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EXPLORING FOOD PRICE SCENARIOS TOWARDS 2030 WITH A GLOBAL MULTI-REGION MODEL

Dirk Willenbockel

Institute of Development Studies at the University of Sussex, UK

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1 BACKGROUND AND TERMS OF REFERENCE

This report is a contribution to the Oxfam report: 'Growing a Better Future'. It explores a range of scenarios for food price increases to 2030 through the GLOBE model. Over and above providing a global perspective, the research provides disaggregated results for a range of countries and country groups identified by Oxfam.

The scenarios of interest to Oxfam include

- Business-as-usual scenarios for 2020 and 2030 under current growth and productivity projections. The focus is on predicted price increases for the major traded agricultural food commodities (rice, wheat and maize) in sub-Saharan Africa (disaggregated by region), Central America, North Africa, and other low-income countries and regions selected by Oxfam; on the domestic supply responses in these regions; on international trade in agricultural commodities; and on food consumption per capita.
- Scenarios of climate change impacts on agricultural productivity by crop and its consequences for food production and prices in sub-Saharan African regions and other developing countries;
- Alternative scenarios in which national agricultural productivity rises above predicted trend levels;
- For regions in sub-Saharan Africa, a scenario in which anticipated climate change impacts on yields are negated or reduced through adaptation and wider measures.

In addition, looking at the baseline net trade positions by food commodity and shares of imports in domestic absorption using a finer country disaggregation level, the Appendix analyzes developing countries' present exposure to world crop price surges using the full geographical disaggregation of the GTAP 7.1 database.

This report is intended to contribute to the case for more effective international responses to the food security threats posed by rising food prices.

2 THE MODEL AND DATABASE

The GLOBE model is in the tradition of multi-country, trade-focused, computable general equilibrium (CGE) models developed to analyse the impact of global trade negotiations and regional trade agreements.[1] The dynamized version of GLOBE used in the present study is based at the Institute of Development Studies (IDS) at the University of Sussex. The model consists of a set of individual country or region models that provide complete coverage of the global economy and are linked through international trade in a multi-region model system. It solves the *within*-country models and *between*-country trade relationships simultaneously. The country models simulate the operation of factor and commodity markets, solving for wages, land rent, profits, and commodity prices that achieve supply–demand balance in all markets. Each country engages in international trade, supplying exports and demanding imports. The model determines world prices that achieve supply–demand balance in all global commodity markets, simulating the operation of world markets.

Multi-country CGE models like GLOBE represent the whole economy including the agricultural sector. Their strength is that they include the value chain from crops, processing and distribution, and finally to demand for food by households. They also incorporate links between agricultural and non-agricultural sectors, and the links between production, factor payments, and household income. Multi-country CGE models are well suited to analysis of policies or scenarios that will change the volume and structure of production, demand, and international trade, and the allocation of factors of production throughout the economy.

The model is initially calibrated to the GTAP 7.1 database (the most recent update of Narayanan and Walmsley, eds., 2008) that combines detailed bilateral trade, and protection data reflecting economic linkages among regions with individual country input–output data (which account for intersectoral linkages within regions) for the benchmark year 2004. For the present study, we use a 19-region, 12-sector/commodity group aggregation of the GTAP database. Table 1 shows the regional disaggregation of the model. The model distinguishes eight food commodity groups: Wheat, Maize/Other Coarse Grains (Maize), Paddy rice (PadRice), Processed rice (PrcRice), Other crops (OCrops), Livestock products, Processed meat products (MeatPrd) and Other processed food (OPrcFood)), as well as four non-food sectors: Extraction, Non-food Manufacturing, Trade and Transport Services, Other Services.

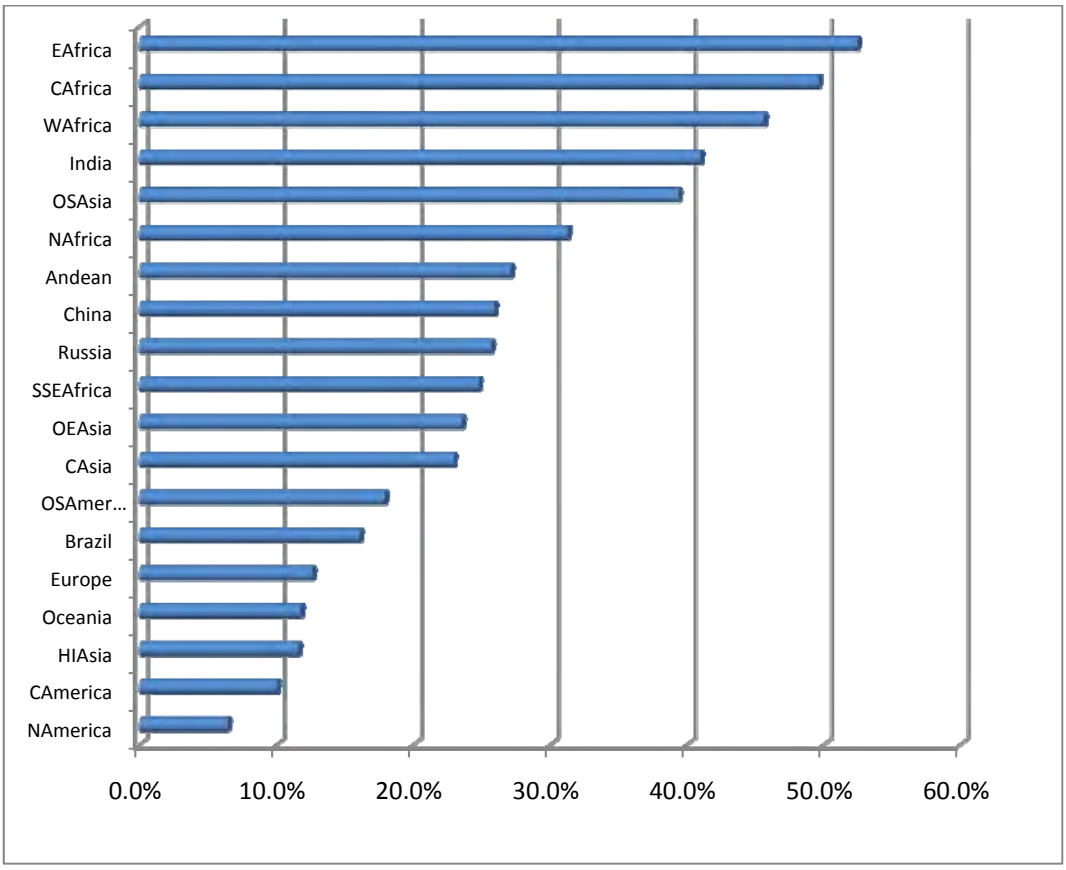
Figure 1 and Tables 2 and 3 show selected relevant initial 2004 baseline share figures by region, including the share of food in total household expenditure, the shares of the various food commodities in total household food expenditure, and the share of imports in domestic (intermediate and final) demand for commodities.

[1] McDonald *et a*l. (2007)

Table 1: Geographical aggregation of the model

Code	Region	Notes
Europe	Europe	including Ukraine, Belarus
Russia	Russian Federation	
NAmerica	North America	USA, Canada
Oceania	Oceania	Australia, New Zealand, rest of Oceania
HIAsia	High-Income Asia	Japan, Hong Kong, Singapore, South Korea, Taiwan
China	China	
OEAsia	Other East + South-East Asia	Cambodia, Indonesia, Lao, Malaysia, Philippines, Thailand, Vietnam, Rest of East + South East Asia
India	India	
OSAsia	Other South Asia	Bangladesh, Pakistan, Sri Lanka, rest of South Asia
CAsia	Central Asia + Middle-East	Kazakhstan, Kyrgyztan, Azerbaijan, Armenia, Georgia, rest of FSU, Turkey, Iran, rest of western Asia
Andean	Andean South America	Bolivia, Colombia, Ecuador, Peru
Brazil	Brazil	
OSAmerica	Other South America	Argentina, Chile, Venezuela, Uruguay, Paraguay, rest of South America
CAmerica	Central America + Caribbean	Costa Rica, Guatemala, Nicaragua, rest of Central America, Caribbean, Mexico
NAfrica	North Africa	Egypt, Morocco, Tunisia, rest of North Africa
WAfrica	West Africa	Nigeria, Senegal, rest of western Africa
CAfrica	Central Africa	Cameroon, CAR, Chad, Congo, Equatorial Guinea, Gabon, Angola, DR Congo
EAfrica	East Africa	Ethiopia, Tanzania, Uganda, rest of eastern Africa
SSEAfrica	South + South-East Africa	South Africa, Botswana, rest of SACU, Malawi, Mozambique, Zambia, Zimbabwe

Figure 1: Baseline shares of food consumption in total household expenditure



Source: GTAP 7.1 Database.

Table 2: Initial baseline commodity shares in household food consumption expenditure *(percentages %)*

	PadRice	Wheat	Maize	OCrops	Livestock	MeatPrd	PrcRice	OPrcFood	Total
Europe	0.0	1.0	0.3	9.8	1.8	14.9	0.3	71.9	100
Russia	0.0	1.6	0.4	12.8	15.1	27.0	0.1	43.0	100
NAmerica	0.0	0.0	0.1	8.1	2.9	18.1	0.3	70.6	100
Oceania	0.0	0.0	0.1	9.5	1.4	11.7	0.7	76.7	100
HIAsia	0.0	0.0	0.1	11.0	1.9	8.1	6.1	72.8	100
China	0.0	0.0	0.2	19.0	16.2	8.4	4.4	51.8	100
OEAsia	0.3	0.1	1.1	16.3	7.3	9.3	14.7	50.9	100
India	3.0	8.2	2.8	29.9	8.3	0.4	12.5	34.8	100
OSAsia	0.1	0.0	0.1	17.0	30.4	1.0	19.0	32.4	100
CAsia	0.7	1.9	3.6	14.9	8.0	28.9	1.6	40.4	100
Andean	0.0	0.8	2.2	17.3	5.1	19.3	5.3	50.1	100
Brazil	0.0	0.1	0.1	5.9	2.8	19.3	2.8	69.1	100
OSAmerica	0.0	0.4	1.3	7.2	6.3	16.2	0.3	68.2	100
CAmerica	0.1	0.5	4.0	19.2	7.7	10.4	2.9	55.3	100
NAfrica	0.6	13.0	4.3	22.9	4.4	11.6	1.8	41.4	100
WAfrica	3.1	1.8	7.2	47.2	6.9	4.0	7.5	22.2	100
CAfrica	0.2	0.3	12.3	18.9	3.2	11.0	2.6	51.5	100
EAfrica	0.3	1.1	11.9	26.1	7.5	6.2	3.5	43.3	100
SSEAfrica	0.1	0.2	3.6	9.0	6.2	14.8	1.0	65.1	100

Source: Author calculations based on GTAP 7.1 Database.

Note that direct household consumption of paddy rice is negligible except in India and West Africa. Paddy rice serves as intermediate input in the production of processed rice. Similarly, to a large extent the other agricultural outputs – wheat, maize, other crops and livestock – enter household consumption indirectly via their use as input in processed food products (which include flour, bread and others). The model explicitly captures the input–output structure of food production and the associated linkage between the prices of agricultural raw outputs and processed food.

Table 3: Initial shares of imports in total domestic demand for food commodities (percentages %)

	PadRice	Wheat	Maize	OCrops	Livestock	MeatPrd	PrcRice	OPrcFood
China	0.0	17.4	3.6	9.6	3.5	3.0	1.3	5.2
OEAsia	0.2	88.3	13.1	19.0	4.7	9.2	5.5	21.8
India	0.0	0.0	0.1	2.3	1.2	2.6	0.0	8.5
OSAsia	0.2	23.1	34.4	14.2	0.5	15.7	4.2	17.4
CAsia	9.6	28.2	40.0	20.2	6.5	9.1	80.5	34.9
Andean	0.2	44.6	29.4	7.0	0.7	1.5	3.2	9.5
Brazil	3.9	75.6	3.0	3.9	0.6	0.9	10.0	3.3
OSAmerica	0.5	19.3	11.2	8.9	2.9	8.3	14.7	11.8
CAmerica	30.2	74.1	15.9	16.6	2.3	21.3	29.3	9.7
NAfrica	0.4	32.3	33.6	10.1	3.9	8.6	6.2	23.5
WAfrica	16.7	98.4	1.1	4.3	2.3	30.7	72.6	63.2
CAfrica	9.3	42.4	1.1	2.9	2.4	24.7	57.5	23.7
EAfrica	1.8	58.1	3.4	4.6	1.1	5.5	29.7	17.1
SSEAfrica	17.3	58.3	13.4	14.3	3.7	6.8	85.2	13.0

Note: Import shares include intra-regional imports for composite regions.

3 BASELINE SCENARIO PROJECTIONS TO 2020 AND 2030

This section presents key results from the dynamic simulation of a 'business-as-usual' scenario in the absence of climate change and policy shifts, based on existing projections for growth in population and labour force, technical progress (i.e. factor productivity growth), capital accumulation, and land use.

3.1 Assumptions

Population and labour force growth by region is based on the UNESA (2009) global medium-variant projections and is consistent with the corresponding baseline assumptions underlying the studies by the World Bank (2010) 'Economics of Adaptation to Climate Change' and the UK Government Office for Science (2011) 'Future of Food and Farming'. As shown in Table 4, the global population is projected to rise to 7.7 billion by 2020 and to 8.3 billion by 2030.

The assumptions about agricultural productivity growth by country and crop type (Table 6) are based on a synopsis of the corresponding projections in Jaggard, Qi and Ober (2010), Nelson *et al.* (2010), and the UN 'Millennium Ecosystem Assessment' (Alcamo *et al.*, 2005). Changes in agricultural land use are based on a synopsis of projections in Smith *et al.* (2010), Nelson *et al.* (2010) and Alcamo *et al*. (2010).

Growth rates of technical progress for industry and services are calibrated residually, such that the growth rates of real gross domestic product (GDP) by region are approximately equal to the baseline growth projections (Table 5) used in World Bank (2010) and Nelson *et al*. (2010).

Table 4: Population growth

	Population (millions)				Population growth per annum (%)		
	2005	**2010**	**2020**	**2030**	**2004–10**	**2011–20**	**2021–30**
Europe	595.5	598.4	597.7	590.8	0.10	-0.01	-0.12
Russia	144.0	140.3	132.4	123.9	-0.51	-0.58	-0.66
NAmerica	332.2	348.5	379.2	405.4	0.96	0.85	0.67
Oceania	33.2	35.2	39.2	42.9	1.21	1.07	0.91
HIAsia	235.1	239.8	244.6	243.8	0.39	0.20	-0.03
China	1313.0	1351.5	1421.3	1458.4	0.58	0.50	0.26
OEAsia	576.6	613.2	678.0	730.3	1.24	1.01	0.75
India	1134.4	1220.2	1379.2	1505.7	1.47	1.23	0.88
OSAsia	383.6	420.9	499.9	574.7	1.87	1.74	1.40
CAsia	309.8	335.7	389.0	434.2	1.62	1.48	1.10
Andean	94.5	100.6	112.8	122.9	1.26	1.15	0.86
Brazil	186.8	199.0	220.0	236.5	1.27	1.01	0.73
OSAmerica	92.2	97.9	108.7	117.7	1.22	1.05	0.79
CAmerica	183.5	195.1	216.9	234.6	1.24	1.06	0.79
NAfrica	152.2	164.5	188.8	209.0	1.57	1.38	1.02
WAfrica	292.2	329.2	408.8	491.4	2.41	2.19	1.86
CAfrica	93.3	108.4	143.9	186.1	3.05	2.88	2.60
EAfrica	271.1	309.3	393.4	480.8	2.67	2.43	2.03
SSEAfrica	113.3	120.6	135.7	151.0	1.27	1.18	1.07
Total	**6536.2**	**6928.4**	**7689.4**	**8340.0**	**1.17**	**1.05**	**0.82**

Source: Aggregations of UN 'Medium Population Growth Projections by Country'.

Table 5: Assumed baseline GDP growth rates and agricultural land area growth
(percentages %)

	Baseline GDP growth per annum			Agric land area growth	
	2004–10	**2011–20**	**2021–30**	**Per annum**	**2010–30**
Europe	3.2	2.8	2.7	0.00	0.0
Russia	5.4	4.6	4.1	0.03	0.6
NAmerica	2.9	2.8	2.8	0.00	0.0
Oceania	3.4	3.0	2.7	0.00	0.0
HIAsia	2.9	2.4	2.3	0.00	0.0
China	7.7	6.1	5.2	0.15	3.0
OEAsia	5.1	4.3	4.0	0.15	3.0
India	6.3	5.6	4.9	0.18	3.7
OSAsia	5.1	4.7	4.3	0.18	3.7
CAsia	4.3	4.2	4.0	0.38	7.9
Andean	4.4	4.2	3.9	0.60	12.7
Brazil	4.1	3.9	3.8	0.70	15.0
OSAmerica	4.4	4.1	3.9	0.80	17.3
CAmerica	3.5	3.6	3.5	0.70	15.0
NAfrica	4.4	4.1	3.7	0.38	7.9
WAfrica	4.5	4.2	3.8	0.91	19.9
CAfrica	5.1	5.0	4.7	0.91	19.9
EAfrica	4.6	4.4	3.9	0.91	19.9
SSEAfrica	3.1	3.0	2.8	0.91	19.8

Table 6: Assumed baseline factor productivity growth in agriculture

	Productivity growth per annum (%)			
	Wheat	**Rice**	**Maize**	**Other Crops**
Europe	1.05	0.76	0.79	1.10
Russia	1.12	1.2	0.88	1.18
NAmerica	0.95	0.82	0.75	1.00
Oceania	1.01	0.78	0.88	1.06
HIAsia	1.05	0.8	0.8	1.10
China	1.26	0.95	1.14	1.32
OEAsia	1.26	0.95	1.14	1.32
India	1.39	0.9	1.11	1.46
OSAsia	1.39	0.9	1.11	1.46
CAsia	1.11	0.9	0.98	1.17
Andean	1.24	1.02	1.2	1.30
Brazil	1.28	1.08	1.18	1.34
OSAmerica	1.24	1.02	1.2	1.30
CAmerica	1.24	1.02	1.2	1.30
NAfrica	1.11	0.9	0.98	1.17
WAfrica	1.5	1.1	1.4	1.58
CAfrica	1.63	0.94	1.46	1.71
EAfrica	1.63	0.94	1.46	1.71
SSEAfrica	1.55	0.97	1.49	1.63

3.2 Baseline simulation results

Food prices

Figure 2 shows the evolution of aggregate global world market price indices for food commodities projected by the model. Compared to 2010, the average world market export price for wheat rises by 28 percent towards 2020 and by 75 percent towards 2030. The average world market price of processed rice rises by 31 percent towards 2020 and by 73 percent towards 2030, relative to 2010. The corresponding figures for maize are 33 percent and 89 percent respectively. The price index of processed food other than rice and meat is projected to rise by around 20 percent between 2010 and 2030.

Table 7 shows the changes in domestic market prices of wheat, maize and rice between 2010 and 2030. For each commodity group, the reported price changes refer to price indices over domestically produced and imported varieties from all regions of origin.

The strong rises in prices for agricultural commodities are associated with pronounced increases in land rents relative to wages and capital returns across all regions and entail marked shifts in the distribution of income in favour of land owners.

Driving the strong crop price increases projected by the model is the combination of population growth, physical limitations to the further expansion of agricultural land (which means that land becomes increasingly scarce), and the assumption (based on past evidence) that agricultural factor productivity growth remains lower than factor productivity growth in industry.

The model also captures the fact that with rising per capita income in emerging economies, the demand for meat products rises more than the demand for staple crops. This entails more intense competition between land use for livestock production and crop production, and contributes to the upward pressure on land rents and crop prices.

It should be emphasized that the model does not capture potential increases in agricultural productivity that are likely to result from increased research and development efforts incentivized by the price increases for agricultural output.

Figure 2: Index of world market export prices for food commodities
(2010 = 1.00)

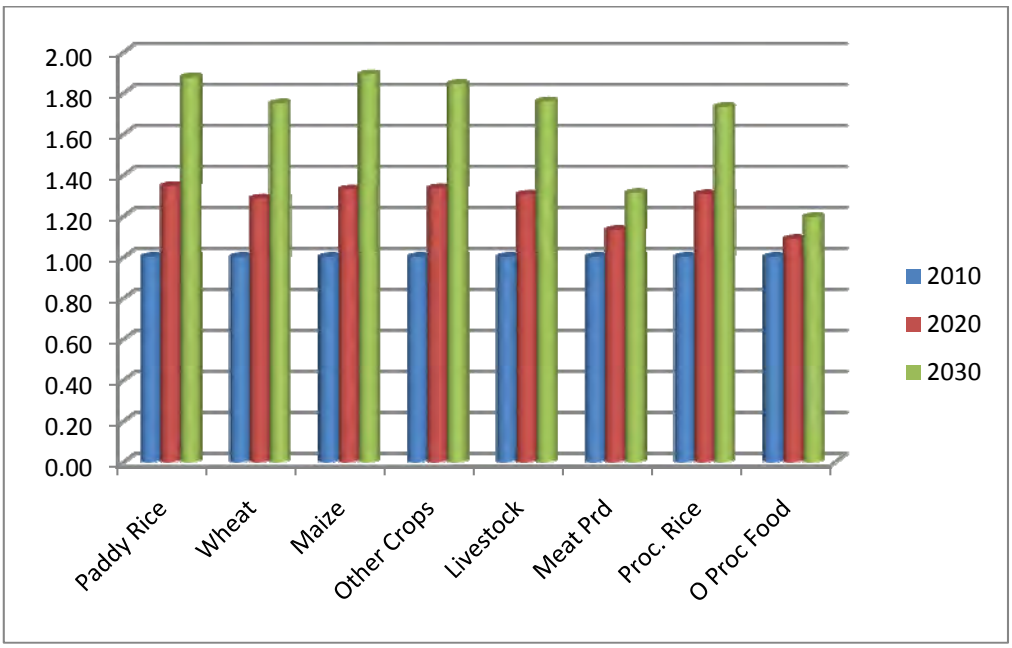


Table 7: Change in domestic user price of rice, wheat and maize
(Change relative to 2010, percentages %)

	Paddy rice		Wheat		Maize		Processed rice	
	2020	**2030**	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Europe	27.4	67.0	17.3	44.1	22.2	58.0	8.4	20.0
Russia	42.7	93.3	41.4	87.0	39.2	83.2	24.2	50.0
NAmerica	40.4	121.8	11.7	44.2	31.3	92.5	0.7	1.5
Oceania	32.2	92.0	34.3	108.5	24.4	74.3	0.8	2.1
HIAsia	17.0	41.8	13.5	43.7	23.0	70.1	12.9	31.6
China	81.6	174.0	44.1	87.0	71.3	154.0	56.8	121.1
OEAsia	48.2	115.2	23.1	62.6	49.6	119.9	38.3	90.8
India	48.7	97.8	26.7	52.2	43.7	89.5	9.0	22.0
OSAsia	32.0	65.5	24.5	50.5	36.6	79.7	16.0	33.3
CAsia	23.0	57.2	19.5	50.2	20.5	52.5	11.2	24.4
Andean	24.3	56.9	24.1	60.2	26.4	65.0	11.6	27.7
Brazil	26.3	70.7	25.6	65.2	26.3	70.8	11.0	29.9
OSAmerica	27.8	70.1	24.2	62.5	28.2	73.0	17.3	44.0
CAmerica	23.2	60.3	16.6	47.4	27.9	73.7	11.2	27.8
NAfrica	17.4	39.6	14.4	33.8	18.7	45.4	13.9	31.6
WAfrica	13.6	34.1	13.5	38.2	15.9	40.2	11.9	24.3
CAfrica	19.8	43.8	16.9	38.3	19.8	45.2	9.0	18.4
EAfrica	9.2	23.2	12.0	27.1	12.1	29.3	8.8	20.6
SSEAfrica	14.9	45.2	8.6	23.1	11.7	34.2	17.5	39.4

Supply responses

Figures 3 to 5 display projected production volumes for wheat, maize/other coarse grains and paddy rice for 2010, 2020 and 2030 by developing regions in Asia, Latin America and Africa under baseline assumptions. Despite the conservative assumptions about future agricultural productivity growth and the explicit recognition of constraints to the further expansion of agricultural land, the projections show generally substantial increases in absolute production quantities, with the exception of wheat production in China and Brazil. The strong rise in crop prices relative to non-agricultural goods raises the profitability of agriculture relative to manufacturing and services and provides the economic incentive for the expansion of agricultural production.

However, the decisive question is to what extent the increases in absolute production quantities will keep up with population growth. Therefore, Figures 6 and 7 show the evolution of production volumes per capita in Africa and the developing regions of Asia. In most cases, the model projects moderate to significant increases in per capita production. But there are noteworthy exceptions. Per capita production of maize/other coarse grains drops in Central Africa and India, and stagnates in East Africa and western Africa. Per capita production of rice declines in South Asia and that of wheat declines in China.

Overall, and in line with previous global long-run food system scenarios,[2] the baseline scenario is certainly not a pure Malthusian doom-and-gloom scenario. However, it has to be borne in mind that this scenario deliberately excludes climate change impacts on agricultural yields.

[2] See Reilly and Willenbockel (2010) and Willenbockel (2009) for recent reviews.

Figure 3: Production volume of wheat, 2010 to 2030

(Values of domestic production by developing region in constant 2004 prices, US$ billions)

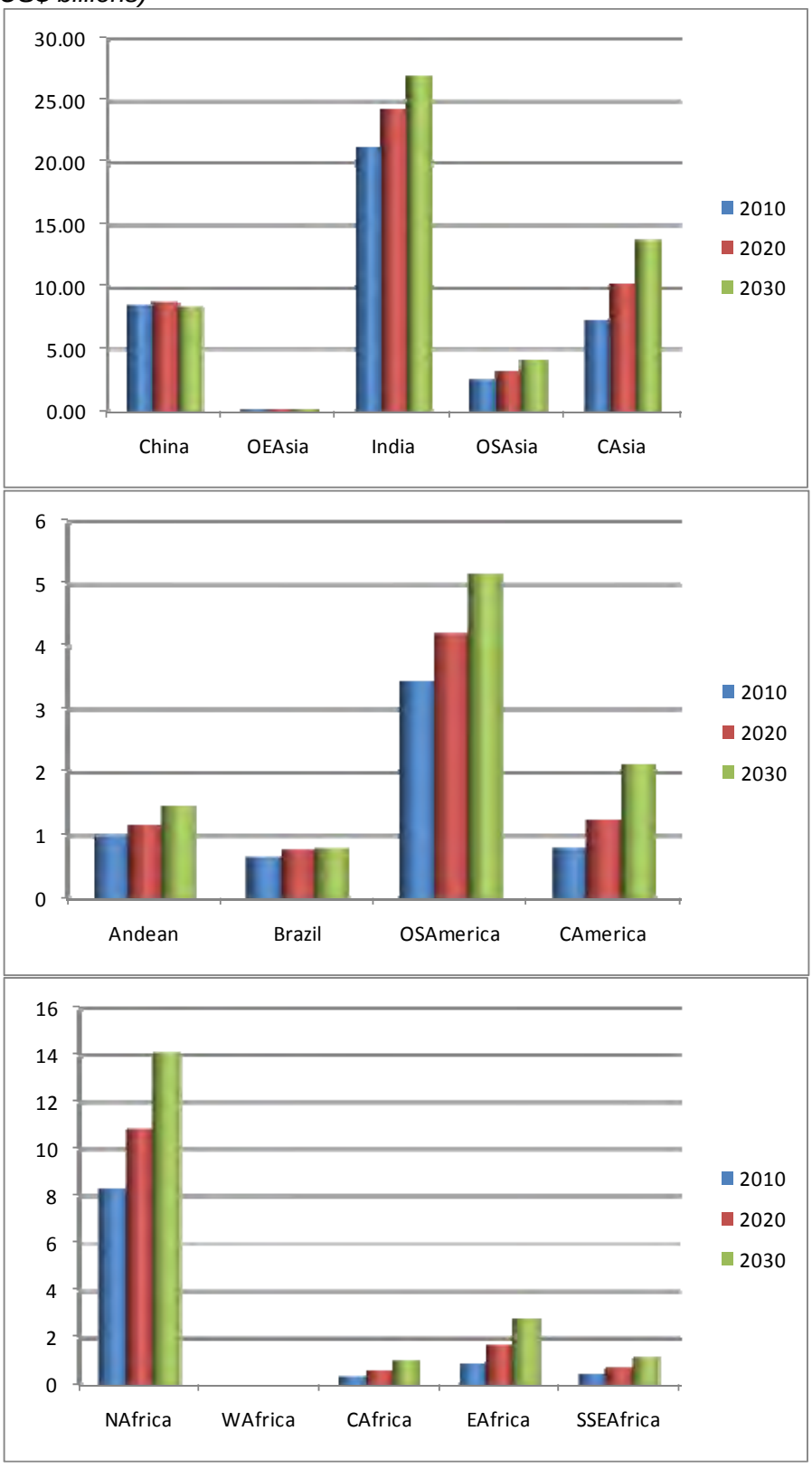
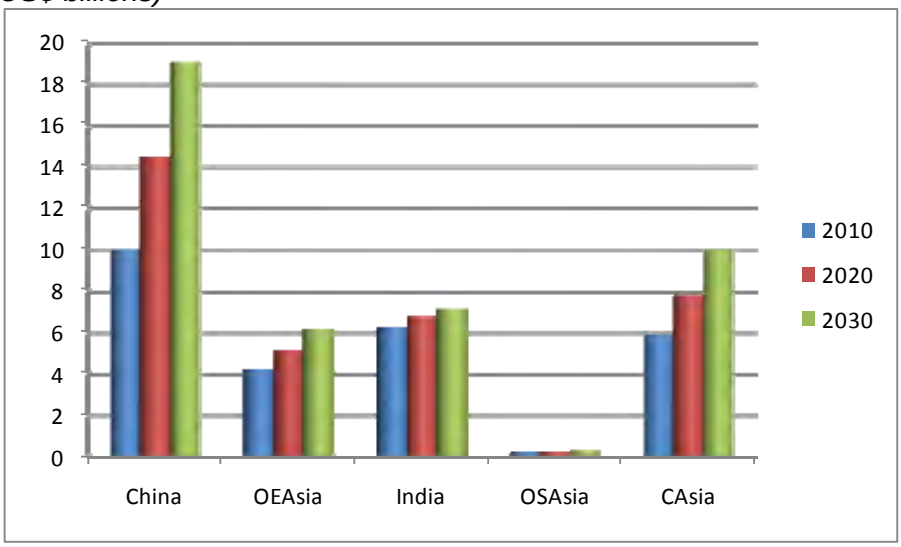
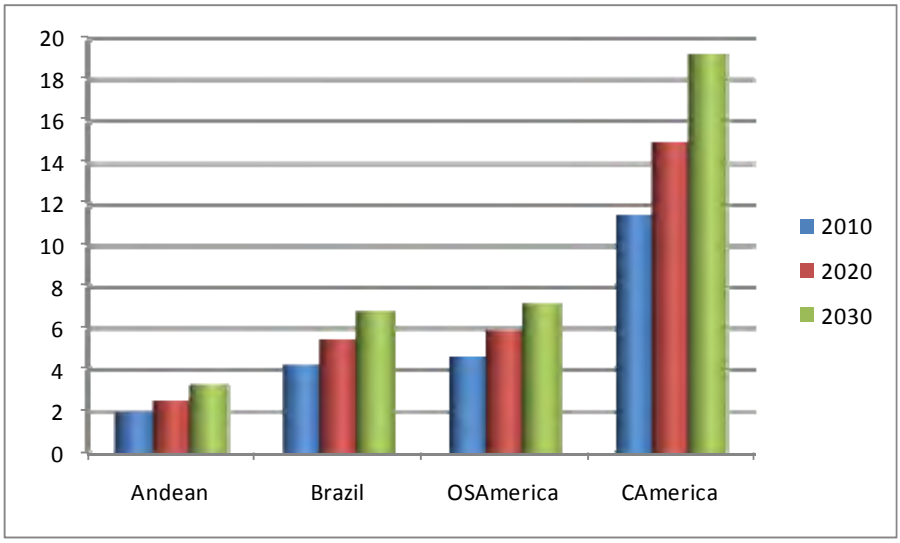


Figure 4: Production volume of maize and other coarse grains 2010 to 2030
(Values of domestic production by developing region in constant 2004 prices, US$ billions)





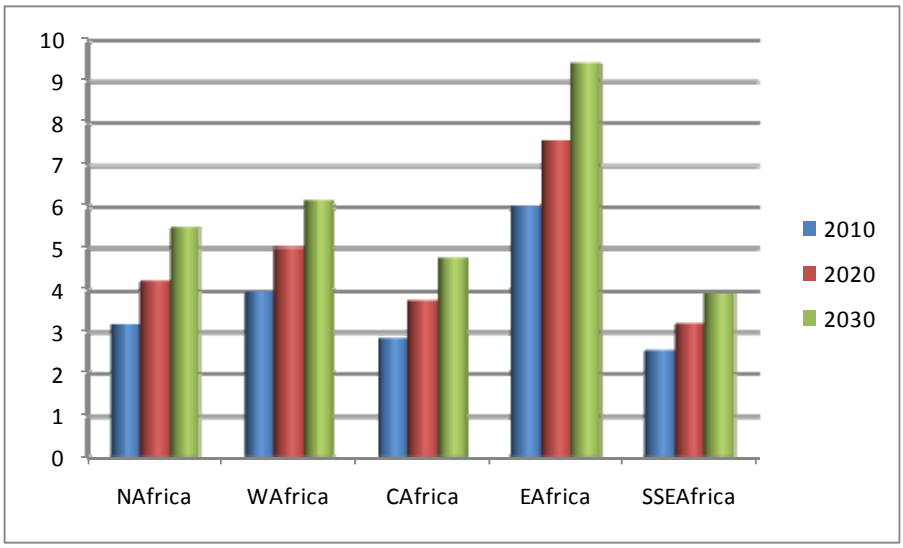
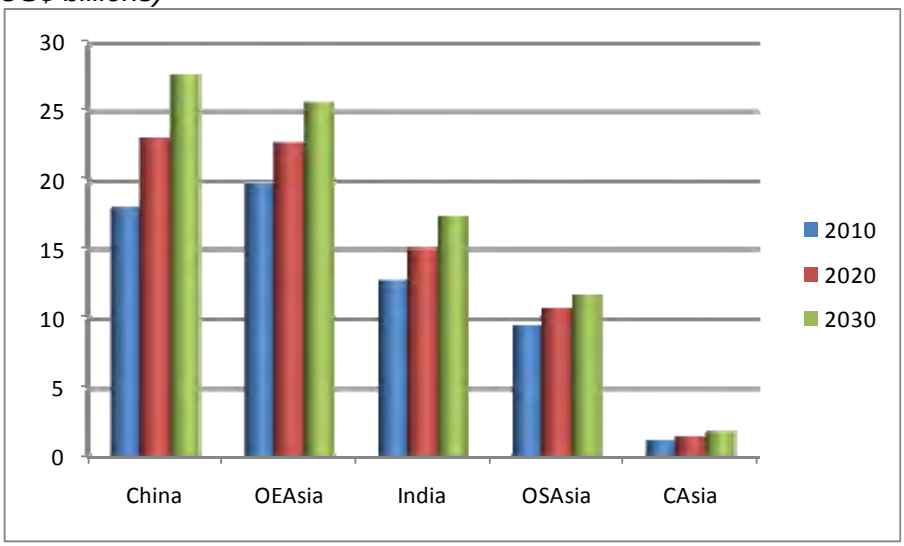
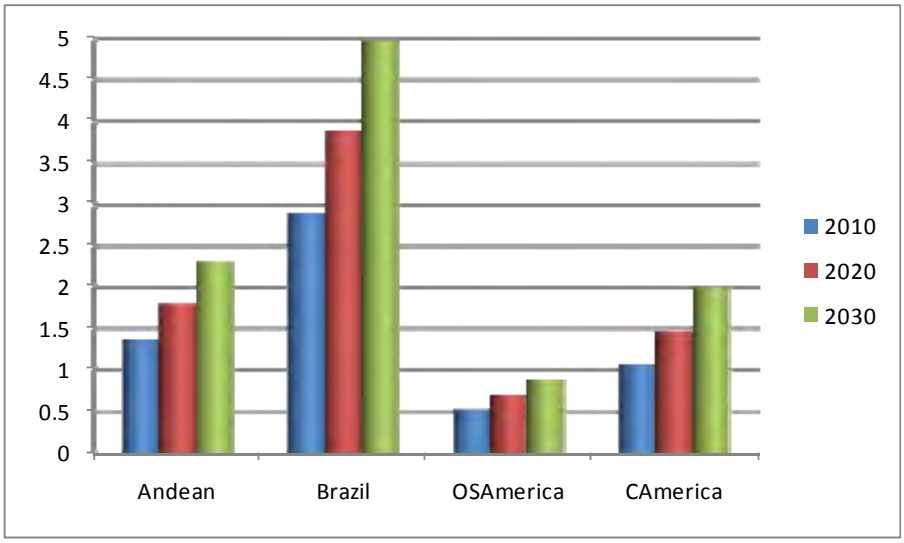


Figure 5: Production volume of paddy rice 2010 to 2030
(Values of domestic production by developing region in constant 2004 prices, US$ billions)





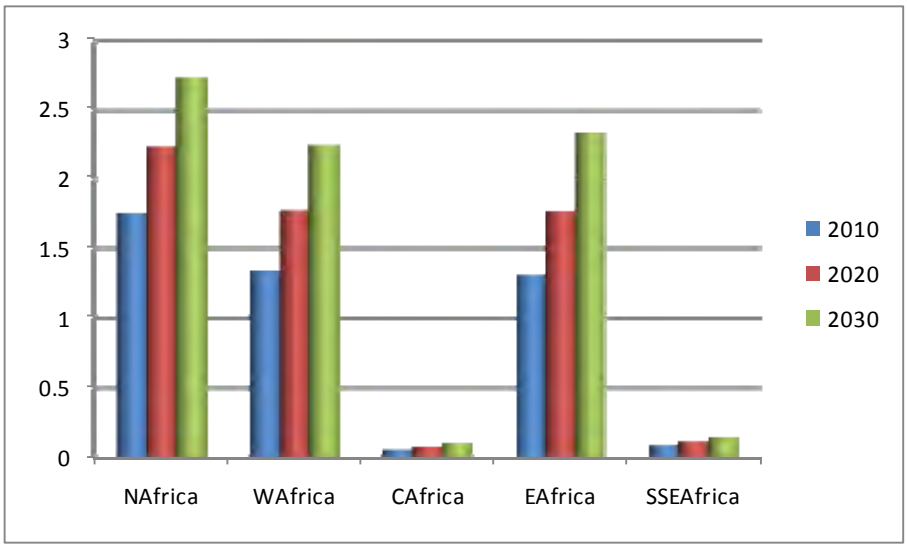
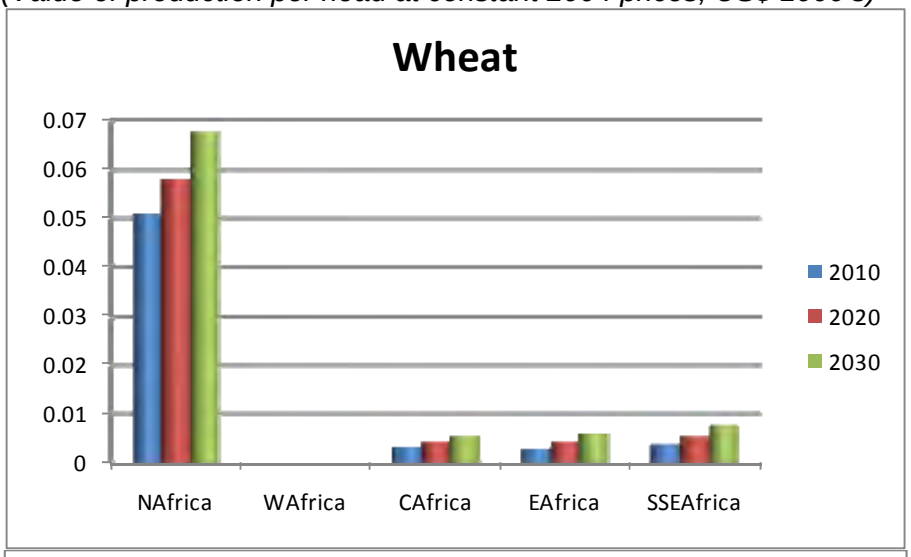
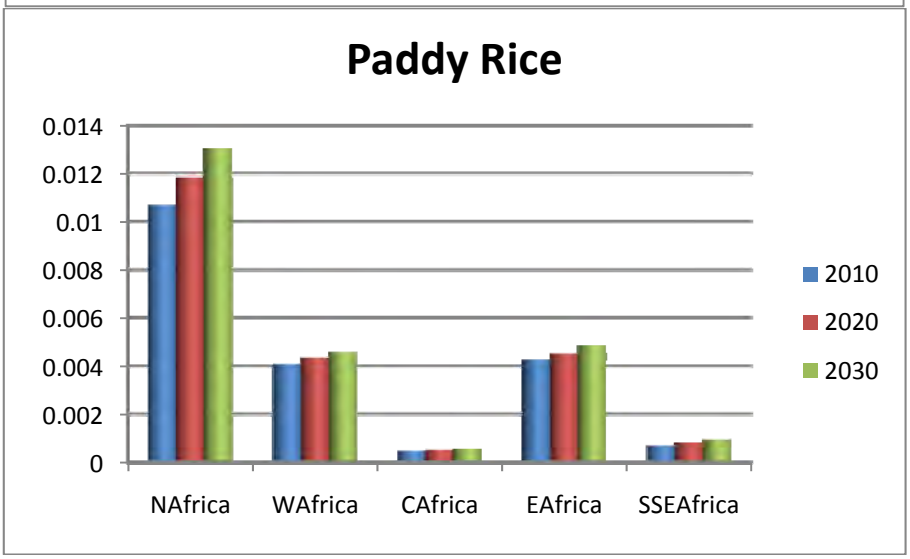


Figure 6: Production volumes per capita in Africa 2010 to 2030
(Value of production per head at constant 2004 prices, US$ 1000's)





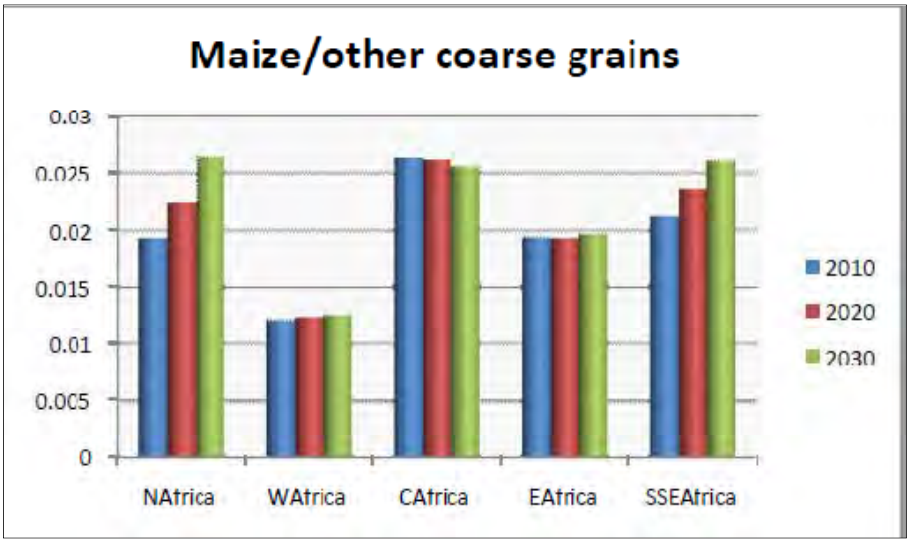
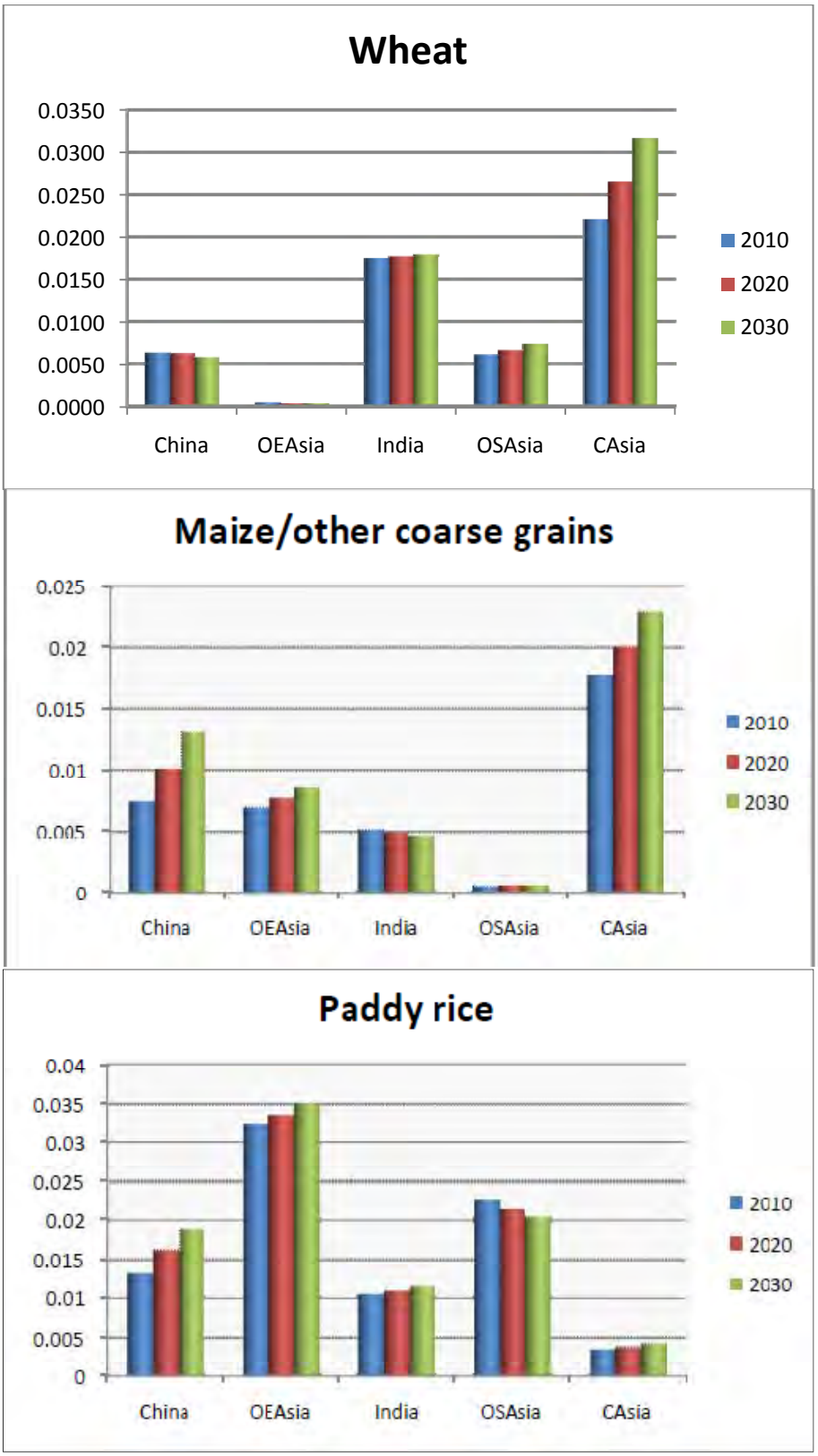


Figure 7: Production volumes per capita in developing Asia 2010 to 2030
(Value of production per capita at constant 2004 prices, US$ 1000's)



International trade in agricultural commodities and processed food

Figures 8 and 9 show both the relative importance of the various food commodity groups in global food trade and the projected growth in the volumes (i.e. quantities at constant prices) of global trade. In Figure 8, rice includes both paddy[3] and processed rice. Global trade in both food crops and processed food is projected to expand strongly between 2010 and 2030.

Figures 10 to 12 display the geographical pattern of global trade in wheat, maize and grain and the projected evolution of trade volumes by origin and destination under the baseline assumptions.

Figure 8: Volume of global trade in food crops 2010, 2020 and 2030
(US$ billions at constant 2004 market prices)

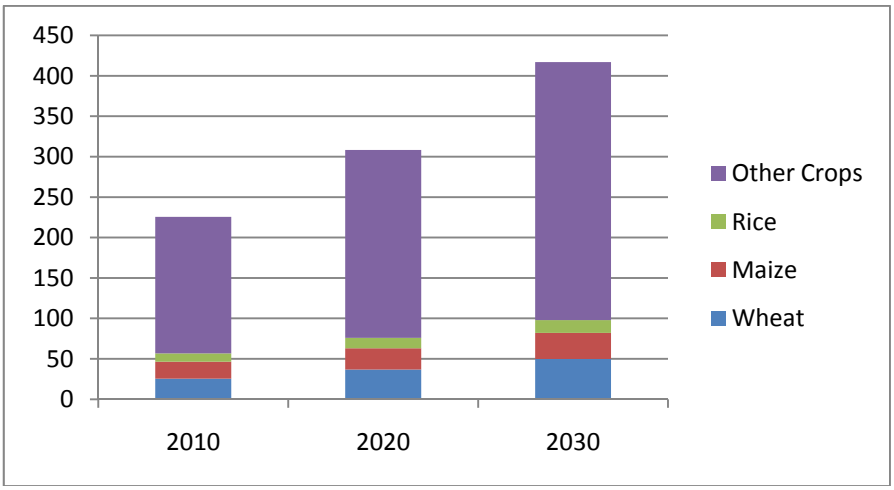
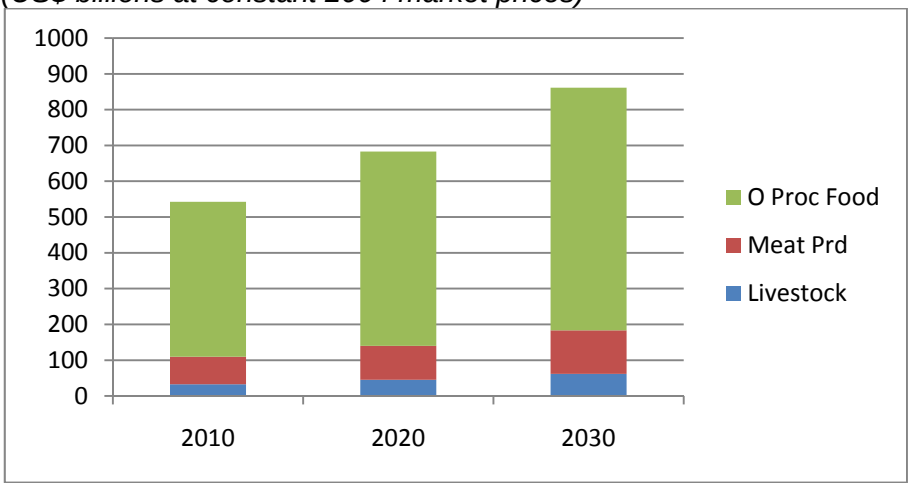


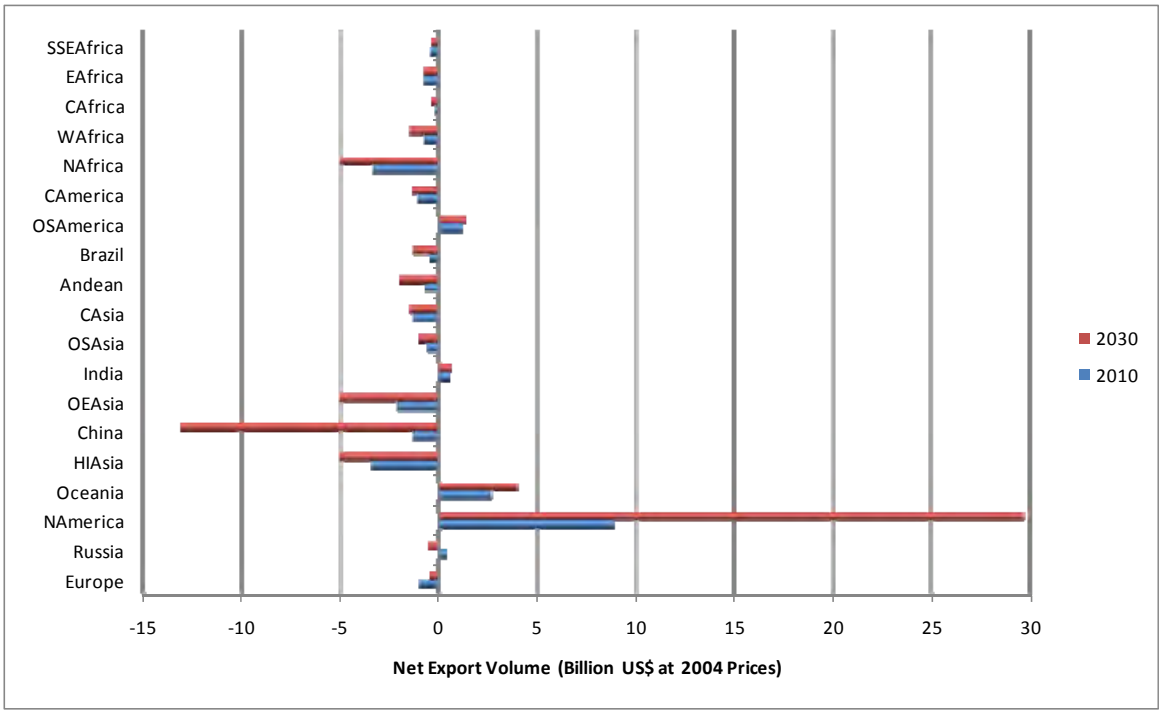
Figure 9: Volume of global trade in livestock and processed food 2010, 2020 and 2030
(US$ billions at constant 2004 market prices)



Note: Trade quantities valued at constant 2004 US$ world market prices

[3] There is little international trade in paddy rice, so rice trade in Figure 3 is overwhelmingly trade in processed rice.

Figure 10: Net export volume of wheat 2010 and 2030
(US$ billions at constant 2004 market prices)



Note: Net exports are exports minus imports

Figure 10 shows net export quantities – that is, exports minus imports valued at constant prices – of wheat in 2010 and 2030. North America is, and will remain, by far the largest wheat exporter and its wheat exports expand strongly between 2010 and 2030 in the baseline simulation. Oceania and Other South America also raise their wheat exports. All African and Asian regions except India, and Europe, are net importers of wheat. Between 2010 and 2030, China's wheat import volume overtakes the import volumes of North Africa and high-income Asia. Russia turns from a wheat exporter to a wheat importer between 2010 and 2030. Wheat imports to sub-Saharan Africa also expand, but the quantities remain small from a global perspective.

Figure 11: Net export volume of maize 2010 and 2030
(US$ billion at constant 2004 market prices)

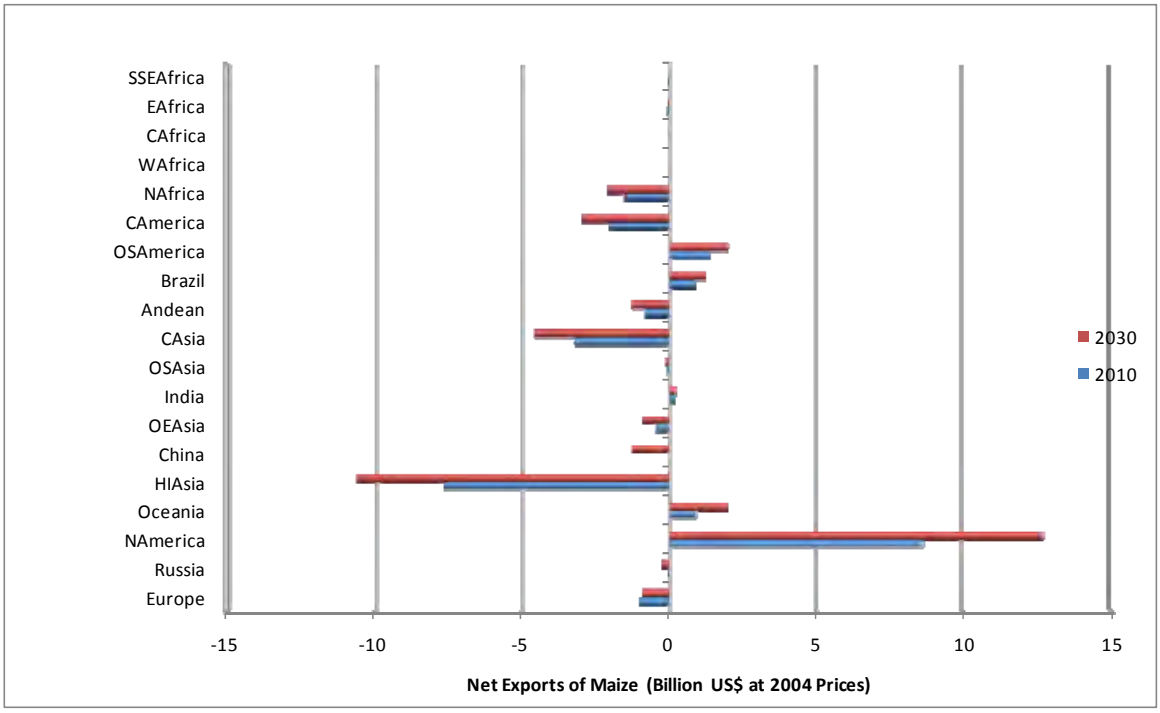
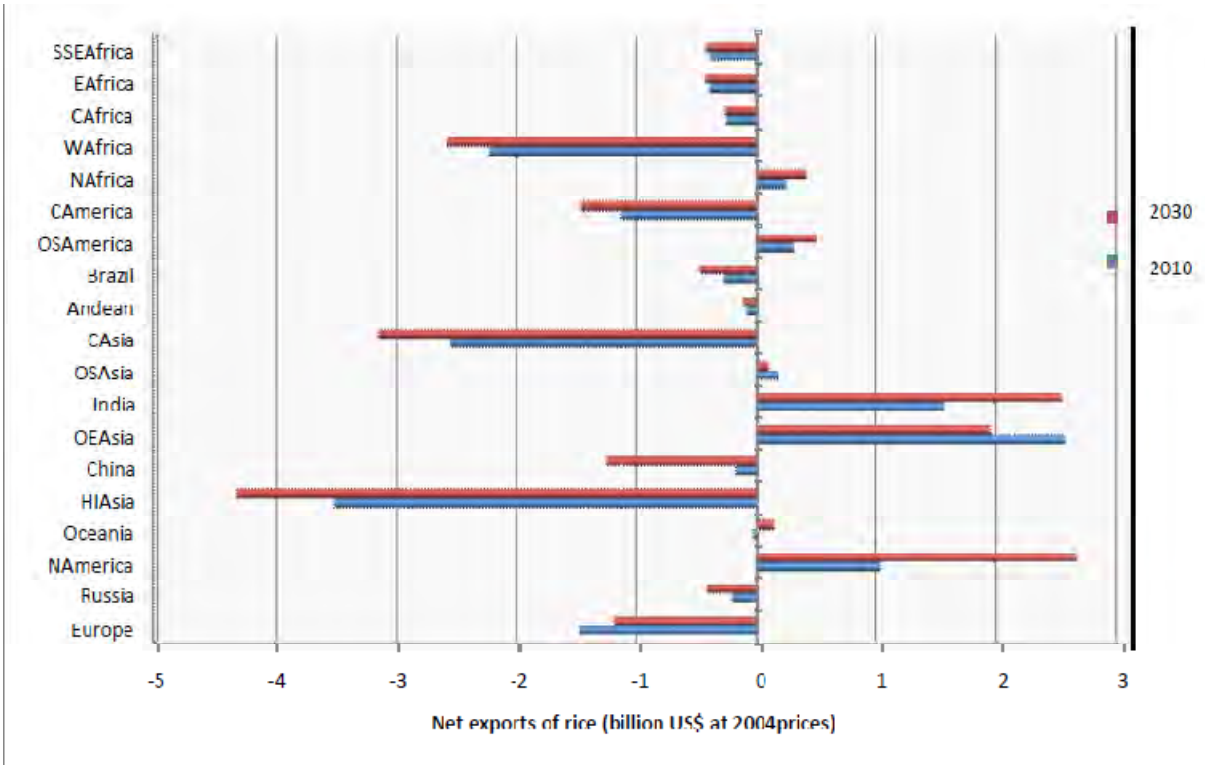


Figure 11 shows the geographical pattern of trade in maize and other coarse grains. The main exporters in 2010 are North America, Brazil and other South America, while the main importers are high-income Asia, Central Asia/Middle East and Central America. The sub-Sahara African regions except West Africa are net importers of maize.

Figure 12: Net export volume of rice 2010 and 2030
(US$ billion at constant 2004 market prices)



Note: The trade volumes include paddy and processed rice.

The main rice exporters are other East Asia, India and North America, while the main net importers are high-income Asia, Central Asia and – notably – western Africa. In relative terms, China exhibits the largest increase in rice imports from 2010 to 2030 in the baseline scenario.

Food consumption

Table 8 shows simple aggregate quantity indices of household food consumption and food consumption per capita in 2010 and 2030 for selected developing regions. The indices are calculated by evaluating the household consumption quantities projected by the model at constant 2004 prices and adding them over all eight food commodity group. With the exception of South Asia, real per capita food consumption generally expands despite the strong domestic food price increases, since average real income per capita is projected to rise. However, the food price increases relative to other commodities means that the share of income that households spend on food remains higher than it would be in the absence of these price increases.

Table 8: Aggregate index of food consumption per capita

Region	Year	Food consumption	Population (millions)	Food consumption per capita
India	2010	205.4	1220.2	0.17
	2030	286.0	1505.7	0.19
OSAsia	2010	65.4	420.9	0.16
	2030	88.4	574.7	0.15
Andean	2010	41.5	100.6	0.41
	2030	66.6	122.9	0.54
CAmerica	2010	73.3	195.1	0.38
	2030	101.9	234.6	0.43
WAfrica	2010	38.3	329.2	0.12
	2030	65.8	491.4	0.13
CAfrica	2010	19.5	108.4	0.18
	2030	41.8	186.1	0.22
EAfrica	2010	40.9	309.3	0.13
	2030	76.3	480.8	0.16
SSEAfrica	2010	40.5	120.6	0.34
	2030	68.9	151.0	0.46

4 CLIMATE CHANGE IMPACTS

The assumed climate impacts on factor productivity in crop agriculture by region (Table 8) used in the following simulations are based on the synthesis of recent studies in Hertel, Burke and Lobell (2010). This synthesis draws on Ainsworth *et al.* (2008), Matthews *et al.* (1995), Parry *et al.* (1999), Jones and Thornton (2003), Lin *et al.* (2005), Alcamo *et al.* (2007), Cline (2007), Xiong *et al.* (2007), Lobell *et al.* (2008), Tebaldi and Lobell (2008), and Schlenker and Roberts (2009) and are consistent with the previous impact syntheses of Cline (2007) and Easterling *et al.* (2007).

Table 8: Assumed impacts of climate change on crop productivity in 2030
(Percentage deviations in total factor productivity from 2030 baseline levels)

	Paddy rice	Wheat	Maize	Other crops
Europe	-5	-5	-17	-5
Russia	-5	-5	-17	-5
NAmerica	-10	-9	-27	-10
Oceania	-5	-5	-17	-5
HIAsia	3	-2	-6	-3
China	-12	-10	-22	-15
OEAsia	-9	-9	-15	-9
India	-15	-10	-17	-10
OSAsia	-13	-10	-17	-10
CAsia	-5	-5	-12	-5
Andean	0	0	-9	0
Brazil	-10	-10	-17	-10
OSAmerica	-10	-10	-16	-10
CAmerica	-15	-15	-12	-15
NAfrica	-5	-5	-12	-5
WAfrica	-15	-15	-22	-15
CAfrica	-15	-15	-22	-15
EAfrica	-15	-15	-22	-15
SSEAfrica	-18	-18	-35	-18

Source: Adapted from Hertel, Burke and Dobell (2010), Table B1 (Low Case).

The low-productivity scenario presented here depicts a world with rapid temperature change, high sensitivity of crops to warming, and a CO2 fertilization effect at the lower end of published estimates.

Figure 13: Impact of climate change on global food prices
(2010= 1.00)

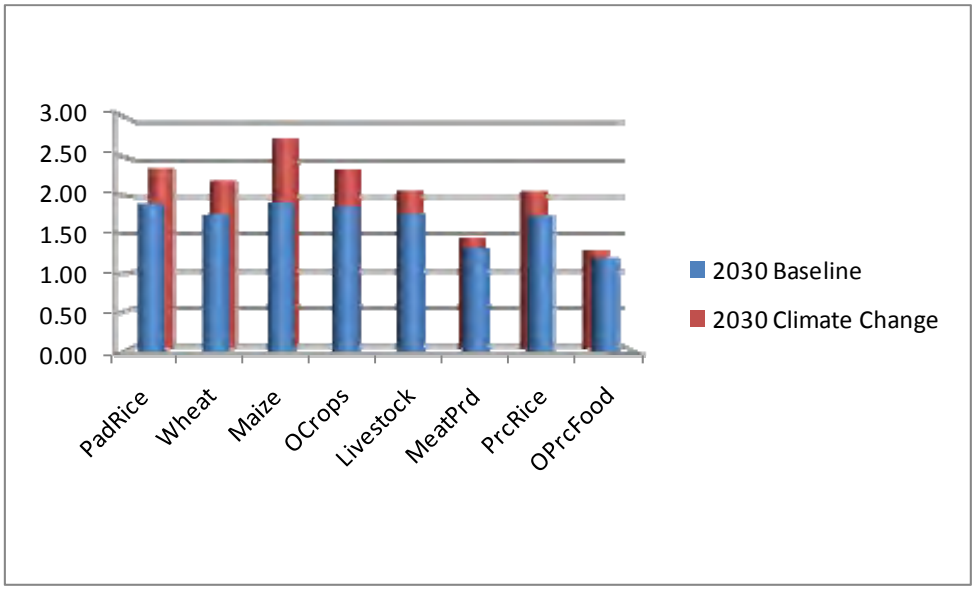


Figure 13 compares world market food prices by commodity group under the simulated climate change impacts with the baseline projections for 2030. Under the stated assumption, climate change entails significant further increases in world market prices for agricultural products and processed foods. The additional price impact is particularly pronounced for maize.

Table 9 shows the percentage changes in domestic user prices without and with climate change between 2010 and 2030.

Table 9: Change in domestic user price of rice, wheat and maize
(Change relative to 2010, percentages)

	Paddy rice		Wheat		Maize		Processed rice	
	2030	**2030CC**	**2030**	**2030CC**	**2030**	**2030CC**	**2030**	**2030CC**
Europe	67.0	96.8	44.1	69.5	58.0	113.3	20.0	29.2
Russia	93.3	110.3	87.0	102.6	83.2	126.2	50.0	62.8
NAmerica	121.8	209.3	44.2	104.0	92.5	213.8	1.5	3.4
Oceania	92.0	136.5	108.5	151.8	74.3	141.7	2.1	3.6
HIAsia	41.8	55.8	43.7	81.7	70.1	161.1	31.6	42.7
China	174.0	224.5	87.0	113.2	154.0	233.6	121.1	157.7
OEAsia	115.2	161.6	62.6	94.9	119.9	185.7	90.8	127.4
India	97.8	137.5	52.2	67.8	89.5	129.3	22.0	25.7
OSAsia	65.5	89.8	50.5	67.6	79.7	121.2	33.3	47.4
CAsia	57.2	76.6	50.2	70.3	52.5	86.7	24.4	33.1
Andean	56.9	72.2	60.2	87.4	65.0	105.3	27.7	36.9
Brazil	70.7	114.2	65.2	103.2	70.8	126.6	29.9	49.1
OSAmerica	70.1	110.7	62.5	102.7	73.0	126.7	44.0	70.2
CAmerica	60.3	114.4	47.4	95.0	73.7	135.7	27.8	48.8
NAfrica	39.6	51.8	33.8	46.9	45.4	76.7	31.6	41.6
WAfrica	34.1	59.0	38.2	59.5	40.2	81.1	24.3	26.9
CAfrica	43.8	74.4	38.3	63.3	45.2	85.2	18.4	22.3
EAfrica	23.2	43.1	27.1	43.4	29.3	57.9	20.6	33.4
SSEAfrica	45.2	107.7	23.1	46.9	34.2	104.8	39.4	59.6

Note: 2030CC = with climate change

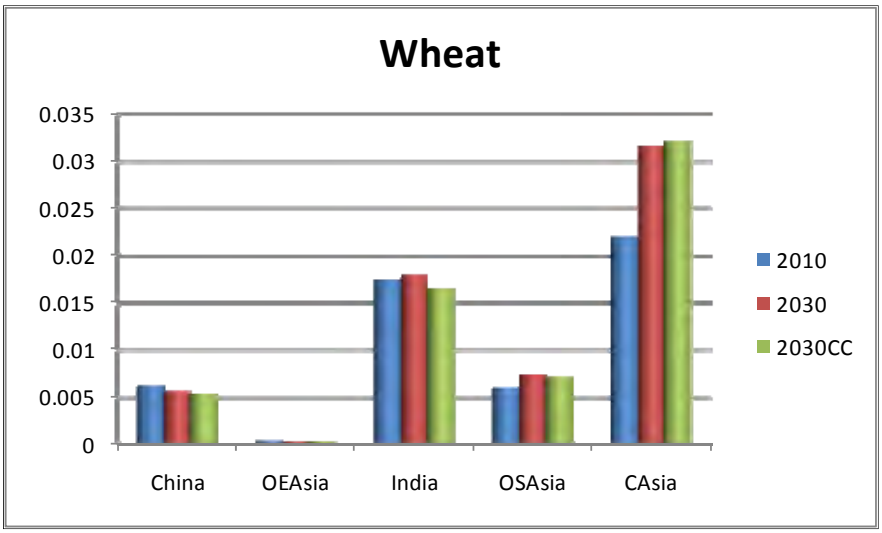
Table 10 displays the changes in agricultural gross output by commodity and region attributable to climate change.

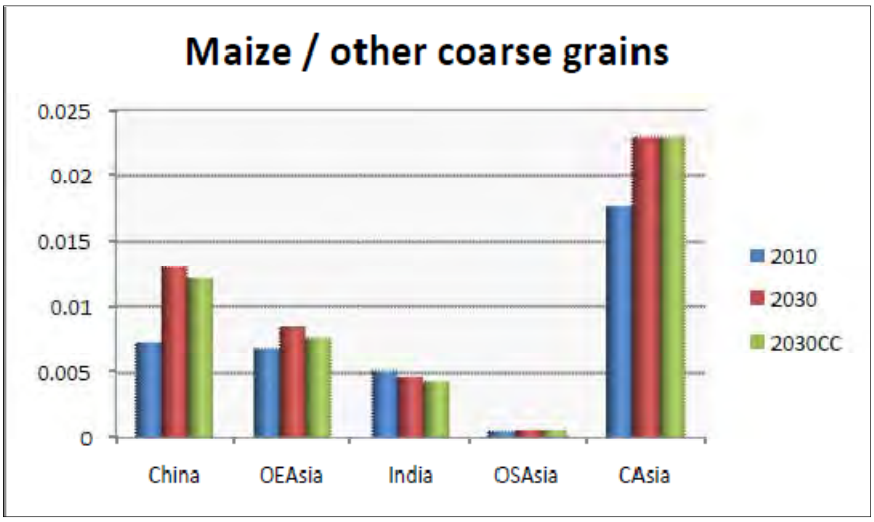
Table 10: Climate change impact on domestic output 2030
(Percentage Changes relative to 2030 baseline)

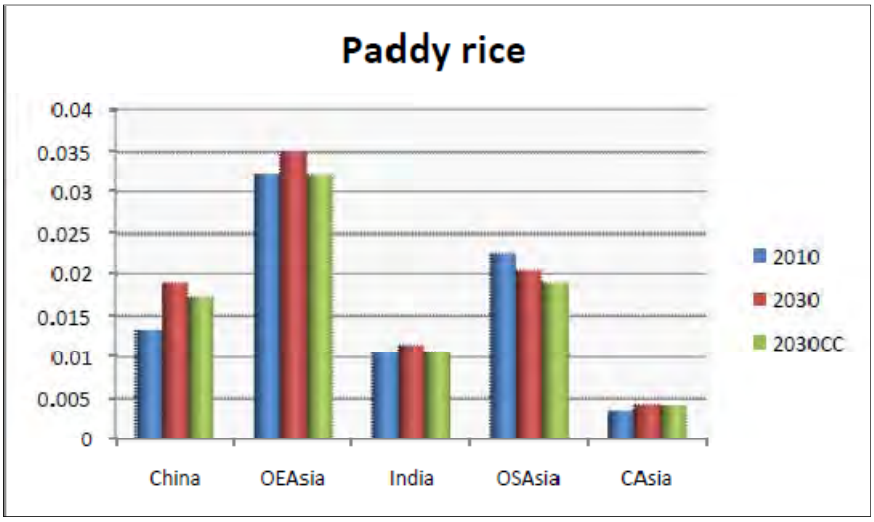
	Paddy rice	Wheat	Maize	Other crops
Europe	6.7	2.0	-0.1	2.6
Russia	-1.1	-3.2	-5.2	-2.1
NAmerica	-4.2	-16.2	-7.5	-6.7
Oceania	1.7	6.8	0.4	-0.8
HIAsia	-0.5	93.2	37.5	3.0
China	-8.5	-5.0	-6.8	-8.4
OEAsia	-8.3	-4.4	-8.2	-4.6
India	-8.1	-8.3	-8.8	-7.0
OSAsia	-6.8	-3.8	-2.9	-4.2
CAsia	-2.2	1.0	0.2	2.1
Andean	-3.0	20.1	1.2	4.6
Brazil	-6.8	-20.5	-6.1	-1.9
OSAmerica	-7.3	-6.4	-6.7	-3.9
CAmerica	-9.4	-5.3	-4.1	-8.0
NAfrica	-3.4	3.1	1.7	-0.6
WAfrica	-10.1	-11.4	-11.1	-11.3
CAfrica	-7.4	-12.0	-11.6	-8.7
EAfrica	-10.3	-6.1	-9.4	-8.8
SSEAfrica	-6.7	1.4	-8.0	-7.1

Figures 14 to 16 compare output per capita in 2010 with output per capita in 2030 with and without adverse climate change impacts for the major crops in developing Asia, Africa and Latin America. In most cases, 2030 per capita output levels under climate change remain above the corresponding 2010 levels. Important exceptions are maize/other coarse grains in West, Central and East Africa as well as wheat in China and India.

Figure 14: Production volumes per capita in developing Asia
(Value of production per capita at constant 2004 prices, US$ 1000's)

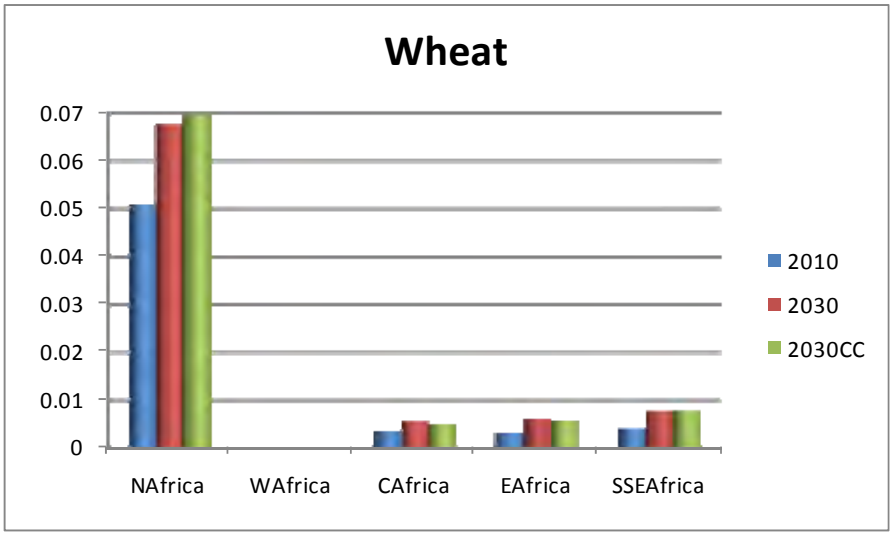


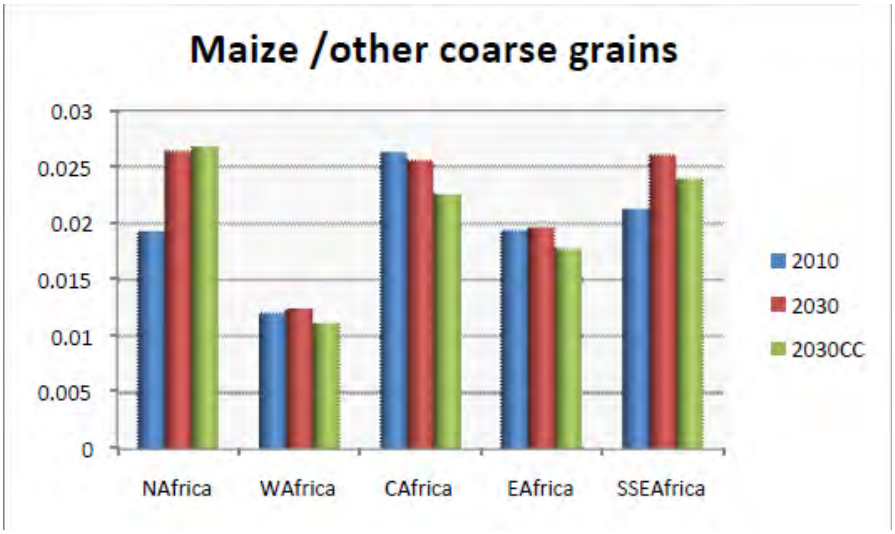


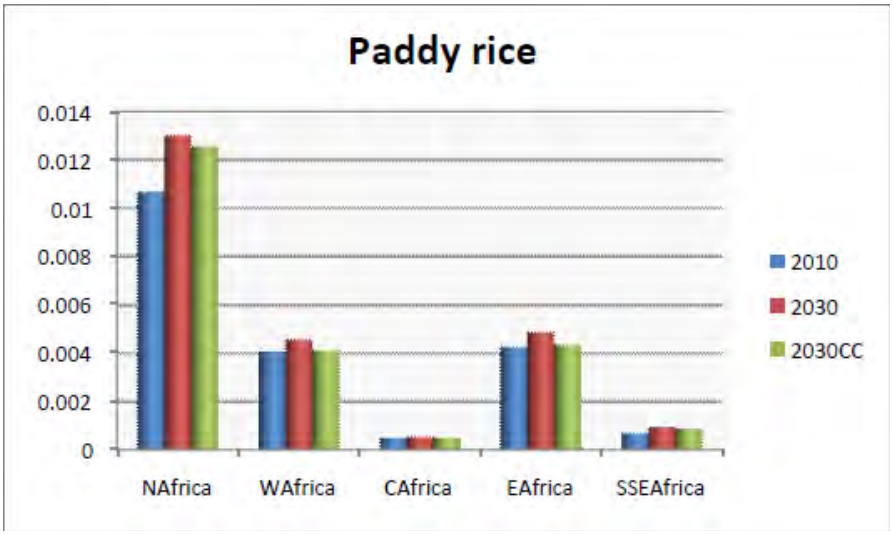


Note: 2030CC: With climate change; 2030: Without climate change

Figure 15: Production volumes per capita in Africa
(Value of production per capita at constant 2004 prices, US$ 1000's)

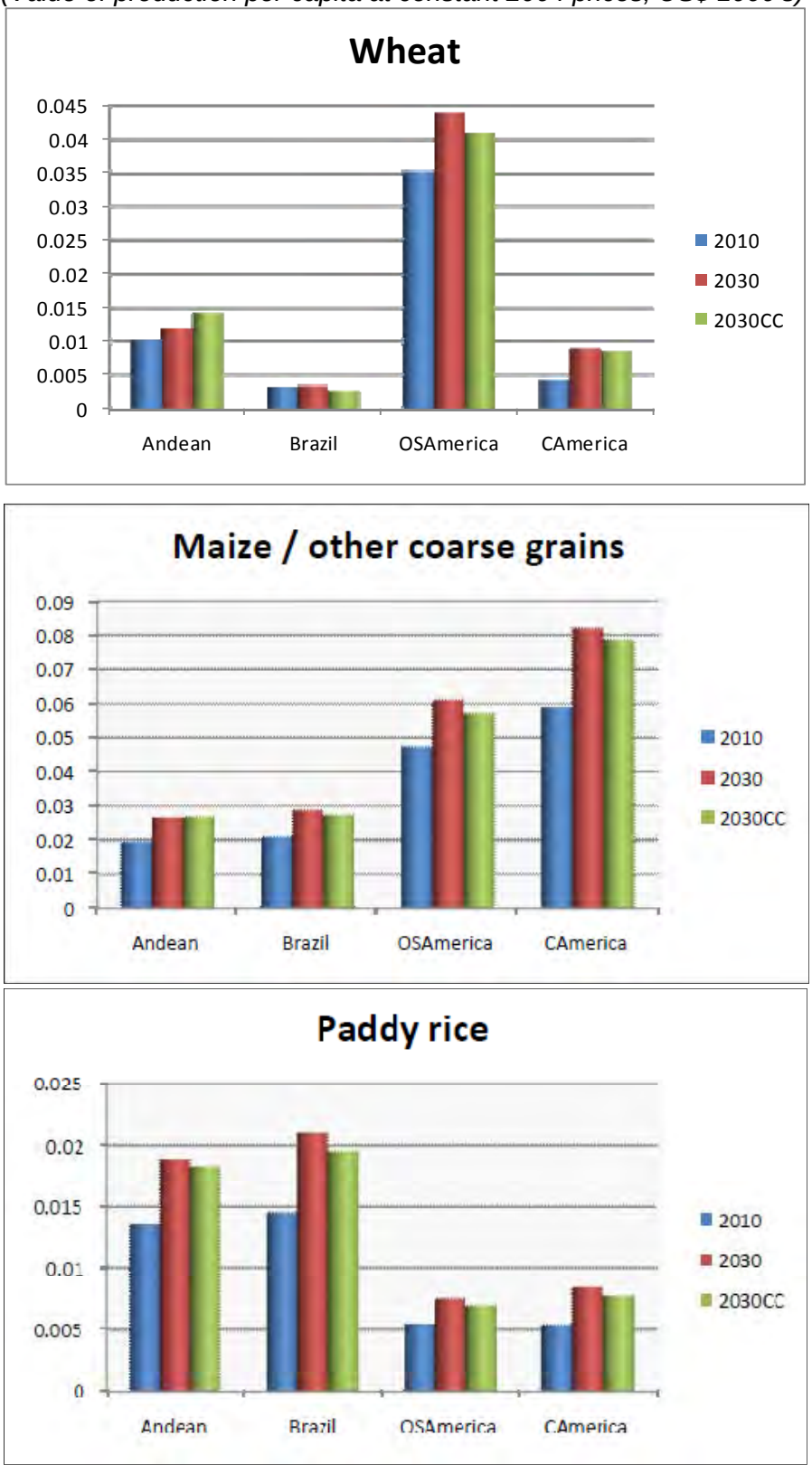






Note: 2030CC: With climate change; 2030: Without climate change

Figure 16: Production volumes per capita in Latin America
(Value of production per capita at constant 2004 prices, US$ 1000's)



Note: 2030CC: With climate change; 2030: Without climate change

5. ALTERNATIVE SCENARIOS

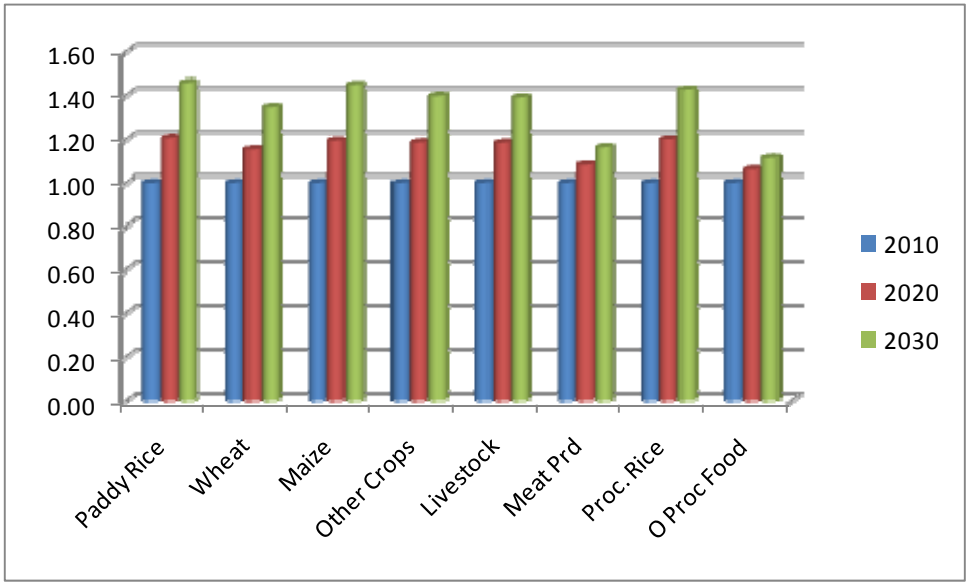
5.1 Optimistic agricultural productivity growth scenario

This scenario assumes that, as a result of increased R&D efforts, accelerated international technology and knowledge transfer, and measures to raise yields in smallholder agriculture etc., total factor productivity growth rates in agriculture are 50 percent higher across all regions and agricultural sectors than in the baseline scenario. For instance, factor productivity growth in maize production in the Andean region accelerates from 1.2 (Table 6) to 1.8 percent per annum and from 1.4 to 2.1 percent per year in West Africa.

Figure 17 and Table 9 show simulation results for world market prices and domestic prices and should be compared with the corresponding baseline results in section 3.

The basic message: food price increases towards 2030 are still strong, but less dramatic than in the baseline scenario.

Figure 17: Index of world market export prices for food commodities
(2010 = 1.00)



Note: Optimistic agricultural productivity scenario. Annual factor productivity growth rates for crops and livestock 50% higher than in the baseline scenario across all regions**.**

Table 9: Change in domestic user price of rice, wheat and maize: optimistic scenario
(Change relative to 2010 in percent)

	Paddy rice		Wheat		Maize		Processed rice	
	2020	**2030**	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Europe	17.8	39.1	8.8	19.3	13.1	29.6	5.0	10.9
Russia	34.3	71.6	31.9	63.1	29.3	58.4	17.1	34.1
NAmerica	21.4	56.3	-2.2	3.4	15.8	40.8	0.3	0.7
Oceania	17.8	44.4	14.0	41.1	9.5	27.7	0.4	1.1
HIAsia	6.3	13.0	0.5	7.0	9.0	25.4	4.7	9.7
China	62.7	125.5	32.3	58.9	56.0	114.6	42.7	85.4
OEAsia	31.8	70.1	11.0	27.6	34.3	76.9	24.9	54.7
India	36.2	71.1	17.9	33.7	33.7	68.4	5.0	11.3
OSAsia	23.2	46.5	16.0	31.3	27.7	58.4	11.3	23.2
CAsia	13.6	31.9	10.4	24.8	12.6	29.7	7.2	15.1
Andean	13.1	28.1	12.0	27.2	15.6	35.1	6.0	13.1
Brazil	12.9	30.9	13.3	29.9	14.1	33.4	5.0	12.2
OSAmerica	14.6	33.0	11.9	27.5	16.0	36.9	9.0	20.4
CAmerica	9.9	22.8	5.2	14.8	13.3	31.0	5.3	11.7
NAfrica	10.6	22.3	7.5	16.1	11.5	25.6	8.2	17.3
WAfrica	5.0	13.0	6.5	17.3	8.6	21.3	9.4	18.8
CAfrica	9.6	18.4	7.6	14.6	13.5	28.2	6.2	12.5
EAfrica	1.8	5.5	4.9	10.0	7.9	18.1	3.7	8.0
SSEAfrica	0.5	3.9	1.7	4.8	4.1	10.6	10.1	21.3

Note: Optimistic agricultural productivity scenario. Annual factor productivity growth rates for crops and livestock 50% higher than in baseline across all regions**.**

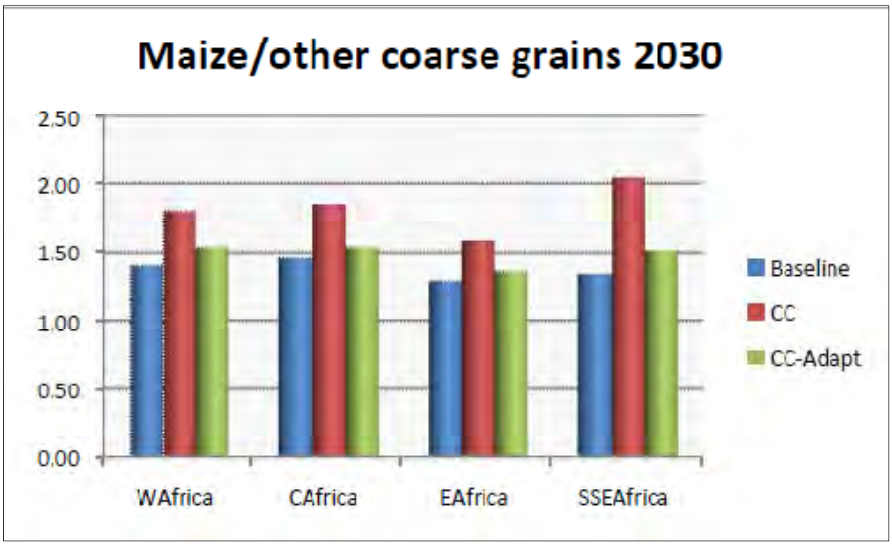
5.2 Climate change adaptation in sub-Saharan Africa

This simulation considers a scenario of successful climate change adaptation in the four sub-Sahara African regions. It is assumed that an appropriate set of externally funded adaptation measures[4] returns productivity growth in crop and livestock agriculture back to the baseline path in the SSA regions. In all other regions, the climate change impacts on agriculture are the same as assumed in section 4 (Table 8).

Figures 18 and 19 compare the domestic user price indices (defined over domestic and imported crops) for the main agricultural crops – maize/other coarse grains and other crops – in 2030 between the baseline scenario, the climate change scenario considered in section 4 (CC), and the adaptation scenario (CC-Adapt).

Basic message: Adaptation measures that succeed in reversing adverse climate change impacts on agricultural yields in SSA would return domestic crop prices close to baseline levels, even in the presence of climate change-induced agricultural price increases in all other world regions.

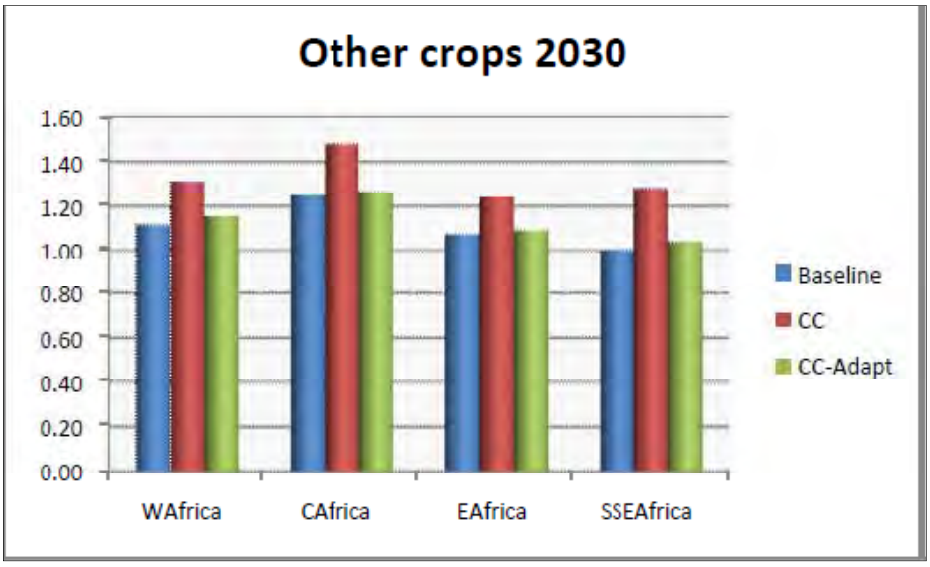
Figure 18: Index of domestic user prices of maize/other coarse grains in sub-Saharan Africa 2030
(2010 = 1.00)



CC: Climate Change Scenario (see Section 4). CC-Adapt: Climate Change Adaptation Scenario.

[4] See World Bank (2010) for a detailed discussion of the potential elements of country-specific climate change adaptation strategies for the agricultural sectors of Ethiopia (East Africa), Ghana (West Africa) and Mozambique (South-East Africa)

Figure 19: Index of domestic user prices of other crops in sub-Saharan Africa 2030
(2010 = 1.00)



CC: Climate Change Scenario (see Section 4). CC-Adapt: Climate Change Adaptation Scenario.

APPENDIX: DISAGGREGATED ANALYSIS OF EXPOSURE TO IMPORT PRICE SURGES FOR MAJOR CROPS

This Appendix analyzes developing countries' present exposure to world crop price surges at a finer disaggregation level using the full geographical disaggregation of developing regions in the GTAP 7.1 database.

In an aggregate sense, net exporters of a crop will benefit from a world market price increase for that crop while net importers will be adversely affected. Among net importers, the degree of exposure to an import price surge for a particular crop is higher for countries with a higher share of imports in total domestic demand for the crop and with a higher share of the crop in total domestic demand for all crops.

Thus, the left-hand panel of Table A-1 shows the 2004 import shares in total domestic demand for rice (paddy plus processed), wheat and maize/other coarse grains for each of the 64 developing/emerging countries and sub-regions distinguished in the GTAP 7.1 database. The middle panel reports the shares of each of these crops in total domestic demand for all crops.[5] The right-hand panel shows a simple index of exposure to import price surges for each crop and each net-importing country, which is calculated as

$$(\text{Import share in domestic demand} \cdot \text{Share of crop in total demand})^{0.5}$$

This index ranges from zero for a country that is completely self-sufficient in a crop or does not consume a crop at all to 100 in the hypothetical extreme case, where a country imports all of its use of a crop (100 percent import share) and consumes no other crops (100 percent crop share). The table highlights all cases where this index is larger than 20 in 2004. For instance, Senegal's exposure to world market price surges is very high, because the import share is nearly 60 percent and rice accounts for 43.5 percent of total crop demand, while Ethiopia's exposure is very low since rice plays only a negligible role in local diets.

[5] In the case of rice, domestic demand is calculated as *final* demand for paddy rice plus total demand for processed rice to avoid double-counting of the intermediate use of paddy rice in the production of processed rice.

Table A-1: Exposure of developing countries to import price surges

Notes: Exposure index values > 20 highlighted; nx: Country is a net exporter of the crop

	Import share in domestic demand (%)			Share of crop in total crop demand (%)			Index of exposure to import price surges		
	Rice	Wheat	Maize	Rice	Wheat	Maize	Rice	Wheat	Maize
China	0.8	17.5	3.7	14.5	5.1	4.5	nx	9.5	nx
OEastAsia	20.6	54.8	39.1	16.3	8.1	6.0	18.3	21.0	15.4
Cambodia	1.9	100.0	4.5	38.1	0.7	3.9	nx	8.5	nx
Indonesia	1.2	99.8	5.0	24.6	2.8	7.9	5.4	16.8	6.3
Laos	0.5	0.0	0.5	62.0	0.0	2.4	nx	nx	nx
Malaysia	34.0	100.0	95.9	14.9	6.0	6.5	22.5	24.6	24.9
Philippines	6.7	65.4	3.9	43.6	7.9	6.7	17.1	22.8	5.1
Thailand	0.1	99.9	5.9	22.4	2.2	3.4	nx	15.0	nx
Vietnam	0.4	99.9	23.3	46.4	3.7	1.9	4.2	19.2	6.7
OSEAsia	2.4	100.0	1.2	42.3	1.5	3.9	10.0	12.2	nx
Bangladesh	2.2	37.0	63.5	53.6	3.6	0.5	11.0	11.6	5.5
India	0.0	0.0	0.1	19.7	12.7	3.8	nx	nx	nx
Pakistan	0.2	12.7	15.4	6.9	12.1	0.8	nx	12.4	3.5
Sri Lanka	10.5	100.0	62.8	20.6	4.8	0.9	14.7	21.9	7.4
OSAsia	1.6	9.2	9.3	55.9	3.2	0.7	9.6	5.4	2.5
Argentina	3.5	0.2	1.3	1.0	5.1	11.6	nx	nx	nx
Bolivia	0.3	46.9	2.3	24.1	3.0	8.4	nx	11.8	nx
Brazil	6.4	75.5	3.0	7.3	4.0	10.9	6.8	17.4	nx
Chile	23.1	5.8	25.1	2.5	28.2	20.4	7.6	12.8	22.6
Colombia	4.3	64.4	44.6	9.8	6.6	14.2	6.5	20.6	25.1
Ecuador	0.1	94.1	26.5	23.3	3.6	10.3	nx	18.5	16.5
Paraguay	1.3	0.0	8.0	1.6	2.3	8.2	nx	nx	nx

	Import share in domestic demand (%)			Share of crop in total crop demand (%)			Index of exposure to import price surges		
Peru	3.7	30.9	20.4	7.0	13.4	11.9	5.1	20.4	15.5
Uruguay	0.3	42.6	27.6	3.3	7.3	6.1	nx	17.6	13.0
Venezuela	1.5	63.9	14.3	0.3	11.7	21.8	nx	27.4	17.6
OSAmerica	1.2	43.4	15.8	10.4	8.8	12.0	nx	19.5	13.8
Costa Rica	24.8	99.5	95.8	6.8	4.5	7.9	13.0	21.1	27.6
Guatemala	18.0	96.4	11.7	3.2	4.0	28.6	7.6	19.7	18.3
Nicaragua	31.3	99.8	10.7	7.6	8.9	25.2	15.4	29.8	16.4
Panama	0.0	0.0	0.2	52.0	0.2	5.1	nx	0.0	1.1
Mexico	58.9	65.9	12.5	0.4	3.1	32.4	4.7	14.3	20.1
OCAmerica	5.2	75.3	31.2	23.9	3.4	10.6	11.1	16.0	18.2
Caribbean	60.6	80.0	18.7	10.7	4.9	15.3	25.5	19.7	16.9
Egypy	0.2	50.3	27.9	11.0	20.0	13.9	nx	31.7	19.7
Morocco	12.3	24.2	24.4	0.5	38.9	17.5	2.4	30.7	20.7
Tunisia	76.7	24.2	57.2	0.1	24.3	4.9	2.8	24.2	16.8
ONAfrica	95.3	30.9	56.2	0.4	27.3	5.1	6.1	29.1	17.0
Nigeria	64.3	98.4	0.0	11.9	5.1	12.1	27.7	22.5	nx
Senegal	59.5	99.8	4.9	43.5	4.0	18.1	50.9	20.0	9.4
OWAfrica	49.0	98.0	1.1	13.9	1.7	13.3	26.1	12.8	nx
CntrlAfrica	48.4	47.3	0.7	5.9	6.5	30.1	16.9	17.5	4.5
SCntrlAfrica	60.7	28.2	1.7	6.7	3.5	33.1	20.2	10.0	7.6
Ethiopia	91.4	34.2	1.3	0.1	12.0	33.5	3.6	20.3	nx
Madagascar	5.0	100.0	5.6	45.1	0.7	1.4	15.0	8.5	2.8
Malawi	24.7	100.0	6.4	1.6	2.0	38.4	6.2	14.1	15.7
Mauritius	99.7	100.0	100.0	6.1	1.4	1.9	24.7	12.0	13.8
Mozambique	62.6	99.9	4.8	10.3	6.4	20.3	25.4	25.3	9.9

	Import share in domestic demand (%)			Share of crop in total crop demand (%)			Index of exposure to import price surges		
Tanzania	18.8	60.4	2.1	5.0	4.7	30.6	9.7	16.9	nx
Uganda	23.7	90.2	2.6	2.1	2.1	13.7	7.0	13.8	nx
Zambia	23.6	20.0	2.4	3.9	4.3	29.5	9.6	9.3	nx
Zimbabwe	38.9	82.5	66.3	3.0	9.8	27.0	10.9	28.5	42.3
OEAfrica	20.5	62.2	4.3	6.7	7.9	26.4	11.7	22.2	10.6
Botswana	85.2	99.4	29.8	7.7	7.0	44.8	25.6	26.4	36.5
South Africa	94.5	47.8	8.4	4.5	7.4	18.6	20.6	18.8	nx
O SACU	74.9	56.4	27.0	3.9	9.0	23.5	17.1	22.6	25.2
Kazakhstan	2.0	0.1	0.5	2.2	28.5	13.9	nx	nx	nx
Kyrgyzstan	35.3	33.5	1.1	0.2	8.8	4.5	2.6	17.1	nx
O FSU	29.6	8.7	2.4	0.5	9.5	5.5	3.8	nx	3.7
Armenia	71.8	20.8	8.1	0.1	34.3	14.7	1.9	26.7	10.9
Georgia	99.6	70.8	1.2	2.8	18.4	13.1	16.7	36.1	3.9
Azerbeijan	59.4	44.2	5.4	0.4	33.9	6.1	5.0	38.7	5.7
Iran	13.6	2.7	21.5	10.7	9.2	21.6	12.1	5.0	21.6
OWAsia	97.0	39.3	58.6	6.7	14.1	14.7	25.5	23.5	29.3
Average	7.1	25.8	18.4	11.0	7.7	9.5	8.9	14.1	13.2

Notes: Exposure index values > 20 highlighted; nx: Country is a net exporter of the crop.

REFERENCES

Ainsworth, E.A., Leakey, A.D.B., Ort, D.R., Long, S.P. (2008) 'FACE-ing the Facts: Inconsistencies and Interdependence Among Field, Chamber and Modelling Studies of Elevated CO2 Impacts on Crop Yield and Food Supply', *New Phytologist* 179 (1), 5–9.

Alcamo, J. *et al*. (2005) 'Change in Ecosystem Services and Their Drivers Across the Scenarios'. In Carpenter, S. R. / P. L. Pingali / E. M. Bennett / M. B. Zurek (eds.), 297–373.

Alcamo, J., Dronin, N., Endejan, M., Golubev, G., Kirilenko, A. (2007) 'A New Assessment of Climate Change Impacts on Food Production Shortfalls and Water Availability In Russia', *Global Environmental Change* 17 (3–4), 429–444.

Carpenter, S. R. ,Pingali, P.L., Bennett, E.M., Zurek, M.B (eds.) (2005) 'Ecosystems and Human Well-being: Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment', *Millennium Ecosystem Assessment Series Vol. 2*, Washington, Covelo and London: Island Press

Cline, W.R. (2007) *Global Warming and Agriculture: Impact Estimates by Country*, Center for Global Development: Washington, D.C.

Easterling, W. *et al.* (2007) 'Food, Fibre, and Forest Products'. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J.V.D., Hanson, C.E. (eds.) *Climate Change 2007: Impacts, Adaptation and Vulnerability,* contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press: Cambridge, UK., 273–313.

Government Office for Science (2011) The Future of Food and Farming: Challenges and Choices for Global Sustainability, GO-Science: London.

Hertel, T.W., Burke, M.B., Lobell, D.B. (2010) 'The Poverty Implications of Climate-Induced Crop Yield Changes by 2030'. *Global Environmental Change* 20, 577–585.

Jaggard, K.W., Qi, A., Ober, E.S. (2010) 'Possible Changes to Arable Crop Yields by 2050', *Philosophical Transactions of the Royal Society B* 365, 2835–52.

Jones, P.G., Thornton, P.K. (2003)' The Potential Impacts of Climate Change on Maize Production in Africa and Latin America in 2055', *Global Environmental Change* 13 (1), 51–9.

Lin, E. *et al*. (2005) 'Climate Change Impacts on Crop Yield and Quality with CO2 Fertilization in China', *Philosophical Transactions of The Royal Society, Series B* 360 (1463), 2149–54.

Lobell, D.B. *et al*. (2008) 'Prioritizing Climate Change Adaptation Needs for Food Security in 2030', *Science* 319 (5863), 607–10.

Lobell, D.B., Field, C.B. (2007) 'Global Scale Climate-Crop Yield Relationships and the Impacts of Recent Warming', *Environmental Research Letters* 2, 004000.

Matthews, R.B., Kropff, M.J., Bachelet, D., Van Laar, H.H. (1995)' Modeling the Impact of Climate Change on Rice Production in Asia', CABI: Los Banos.

McDonald, S., Thierfelder, K., Robinson, S. (2007) 'Globe: A SAM Based Global CGE Model using GTAP Data', *USNA Working Paper* 14. US Naval Academy: Annapolis.

Nelson, G.C. et al. (2010) Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options. IFPRI: Washington, DC.

Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G., Livermore, M. (1999)' Climate Change and World Food Security: A New Assessment', *Global Environmental Change* 9, S51–67.

Reilly, M., Willenbockel, D. (2010) 'Managing Uncertainty: A Review of Food System Scenario Analysis and Modelling', *Philosophical Transactions of the Royal Society B* 365, 3049–63.

Schlenker, W., Roberts, M.J. (2009)' Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields Under Climate Change', *Proceedings of The National Academy Of Sciences* 106 (37), 15594–98.

Smith, P. *et al.* (2010) 'Competition for Land', *Philosophical Transactions of the Royal Society B* 365, 2941-57.

Tebaldi, C., Lobell, D.B. (2008) 'Towards Probabilistic Projections of Climate Change Impacts on Global Crop Yields', *Geophysical Research Letters* 35, L08705.

UNESA (2009) *World Population Prospects: The 2008 Revision*. United Nations Department of Economic and Social Affairs: New York.

Willenbockel, D. (2009) 'Global Energy and Environmental Scenarios: Implications for Development Policy', *German Development Institute Discussion Paper* No. 8/2009.

World Bank (2010) The Economics of Adaptation to Climate Change: Synthesis Report. The World Bank Group: Washington, DC.

Xiong, W., Lin, E., Ju, H., Xu, Y. (2007) 'Climate Change and Critical Thresholds in China's Food Security', *Climatic Change* 81 (2), 205–21.

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