity in the baseline). The effect of lower GDP growth is quite strong for Pakistan, reducing the relative income loss from climate change by about one-third. However, the absolute level of GDP after climate change losses under the regular GDP growth assumption remains significantly higher than the absolute GDP level under the lower GDP growth assumption. Unskilled workers are affected in similar ways as the overall economy. This is consistent with the modeling choice made in this paper where reductions in TFP are neutral across production factors.

Multilateral trade liberalization (MULTI) under the lower GDP growth baseline leads to a substantial increase in imports of staple foods in SAFTA countries but a significant reduction of in agro-food imports. Following a reduction the size of the SAFTA economy (in absolute and in relative compared to the world) and lower agricultural production in the region, food imports need to increase given that population growth remains unchanged.

5.3.2 Consequences of higher population growth

The effects of lower per capita GDP through accelerated population growth are quite distinct from lower per capita GDP resulting from lower economic growth. For overall real income, no significant differences appear between the standard population growth baseline and the one with higher population growth. However, countries with a large population will face larger employment challenges under the high population growth rate baseline. The larger size of the population will decrease the price of labor (resulting from the model's full employment assumption) and provide an incentive to use relatively labor intensive production technologies and tilt the production structure towards more labor intensive activities/sectors. The negative climate change shock on crop yields will translate into a significant decline in the marginal labor productivity due to the concavity of the production functions in the model. This will lead to a decline in real wages making higher population growth an even more adverse situation for the poor.

Overall, the sensitivity analyses performed in this section do not change the previous qualitative assessment in terms of trade policy options - but they do show that changes in GDP per capita, depending on their origin, could change the cost of adjusting to climate change. More dynamic economies that have recorded large TFP growth are likely to suffer higher losses from climate

change simply because their initial economic potential is higher. But they also have larger domestic markets and better capacity to adapt internally and they are less dependent on trade. On the other hand, countries that face serious econoic growth problems and slow productivity gains will need to use international markets to deal with the yield shock caused by climate change. Except if the productivity gap would particularly affect unskilled workers, no particular anti-poor biases are likely to occur. On the other hand even if the overall economy would be exhibiting steady economic growth but demographic growth is not controlled, climate change will exacerbate the problems for the poor.

6 Concluding Remarks

Besides providing the traditional summary, this final Chapter centers on the following two questions: (i) Given the analyses performed in this paper, which policy recommendations regarding the optimal trade policy to follow can be considered as robust? (ii) What are the limitations of the analyses performed and how should these limitations be addressed in the future?

This paper suggests that South Asia will be one of the most adversely affected regions in terms of the impact of climate change on agricultural yields and incomes. At the regional level the average decrease in GDP is estimated at 0.5 percent but with wide variance between individual countries. Whereas for India the change in GDP is estimated at between -0.6 percent and +0.5 percent depending on the climate change occurrence, Pakistan may lose up to 4 percent of its GDP as result of climate change. Indeed, uncertainty about the intensity of climate change and its exact geographical location, embodied in the 12 SRES scenarios considered in this paper, leads to a high degree of variability regarding its impact. This makes it difficult to pinpoint exactly which trade policies South Asian countries should follow in an attempt to mitigate the negative impact of climate change. Climate change and trade interact through rich and complex mechanisms and it is difficult to provide ex-ante standard recommendations. However, the quantitative assessment done in this paper based on a large number of (uncertain) scenarios has generated a wide menu of possible outcomes which in turn provide policy makers with useful guidance for trade policy decisions.

Based on a simple average of climate change scenarios (i.e. assuming equal probability of each scenario and without consideration of volatility - no risk aversion of policy makers), it seems that except for India all other South Asian countries should favor the status quo or the deepening of regional integration focused on SAFTA. India may have a preference for more ambitious trade policies consisting of a trade agreement agenda at the pan Asia level or even at a global scale. Nonetheless, India would need to obtain access to foreign markets in order to choose this path and unilateral trade liberalization is not an optimal strategy for managing the impact of climate change since the exact nature, location and effects of climate change remain highly uncertain.

The specific case of India warrants closer attention since it has implications for the South Asian region as a whole. On the one hand, India is a large and fast growing country, and by 2050 can

be expected to have even larger market power. Unilateral trade liberalization by India may expose the country to negative price shocks and large terms of trade losses. By maintaining trade restrictions, India could use its market power and the traditional "optimal tariff argument" to mitigate the impact of increases in world prices on domestic prices and limit the deterioration of its terms of trade. At the same time, India would benefit from the opening of foreign markets. But the strengths of India go even beyond its international market power. The size of its domestic market enables India to reallocate production factors across crops while allowing regions to redefine an optimal production pattern compatible with changing climatic conditions. In particular, India may rely on vast amounts of land currently used for cotton to produce additional food crops. For smaller countries, such an internal diversification strategy is much less feasible. This stresses the importance for the region as a whole of having flexible commodity as well as factor markets in order to ensure sufficient adaptation capacity and efficient allocation resources.

Besides the effects on real GDP, the distributional effects of climate change are also important. Unskilled workers' real wages, a proxy for poor people's incomes, are mostly negatively impacted by climate change. This is to be expected since wages are directly impacted by changes in agricultural productivity. In the case of Pakistan, the decrease in the wage of unskilled labor exceeds 5.5 percent in real terms (using the country wide price deflator). In the case of India, even if on average unskilled laborers' wages show an increase (of about 1.6 percent) under a policy of status quo, the range of uncertainty is large: the change in unskilled workers' real wages varies between +8.2 percent and -9.1 percent depending on the climate change scenario. For the poor in India unilateral liberalization, including liberalization of sensitive products in some cases, may be the preferred trade liberalization strategy. But this is not the case for the poor in countries other than India where unilateral liberalization is the best strategy only in the most adverse climate change case.

In spite of the above trade liberalization, especially on a global scale, would mitigate increases in the prices of key food products and contribute to price stability. Again uncertainties regarding climate change lead to diverging forecasts: global agricultural trade may increase or decrease depending how traditional exporters (e.g. countries belonging to the Cairns group) would be affected and how traditional importers would need to find new partners or to develop domestic solutions. Indeed and in addition to developing global markets, agricultural trade liberalization

would also lead to important market opportunities for South Asia in other developed and developing markets. When climate change will occur, South Asian exports can focus on intra-regional markets, in this way mitigating (in some cases by half) the price increases driven by reductions in yields.

Beyond the uncertainty inherent in climate change analysis, this paper has its own limits that should lead to a cautious interpretation of the results and conclusions:

First, the determination of the effects of climate change on crop yields is incomplete. The approach followed in this paper consists of the use of crop models to measure the effects of changes in temperature and water availability on yields. But climate change affects yields not only via water and temperature - for example, yields are also determined by the optimal planting season which may well change as a result of climate change. The latter may also lead to changes in pest and disease frequencies which are not taken into account (and new ones are not introduced), and carbon fertilization is also not considered. Thus, better measurements of the yield impacts of climate change are required for all crops in the CGE model – and this holds in particular for other coarse grains, cotton, pulses and vegetables. Moreover and as shown in the results, changes in production patterns, land allocation, and expansion of initially minor crops (e.g. maize in India) can also play a major role in the climate change adaptation strategy.

Second and perhaps even more importantly, explicit modeling of endogenous irrigation investment strategies is not part of this paper. In the current version of the CGE model, the ratio of irrigated to non-irrigated land is constant, thus basically ignoring the possibility to improve existing irrigation systems and/or building new ones. The costs associated with maintaining irrigation systems are also not taken into account. The model predicts movement of capital in and out of agriculture - but how this private and public capital will be put to use remains a modeling challenge. Concerning water and water availability for agriculture, the issue of energy production in the region (nuclear and hydroelectric) warrants consideration as well. Indeed, at this stage only crude assumptions have been made and no consistency has been ensured between water demand for energy (which is not modeled) and increases in energy demand caused by economic growth. Land availability is another aspect that requires improvement in the model. In the simulations performed in this paper, land suitability affects crop yields but increasing demand for land caused by continuing urbanization (e.g. in India an estimated 78 percent of the total population is expected to live in urban areas by 2050) is not

modeled but could well become a significant limitation to agricultural production for South Asia in the coming decades. The same may hold regarding the effects of rising sea levels on land availability.

Third and in terms of capital accumulation, the modeling framework adopted in this paper does not account for foreign direct investment (FDI) or new flows of public aid. This implies that all investments have to be financed out of domestic savings. As a result in the model India, being the largest economy with the highest income growth, has the largest capacity to invest and adapt to climate change (by reallocating investment across sectors). Accounting for foreign flows of capital (public and private) in the model would increase the adaptive capacity of the smaller economies in the region.

Fourth, the dynamic setting embodied in the modeling framework employed in this paper has only two types of irreversibility: investments decisions in terms of human capital and physical capital. Since only the latter is a sunk cost and sector specific, it is the only source of irreversibility and leads to potential path-dependent effects. This in turn leads to the following question: do trade policies lead to long term costs if they have been erroneously adopted and to what extent do they drive specialization in domestic sectors that would be negatively affected by climate change? In general terms, the model displays “weak memory” towards the end of the simulation period (2050). This may partially explain the relatively limited variance in the results obtained under different trade policy baseline scenarios. In reality alternative trade policy scenarios may lead to more diverging results based on the following concepts: fixed sunk costs in trade (based on the growing literature on international trade on this issue); decisions regarding R&D investment and other related infrastructure; and political economy locking mechanisms (i.e. the notion that once support or protection is given to a sector, it may be virtually impossible to eliminate it at a later stage even if the sector’s comparative advantage improves).

Finally, the analytical framework in this paper based on a large number of simulations has generated valuable information, not only regarding average outcomes but also regarding the risk driven by climate change of different trade policy options. Adopting a risk analysis approach and assuming different levels of risk aversion among regional policy makers could provide guidance regarding the choice of an “optimal” strategy, taking simultaneous account of levels and variance of expected outcomes (as in a portfolio approach). The degree of hysteresis and

the sunk cost nature of some investments will be very important aspects in assessing the costs of ex-post modification of trade policy options once they have been chosen ex-ante.

7 References

Ali et al. 2008.

Al-Riffai, D. Laborde and B. Dimaranan. 2010. Global trade and environmental impact study of the EU biofuels mandate. IFPRI report for the EC.

Armington. 1969.

Bouet A. and E. Corong. 2009. Regional Trade Cooperation and Food Prices: An Assessment for South Asia. IFPRI report for the World Bank.

Climate Projection Data Download. 2009.

FAO. 2009.

Ganesh-Kumar A., D. Roy and A. Gulati. 2010. Liberalizing Foodgrains Markets: Experience, Impacts and Lessons from South Asia. Oxford University Press.

Harmonized World Soil Database 2009.

Hertel and Villoria. 2009.

Laborde D. 2010. ADEPTA: an Analytical Database for Economists on Protection and Trade. IFPRI mimeo.

MIRAGEwiki. 2010. http://www.mirage-model.eu/miragewiki/index.php?title=Accueil

Nagarajan, S. 2005. Can India produce enough wheat even by 2020? Current Science, Vol. 89, No. 9, 10 November 2005.

Narayanan. 2008.

Nelson, G., M. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, Z. Tinju, T. Sulser, C. Ringler, S. Msangi, and L. You. 2010. Food Security, Farming, and Climate Change to 2050. IFPRI monograph research.

Sage. 2009.

Villoria, N. 2009. The Role of Geography in Determining the Global Land Use Impacts of Biofuels. Purdue University mimeo.

8 Appendix

Table 19 Detailed real Income effects by country and scenarios. 10^9 constant USD (2004)

	BASE	SAFTA	SAFTAFULL	UNIAGR	UNIALL	UNISEN	FTA	MULTI
Bangladesh								
cnr_a1	-48.6	-48.6	-47.5	-46.8	-46.1	-46.9	-48.2	-47.7
cnr_a2	-51.5	-51.7	-50.6	-49.9	-49.1	-49.9	-51.3	-50.8
cnr_b1	-30.6	-30.9	-30.3	-29.8	-29.4	-29.8	-30.8	-30.6
csi_a1	-38.8	-39.2	-38.3	-37.6	-37	-37.7	-38.6	-38.4
csi_a2	-53.4	-54	-52.8	-52.2	-51.2	-51.7	-53.3	-53.4
csi_b1	-30.3	-30.9	-30.2	-29.4	-29.1	-29.7	-30.4	-30.4
ech_a1	-46	-46.2	-45.1	-44.5	-43.8	-44.5	-45.6	-45.2
ech_a2	-28.3	-28.6	-27.9	-27.4	-27	-27.5	-28.2	-28.2
ech_b1	-28.8	-29	-28.3	-27.8	-27.4	-27.9	-28.6	-28.5
mir_a1	-16.6	-16.8	-16.3	-16	-15.8	-16	-16.6	-16.4
mir_a2	-11.4	-11.7	-11.3	-11	-10.9	-11	-11.5	-11.3
mir_b1	-23.1	-23.4	-22.9	-22.4	-22	-22.4	-23.1	-22.8
India								
cnr_a1	-316.1	-315.9	-315.4	-330	-339.4	-328.6	-321.5	-325.6
cnr_a2	-290.2	-289.9	-289.3	-303.9	-312.9	-301.3	-295.5	-304.9
cnr_b1	-165.9	-165.4	-164.8	-180.2	-186.8	-173.2	-165	-171.1
csi_a1	67.5	68.3	70.4	55.2	50.1	65.6	73.8	73.2
csi_a2	63.8	65	67.5	44	41.1	66.8	67.4	57.5
csi_b1	147.3	148.4	150.4	132.6	132.4	146.5	156.5	149
ech_a1	-314.5	-314.1	-312.6	-324.9	-333	-324.3	-321	-322.9
ech_a2	34.6	35.3	37.1	21.5	16.6	32	41.6	36.3
ech_b1	173.8	174.7	176.9	162.3	157.6	173.6	185.4	182.9
mir_a1	225.2	225.9	227.5	215	211.4	224.1	246.8	246.9
mir_a2	280.2	281.1	282.7	271.3	267	279.1	304.5	308.8
mir_b1	250.8	251.7	252.9	241.8	238.5	250.7	271.4	272.5
Pakistan								
cnr_a1	-235	-235.9	-239.1	-238.8	-232.1	-236.2	-244.2	-245.3
cnr_a2	-201.1	-201.9	-204.9	-205	-199.1	-202.6	-208.6	-210.8
cnr_b1	-154.3	-155	-157.5	-158.4	-153.6	-156	-161.2	-162.1
csi_a1	-238.8	-239.9	-244.2	-243.3	-235.5	-240.4	-248.6	-248.9
csi_a2	-249.7	-250.8	-255.6	-255.6	-247	-251.6	-260.8	-261.3
csi_b1	-177.3	-178.2	-181.9	-184	-175.7	-179.3	-185.8	-185.4
ech_a1	-304.3	-305.6	-310.1	-309.1	-300	-305.7	-316.4	-316.4
ech_a2	-233.2	-234.3	-238.1	-237.1	-229.6	-234.3	-242.5	-243
ech_b1	-238.5	-239.7	-243.9	-242.2	-234.5	-239.8	-247.7	-248.1
mir_a1	-305.4	-307	-311.6	-310.1	-300	-305.9	-317.8	-316.9
mir_a2	-291.3	-292.8	-297.4	-295.9	-286.3	-292.1	-303.4	-302.1

mir_b1	-228.3	-229.7	-233.4	-232.2	-224.6	-229	-238.1	-236.9
Sri Lanka								
cnr_a1	-1.3	-1.2	-1.3	-1.8	-1.8	-1.3	-2.4	-2.5
cnr_a2	-1.7	-1.7	-1.8	-2.2	-2.2	-1.8	-2.7	-3
cnr_b1	-1.7	-1.7	-1.8	-2.2	-2.2	-1.8	-2.7	-2.9
csi_a1	-1.9	-1.9	-2.1	-2.3	-2.2	-2	-2.8	-3
csi_a2	-3.1	-3.1	-3.4	-3.5	-3.5	-3.3	-4.2	-4.3
csi_b1	-2.2	-2.3	-2.4	-2.5	-2.6	-2.4	-3.2	-3.4
ech_a1	-2.2	-2.1	-2.2	-2.5	-2.6	-2.2	-3	-3.4
ech_a2	-1.6	-1.5	-1.7	-1.9	-1.9	-1.6	-2.4	-2.7
ech_b1	-1.3	-1.3	-1.5	-1.6	-1.6	-1.4	-2	-2.3
mir_a1	-2	-2	-2.5	-2.8	-2.8	-2.4	-3.3	-3.5
mir_a2	-1.8	-1.8	-2.2	-2.7	-2.6	-2.1	-3.4	-3.4
mir_b1	-1.4	-1.4	-1.8	-2.1	-2.1	-1.7	-2.7	-2.8
Rest of South Asia								
cnr_a1	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-4.8	-4.8
cnr_a2	-3	-2.9	-2.9	-2.9	-3	-2.9	-3.9	-3.9
cnr_b1	-1.3	-1.3	-1.2	-1.3	-1.3	-1.2	-2	-2
csi_a1	-5.2	-5.3	-5.4	-5.3	-5.2	-5.2	-6.7	-6.5
csi_a2	-4.4	-4.5	-4.5	-4.6	-4.5	-4.4	-5.7	-5.6
csi_b1	-1.4	-1.4	-1.3	-1.5	-1.5	-1.3	-2.3	-2.3
ech_a1	-5.5	-5.6	-5.6	-5.7	-5.6	-5.5	-6.8	-6.6
ech_a2	-4.6	-4.7	-4.7	-4.7	-4.6	-4.6	-5.8	-5.8
ech_b1	-4.2	-4.3	-4.4	-4.3	-4.2	-4.2	-5.4	-5.2
mir_a1	-2	-2.1	-1.9	-2	-1.9	-1.8	-2.2	-2.3
mir_a2	-1.6	-1.7	-1.5	-1.6	-1.5	-1.4	-1.9	-1.9
mir_b1	-3.7	-3.8	-3.8	-3.8	-3.7	-3.6	-4.6	-4.5