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General information

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Executive summary

This deliverable explores the impact of accounting for heterogeneity in land when assessing the impact of trade liberalization on developing countries. The main motivation for this study as that there is an obvious variation in the productivity of land, land is a main input of agricultural production and agricultural on its turn is a key sectors in developing countries. These facts make it likely that the way in which land is modelled when assessing the impact of (trade) policies will affect the results of the analysis.

Starting from an existing global general equilibrium model (GTAP-AGR) we develop a model in which land used in crop production is composed of 18 different agro-ecological zones called SEAMTAP. The main contribution of SEAMTAP is a direct link between suitability of a type of land for a specific crop through productivity indices. These productivity indices are derived from a detailed database containing the yields and harvested areas at detailed crop and country level. This approach allows us to include 18 AEZs in the model without and 'explosion' in model size and with no significant impact on model performance.

The variation in suitability of land for specific crops and adjustment costs when shifting use is implicitly included in GTAP-AGR by restricting the movement of land between sectors. In SEAMTAP we replace this by a direct connection between crops sectors and types of land by making the productivity of land in a sector dependent upon the suitability of the AEZs used in that sector. To analyze the way in which this productivity link functions we abstract from the presence of adjustment costs and assume that AEZs can move freely between sectors with no further costs incurred apart from the impact on productivity of land. We furthermore fix the available amount of land at the initial crop area.

We analyzed the impact of multilateral trade liberalization using three model (versions): GTAP-AGR, SEAMTAP with full employment and SEAMTAP with unemployment. The SEAMTAP model with unemployment differs from the 'standard' SEAMTAP by assuming unemployment in all but the high income regions. This is translated in a fixed real wage with the total size of the labour force adjusting to balance supply and demand of labour.

Trade liberalization raises global welfare with all three models, which is the common finding of this type of analysis. Gains are higher when introducing AEZs and even higher again when introducing unemployment. In SEAMTAP with unemployment there is a multiplier effect whereby lowering of trade barriers promotes specialization in line with the comparative advantages of each region. Increased production possibilities are promoted by fixed real wages in regions with unemployment which limits production costs and increases employment. The increase in employment on its turn increases labour income which increases demand and results in additional demand for products. As a result the welfare increase in the SEAMTAP model with unemployment is about three times welfare increase

when assuming full employment in all regions in the SEAMTAP model with full employment.

The introduction of AEZs with the assumption of no adjustment costs of moving AEZs between sectors apart from the impact on aggregate land productivity increases the supply response of agriculture, thereby reducing price changes compared to GTAP-AGR.

In terms of distributional impacts between regions we find that the LDCs experience a larger welfare gain when accounting for AEZs. This gain is mostly driven by a strong increase in the price of sugar (related to a reduction in the strong protection of the EU sugar market). The LDCs are well placed to benefit from this price increase since the crop with the highest productivity on the tropical land (which constitutes the major part of the LDCs' land endowment) is sugar cane. The connection with the change in sugar price implies that if the EU would denominate sugar as a sensitive product in order to avoid a strong reduction in tariffs (which is an option in the current WTO negotiations) this positive impact on the LDC economies may not materialize.

The impact of the suitability of AEZs for specific crops is illustrated by an analysis of the changes in AEZ use by sugar cane. Expansion on tropical moist AEZs is limited despite their suitability for sugar cane. This is due to a price increase for other crops which do not grow well on humid tropical soils, whereas this poses no problem for sugar cane. Other crops are thus allocated to moist tropical soils whereas sugar cane expands on dry and humid AEZs. This illustrates that the model not only assess the suitability of a soil for a specific crop but also takes into account the suitability of the AEZ for other sectors.

Our aim was to assess the impact of including a direct link between AEZs and their suitability for specific crops ignoring adjustment costs of shifting AEZs between sectors. Future applications may consider extensions by accounting for such costs by making the movement of AEZs between sectors sluggish (identical to the treatment of land in GTAP-AGR) or introducing the possibility of an expansion of crop land by adding a land supply module to the model. This would be a straightforward extension of the model since SEAMTAP already includes market clearing conditions in level terms at AEZ level. Introducing land supply would thus imply that instead of the currently fixed amount of crop land by AEZ a function is specified which determines the availability of AEZs as is done in van Meijl et al. (2005) for land.

1 Introduction

This report documents simulation results SEAMTAP which can serve as input for global and country level analysis with other models used in SEAMLESS. SEAMTAP is a global general equilibrium model that accounts for productivity differences among different types of agro-ecological zones. It has been developed from an existing GTAP (Global Trade Analysis Project) model aimed at analyzing agricultural policies (GTAP-AGR) using Version 7, final release candidate 2 of the GTAP database.

The technical details of the development of SEAMTAP are discussed in D 3.8.7. The focus of this report is on simulation results that can be used in other models employed in SEAMLESS. The main aim is to provide changes in global prices for main agricultural commodities that may be used in FFSIM models for developing countries, like the models for cotton producers in Mali. Although the results of SEAMTAP for factor prices could be used in SEAMCAP, the work on linking SEAMCAP and a GTAP model offers better prospects for a consistent exchange of data (see D3.8.3 for a description of the link between SEAMCAP and GTAP). We therefore focus in this report on the impact of changes in global policies on developing countries and world prices of key agricultural products in particular.

We analyze the impact of a realistic multilateral trade liberalization scenario. This scenario is build upon the most recent modalities for liberalization in the ongoing WTO negotiations referred to as the Doha Round. Since our focus is on the impact of trade liberalization on developing countries we need to carefully consider some of the key assumptions on how economies in developing countries work. In particular we will assess the impact of assumptions on the labour market, contrasting results from a model assuming full employment (wages adjusting to maintain full employment) to a model assuming widespread unemployment (resulting in fixed real wages and changes in employment with scenarios).

We start by providing a short description of the SEAMTAP model. The next chapter describes the various sources of data used in SEAMTAP. Chapter 4 introduces the scenario of multilateral trade liberalization and modelling results. Chapter 5 concludes.

2 The SEAMTAP model

This chapter provides a short description of the key features of the SEAMTAP model. A more detailed technical documentation is available in D3.8.7.

Figure 2.1: A simplified illustration of a regional model within the GTAP model

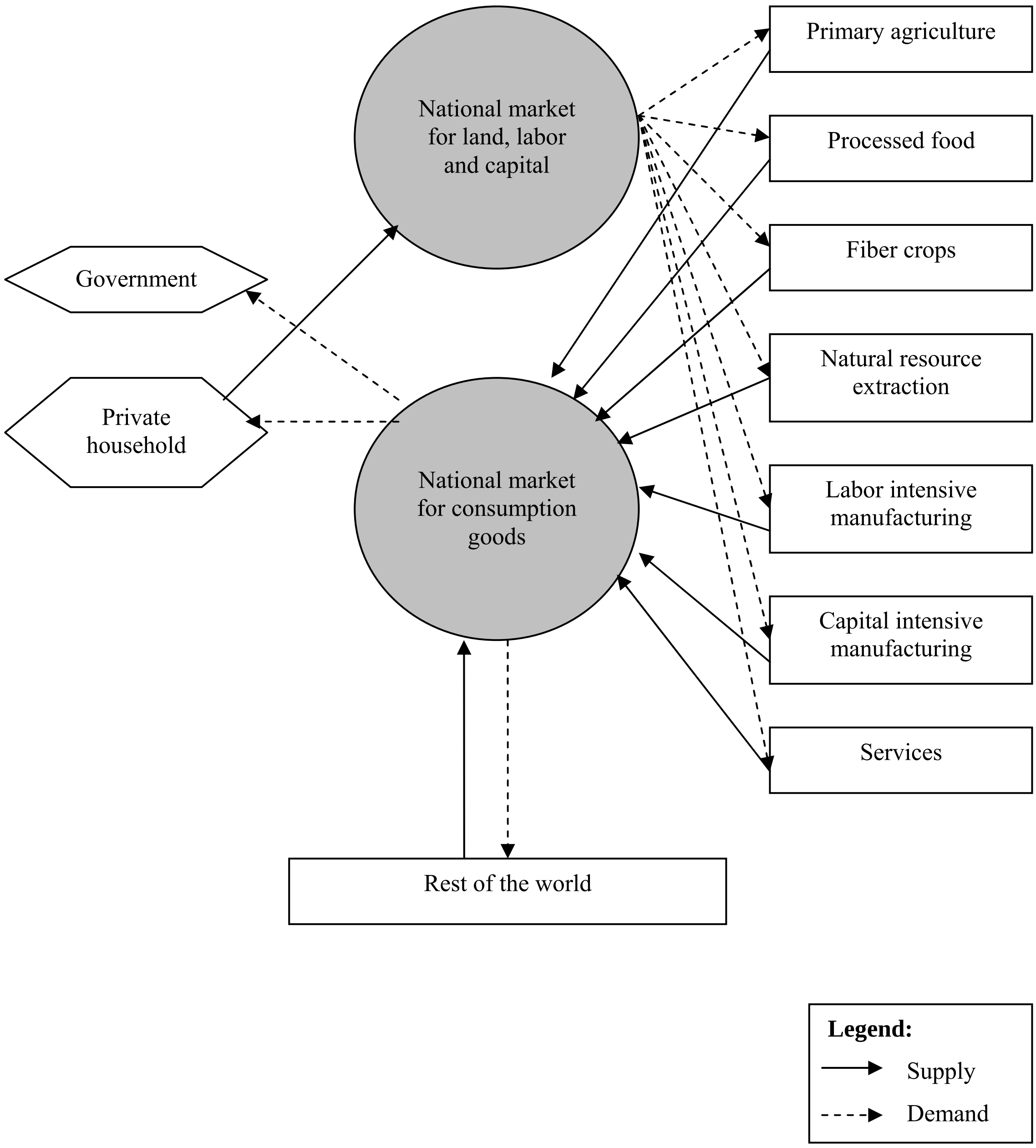
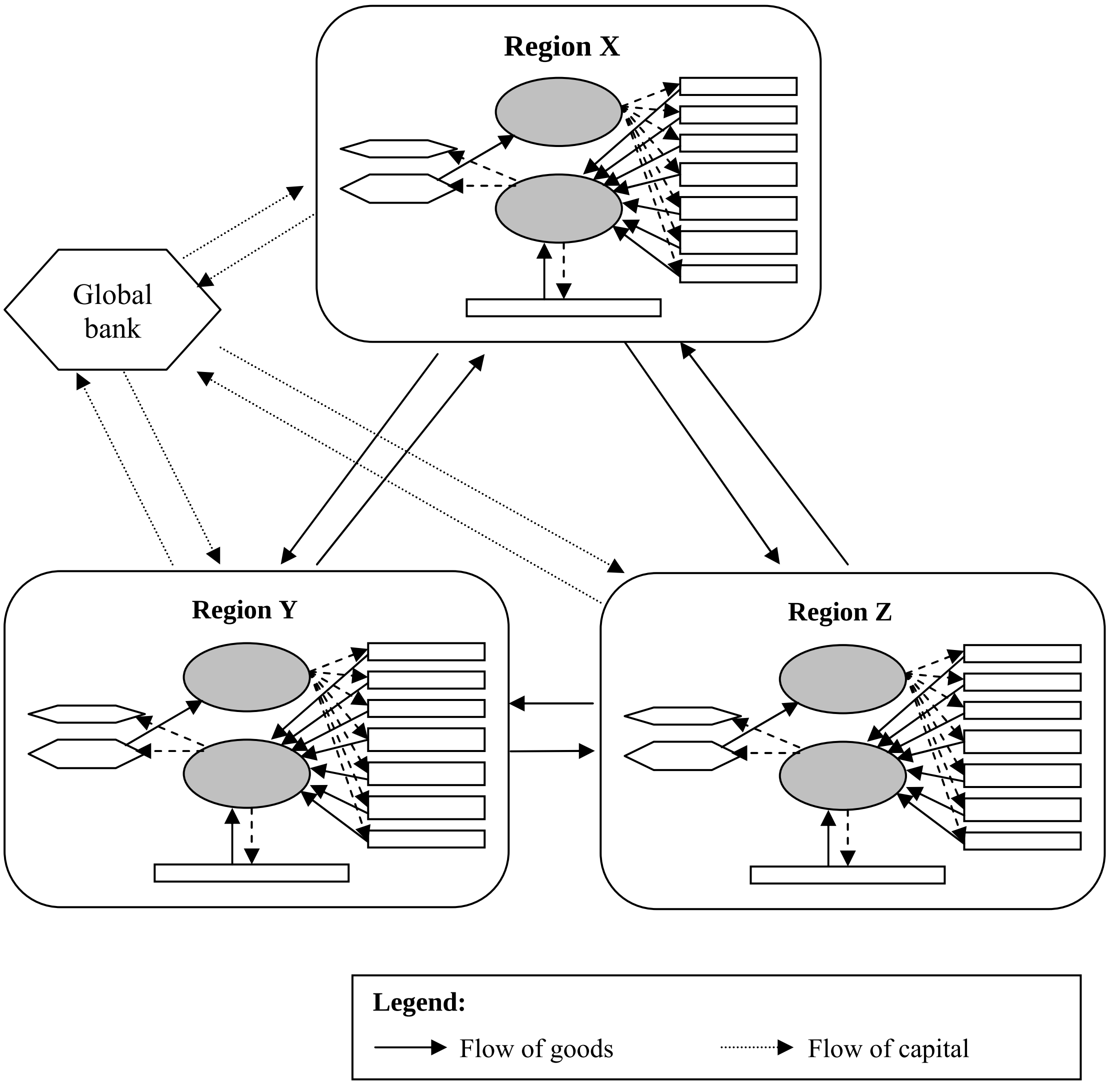


Figure 2.2: Simplified illustration of links between regional models in the GTAP model



2.1 Standard GTAP in a nutshell

The standard GTAP model is a so-called AGE (applied general equilibrium) or CGE (computable general equilibrium) model. General equilibrium refers to the model covering all sectors of the economy (agriculture, manufacturing and services) as opposed to partial equilibrium models (like SEAMCAP focussing on agriculture). In addition GTAP is a global model covering the entire economies of all countries in the world. In the most recent version of the model (Version 7, pre-release 6) 2004 data are available for 110 regions and 57 sectors.

For every region in the model there is a single representative household demanding consumption goods (including savings) on the behalf of all private households and a government (figure 2.1). Total demand is determined by income earned by land, labour and capital as well as income from taxes. The demand for goods can be met by national producers or by imports. For each sector there is a single producer, i.e. there is a one producer of agricultural goods, one for labour intensive manufactured goods, one of services etc.

The model traces trade between all regions in the model and accounts for trade barriers between regions through inclusion of tariffs (figure 2.2). These tariffs may drive a wedge between prices in regions, i.e. the same product may be more expensive in one region than in another because of tariffs. Whereas international trade is modelled by tracing all bilateral flows international capital flows are governed by a global bank. This bank collects savings and uses these for international investments. Since savings are pooled by the global bank before being sued for investments there is no tracing of bilateral capital flows.

Prices of goods and of land, labour and capital in each region adjust to assure that both national and international demand and supply are equal, hence the term general equilibrium models. Thus when a policy simulation is run, for example lowering tariffs between regions, the model computes by sector for each region production, consumption and trade (both imports and exports) as well as price levels that result in equilibrium at national and international markets.

More technical information on the standard GTAP model can be found in several publications. An elaborate description is available from Hertel (1997) with updates of the model described in various technical papers available at www.gtap.org. A good starting point for understanding the model is the graphical exposition of the model in Brockmeier (2001).

2.2 Starting point of SEAMTAP: GTAP-AGR

SEAMTAP has been developed to assess the impact of differences in land quality on agricultural production and trough agricultural production on the rest of the economy. SEAMTAP has been build upon an existing GTAP model targeted towards analyzing agricultural policies. This model named GTAP-AGR differs from the standard GTAP model in the following ways:

- *Segmentation of labour markets*: Differences in factor payments area observed to exist between the agricultural and non-agricultural sectors indicating that factors are not perfectly mobile. This is especially so in developing countries where substantial differences in rural and urban wages are observed. Although ideally these wage differentials are modelled by capturing the actual barriers such an approach requires detailed country level information. Lacking such data for the all countries in the GTAP database limitations to factor mobility are modelled through a constant elasticity of transformation (CET) function that ‘transforms’ agricultural into non-agricultural labour. This introduces wage differentials between agricultural and non-agricultural employment.
- *Segmentation of capital markets*: For capital differences in returns between agriculture and non-agriculture are also observed. For capital market segmentation using a CET function is therefore also introduced in the model.
- *Substitution between intermediate inputs*: Whereas the standard GTAP model only allows substitution between primary factors, GTAP-AGR allows substitution among intermediate inputs as well as between primary factors and intermediate inputs.
- *Crop-livestock interactions*: Empirical evidence indicates the importance of interactions between crop and livestock activities resulting from the use of feed in livestock production. Crops are substituted for each other in feedstuff production which can affect (global) markets. To capture this possibility demand for feedstuff is modelled through an additional CES nest in intermediate input demand that captures the average substitution possibility between crops and food products in livestock production.
- *Accounting for impacts on farm households*: The standard GTAP model has a single regional household making it impossible to distinguish the effects on different types of households, like for example rural and urban households. GTAP-AGR also only has a

single household (lacking global data needed to include multiple households) but computes from the model solution changes in income for a representative farm household in OECD countries. With the income from agriculture following directly from the model, the key assumption in this module is the share of income of the farm household coming from outside agriculture. This share of off-farm income will determine to what extent changes in the agricultural sector will affect the disposable income of the farm household.

2.3 Specific features of SEAMTAP

Building upon GTAP-AGR SEAMTAP shares the extensions to the standard GTAP model summarized above. SEAMTAP differs from GTAP-AGR by including different types of land that differ in productivity. SEAMTAP includes 18 different types of agro-ecological zones (which will be described in more detail in the next chapter). These zones vary in terms of their productivity which varies by region and crop. Moreover, we include the data on the actual available areas of each agro-ecological zone. The standard database includes land only in value terms, land is thus measured in dollar terms and not in terms of area. Including agro-ecological zones in terms of area may facilitate the connection with models concerned with biophysical processes.

The changes made to the existing code for SEAMTAP have been kept as little invasive as possible, i.e. we added changes in a modular fashion and limiting changes to the existing code to a minimum. This allows an easy transfer of the code for including agro-ecological zones to different GTAP models. By exploiting the existing variables in the model we can also easily tract the impact of our introduction of agro-ecological zones. The crucial change is making the technological shifter for land endogenous and depending on the mixture of AEZs used in production. Although land is now a composite 'produced' by AEZs, we kept land as an endowment in the model, reducing changes to the model code to a minimum. Regional household income, for example, is computed from the endowment of land and not from AEZs. By linking the price and quantity of land to AEZs these are indirectly accounted for in the income computations. Apart from allowing an easy transfer of the AEZ module to different versions of the GTAP model this also allows us to assess the impact of the AEZs through the impact of changes in the technology shifter for land, which is a standard feature of welfare decomposition tools for GTAP.

The introduction of AEZs focuses on capturing the suitability of AEZs for specific crops. This is achieved by adding a CES-nest to the value-added part of the crop production function and computing a land composite on the basis of the areas of AEZs used in production. By setting the substitution elasticity very high AEZs become perfect substitutes and the land composite is effectively computed as the sum of areas of the AEZs. To account for the productivity differences among AEZs we then shift the productivity of land based on the mixture of AEZs used in its production. This reduces the incentives to shift AEZs to crops for which they are less suited by 'punishing' the productivity of land.

Explicit modelling of the productivity differences among AEZs does not account for other impediments to shifting like conversion or management costs. This is captured by making the AEZs imperfectly mobile between sectors. We model this through a single level nest as opposed to more elaborate nesting structures among different agricultural sectors employed in the literature (see for example Golub et al., 2007 or van Meijl, 2005) since we already capture the suitability of AEZs for specific sectors through the productivity linkage.

In addition to the introduction of agro-ecological zones we also want to address a particular feature of developing economies, widespread unemployment. To explore this issue we do not need to make additional changes to the model code when we limit ourselves to two extremes, namely full employment with wages adjusting to maintain equilibrium on the labour market (the standard assumption in GTAP-AGR) and widespread unemployment causing real wages to be fixed while employment adjusts to the demand for labour by production activities. These two contrasting assumptions on the way in which the labour market works can be modelled through a change in closure defining endogenous and exogenous variables in the model. In the case of full employment the amount of available labour is fixed exogenous and wages are endogenous. For the unemployment closure we make the availability of labour endogenous while the real wage is fixed. The choice of closure can have a major impact on model results and we will contrast the impact of trade liberalization using two versions of the model.

3 SEAMTAP data

This chapter documents the data used in SEAMTAP and the baseline projection that will serve as a reference point for the simulations later in this report. We start by discussing the GTAP base-data that which form the core of the model data. We then discuss the agro-ecological zone data that have been added in SEAMTAP. We end by defining parameters for the baseline projection that will serve as a reference for the model simulations.

3.1 GTAP base-data

The core of the database on which SEAMTAP runs is the standard GTAP database. To be in line as much as possible with the 2003 base-year used in SEAMLESS we build the SEAMTAP model using the GTAP 7 final release candidate of November 2008 which reflects the world economy in 2004. The database itself contains 113 regions and 57 sectors. In order for the model to be manageable we aggregated the data to 12 regions and 22 sectors. Annex A describes the mapping used for this aggregation.

Given our focus on developing countries and on the impact of agro-ecological zones on model results we aggregated the regions on the basis of income level using the World Bank classification of countries in LDC (least developed), low income, middle income and high income countries. The second dimension for aggregation is the dominant type of land in terms of humidity which is directly linked to the length of the growing period. Based on the agro-ecological zones (see below) we distinguish dry land (arid and dry semi-arid land with a growing period of 0 to 119 days), moist land (moist semi-arid and sub-humid land with a growing period of 120 to 239 days) and humid land (growing period of 240 days to year-round production). Combing four income groups with three types of dominant land we arrive at 12 model regions.

For the sector aggregation we maintain as much detail in the agricultural sector as possible resulting in 12 primary sectors and eight processing industry sectors. We aggregate all manufacturing in a single manufacturing sector and all services sectors in single services sector. This leads to a total of 22 sectors with a clear focus on agriculture.

In the remainder of this section we explore some key descriptive of the GTAP data used in SEAMTAP. Table 3.1 starts by presenting GDP and population data. The grouping of countries on income is clearly reflected in the income per capita numbers with especially the middle and high income regions having a distinctly higher income per capita. The differences between the low income and least developed countries are less pronounced. One interesting feature is the distinctly lower income of the LDCs with moist land. This region comprises Senegal, Ethiopia, Malawi, Mozambique, Tanzania, and Zambia thus including some of the poorest countries in the world. Apart from this region there is no very distinct impact of the agro-ecological endowments on the income per capita in the base-data within each income group.

Table 3.2 presents the total value of output and the share of this contributed by primary agriculture, processed agriculture, manufacturing and services. Moving from LDCs to high income countries we see the structural transformation that occurs when incomes rise: agriculture becomes less important, manufacturing increases and then decreases again in relative importance for the high income countries, while services become the dominant sector in high income countries. Services however already represent a significant share of the value of output in LDCs and low income countries which seems to contradict a general view of developing countries relying on agriculture.

Table 3.1: GDP and population data by region

Region	*GDP (US$ billion)*	*Population (million persons)*	*GDP/capita (US$/capita)*
LDC, dry land	115	273	420
LDC, moist land	39	168	233
LDC, humid land	144	361	400
Low income not LDC, dry land	117	197	593
Low income not LDC, moist land	73	142	513
Low income not LDC, humid land	43	83	518
Middle income, dry land	369	193	1906
Middle income, moist land	3386	1816	1865
Middle income, humid land	3301	2012	1641
High income, dry land	13002	434	29976
High income, moist land	7155	262	27359
High income, humid land	13226	463	28571
World	*40970*	*6405*	*6397*

Note: all monetary values are in 2004 US$. Source: GTAP Version 7 database, authors' calculations

Table 3.2: Economic structure by region

Region	**Total output**	**Output by sector (%)**			
	(US$ billion)	*Primary agriculture*	*Processed agriculture*	*Manufacturing*	*Services*
LDC - dry	193	19.5	10.5	23.6	46.4
LDC – moist	69	19.0	11.2	19.5	50.2
LDC – humid	273	12.2	10.3	32.7	44.8
Low income – dry	228	16.6	7.1	28.3	48.0
Low income – moist	90	12.8	1.8	50.5	34.9
Low income – humid	100	7.7	10.1	54.1	28.0
Middle income – dry	704	7.0	7.6	39.0	46.4
Middle income – moist	6615	6.7	7.9	38.5	46.8
Middle income – humid	7679	6.2	5.8	46.2	41.8
High income – dry	22943	1.4	3.3	24.1	71.3
High income – moist	13475	1.7	5.1	33.1	60.2
High income – humid	25383	1.4	4.7	31.3	62.6
World	*77753*	*2.6*	*4.8*	*31.7*	*61.0*

Note: all monetary values are in 2004 US$. Source: GTAP Version 7 database, authors' calculations

To explore the economic structure in some more detail we focus on the pattern in employment over sectors by region (table3.3). The GTAP database distinguishes two types of labour, unskilled and skilled. There is a clear relationship between income level and share of skilled labour in the total labour force, doubling from about 20 in LDCs to 40 percent in high income countries. If we then turn to the share of unskilled labour in labour use by sector we find less pronounced differences. In all regions primary agriculture is dominated by unskilled labour, accounting for 99 percent of labour use in all but the high income regions. Processed agriculture and manufacturing have comparable shares of unskilled labour (roughly about 85 percent) for all regions with again the exception of high income regions that use especially less unskilled labour in manufacturing (about 67 percent). In all regions unskilled labour is used least in the services sector, although a major average contribution remains of 56 percent.

Table 3.3: Employment by sector and region

Region	**Total labour (%)**		**Share of unskilled labour in total labour use (%)**			
	Unskilled	*Skilled*	*Primary agriculture*	*Processed agriculture*	*Manu-facturing*	*Services*
LDC - dry	80.5	19.5	99.0	83.0	88.5	61.9
LDC – moist	80.9	19.1	99.2	83.9	92.3	63.8
LDC – humid	78.1	21.9	99.1	83.9	88.6	68.2
Low income – dry	72.9	27.1	99.0	84.9	86.1	64.7
Low income – moist	71.7	28.3	99.2	86.3	86.2	44.9
Low income – humid	75.8	24.2	99.3	84.5	86.7	58.6
Middle income – dry	72.4	27.6	98.5	85.4	85.1	62.2
Middle income – moist	69.6	30.4	99.0	83.7	84.6	59.4
Middle income – humid	73.6	26.4	98.9	85.0	85.3	63.3
High income – dry	56.7	43.3	94.3	76.6	63.7	54.7
High income – moist	59.6	40.4	93.6	76.2	69.1	55.7
High income – humid	59.8	40.2	95.2	73.1	67.5	56.9
World	*60.2*	*39.8*	*97.1*	*77.4*	*69.7*	*56.3*

Source: GTAP Version 7 database, authors' calculations

We finally take a closer look at the importance of different primary agricultural sectors (table 3.4) The three sectors that dominate in most regions (Vegetables, fruit, nuts; Crops nec; Animal products nec) are in fact aggregated sectors covering a wide range of crops and livestock activities. Moreover, vegetables are high value products making them account for a larger share of the value of primary agriculture. In area terms their contribution will be much more limited since most vegetable activities are highly capital- and labour-intensive while using limited land. Paddy rice production is especially important in humid LDCs and low income countries. This is related to their location in the tropical regions (see below) making the well suited for rice production.

Apart from the composition of agriculture the dependence on imports is an important factor when analyzing the impact of trade liberalization. We therefore also assess for each region self sufficiency (share of domestic production in total use) which indicates the reliance of regions on imports (table 3.5). Focussing on staple crops which are of direct relevance for the livelihoods of the poor we find for wheat a strong reliance on imports by the LDC and low income countries. The moist and humid low income countries are completely dependent on imports for the wheat consumption which may be due to their climatic inability to grow wheat. If trade liberalization would induce large changes in world market prices for wheat this can be expected to especially impact these low income countries. The direction of this impact will depend on the direction prices take.

Table 3.4: Importance of primary sectors by region

Region	Value of output (US$ billion)	Share of sectors in total primary agricultural output (%)											
		Paddy rice	*Wheat*	*Cereal grains nec*	*Vegetables, fruit, nuts*	*Oil seeds*	*Sugar cane, sugar beet*	*Plant-based fibers*	*Crops nec*	*Cattle, sheep, goats, horses*	*Animal products nec*	*Raw milk*	*Wool, silk-worm cocoons*
LDC - dry	38	6.2	1.2	13.0	33.7	3.2	1.5	4.7	21.2	5.2	6.6	1.1	2.3
LDC – moist	13	3.5	2.2	23.6	17.7	4.7	6.2	3.2	24.5	3.5	8.3	1.5	1.2
LDC – humid	33	24.2	1.8	8.8	18.3	2.7	2.7	5.8	16.8	10.0	5.6	1.3	2.0
Low income – dry	38	2.6	5.1	0.6	17.3	0.8	3.8	10.2	7.3	9.9	8.5	31.7	2.2
Low income – moist	12	3.7	0.2	10.6	57.0	1.9	0.9	2.5	7.8	4.5	10.0	0.7	0.3
Low income – humid	8	37.4	0.0	0.8	21.5	1.0	2.2	0.3	18.9	1.6	16.2	0.0	0.0
Middle income – dry	49	5.8	9.1	9.8	25.7	3.1	2.4	5.1	7.3	8.0	10.6	12.0	1.2
Middle income – moist	443	3.9	9.2	8.0	27.9	6.4	3.8	3.5	9.3	6.0	11.5	9.1	1.4
Middle income – humid	478	6.9	2.7	4.5	32.9	7.7	1.5	1.9	8.0	5.6	24.8	2.6	0.9
High income – dry	312	0.5	4.5	8.7	23.4	6.0	0.9	5.5	8.3	14.4	16.3	10.7	0.8
High income – moist	227	0.2	5.2	5.5	23.8	4.5	1.7	2.8	17.7	8.0	17.0	13.7	0.1
High income – humid	353	7.9	2.9	2.6	29.5	1.7	1.5	1.4	18.0	9.2	14.2	10.9	0.2
World	*2003*	*4.9*	*4.9*	*6.1*	*28.0*	*5.2*	*2.0*	*3.2*	*11.7*	*8.2*	*16.2*	*8.7*	*0.9*

Note: all monetary values are in 2004 US$, three most important sectors are highlighted in grey for each region. Source: GTAP Version 7 database, authors' calculations

Table 3.5: Self sufficiency by agricultural sector and region

Region	**Value of net imports** (US$ billion)	**Share of domestic production in total use**											
		Paddy rice	*Wheat*	*Cereal grains nec*	*Vegetables, fruit, nuts*	*Oil seeds*	*Sugar cane, sugar beet*	*Plant-based fibers*	*Crops nec*	*Cattle, sheep, goats, horses*	*Animal products nec*	*Raw milk*	*Wool, silk-worm cocoons*
LDC - dry	38	0.9	0.4	1.0	1.1	1.2	1.0	2.3	1.9	1.1	1.0	1.0	1.0
LDC – moist	13	1.0	0.4	1.0	1.1	1.4	1.0	2.4	1.3	1.0	1.1	1.0	1.0
LDC – humid	33	1.0	0.6	1.0	1.0	0.9	1.0	0.8	1.2	1.0	1.0	1.0	1.0
Low income – dry	38	1.1	0.9	0.9	1.0	0.6	1.0	1.2	0.9	1.0	1.0	1.0	1.0
Low income – moist	12	1.0	0.0	0.9	1.0	1.1	1.0	2.5	4.2	1.0	1.0	1.0	1.0
Low income – humid	8	1.0	0.0	0.9	1.2	1.5	1.0	0.1	2.5	1.0	1.0	0.4	0.9
Middle income – dry	49	1.0	0.8	0.8	1.1	0.7	1.0	1.1	1.0	1.0	1.0	1.0	1.0
Middle income – moist	443	1.0	0.9	1.0	1.1	0.9	1.0	0.9	1.0	1.0	1.0	1.0	1.0
Middle income – humid	478	1.0	0.8	1.1	1.1	1.0	1.0	0.7	1.3	1.0	1.0	1.0	0.8
High income – dry	312	1.3	2.1	1.3	1.0	1.6	1.0	1.4	0.9	1.0	1.0	1.0	2.4
High income – moist	227	0.8	1.2	1.0	0.8	0.8	1.0	1.0	0.8	1.0	1.0	1.0	0.4
High income – humid	353	1.0	0.7	0.6	0.9	0.4	1.0	0.7	0.9	1.0	0.9	1.0	0.6

Note: all monetary values are in 2004 US$, values above 1 indicate net exports, values below 1 indicate net imports, self-sufficient shares of less than 0.75 are marked in grey. Source: GTAP Version 7 database, authors' calculations

3.2 Agro-ecological zone data used in SEAMTAP

The standard GTAP database does include land as a production factor, next to (skilled and unskilled) labour, capital and natural resources (used in extraction industries). The GTAP database however does not distinguish between different types of land. Variations in productivity are incorporated very indirectly since all factors of production are measured in monetary terms. Thus the amount of land available for production in a specific country is not expressed in area terms but in an amount of money representing the value of land in production (measured in 2004 million US dollars to be precise). In case land is very unproductive in a specific region the value of land will be lower as well. However, the total value of land could also be low because of a small territory (and with average to high productivity). The standard GTAP database is thus not well suited to account for the obvious differences in the productivity of land.

Recently an expansion of the standard GTAP dataset has recently been made available (Lee, Hertel *et al.*, 2005). This land use database aims at providing input for quantitative analyses of (changes in) greenhouse gas emissions and provides the first global dataset on land use and land endowments compatible with the GTAP database. The latest version of this dataset, the agro-maps dataset (released in October 2007) contains data on land cover, area harvested and production for 175 crops and 157 countries for the year 2000. The construction of this database is documented in Monfreda et al. (forthcoming).

The data in the agro-maps dataset distinguish 18 agro-ecological zones defined through a combination of length of growing period (LGP) and climate (tropical, temperate and boreal) (see table 3.6). Computing the share of each agro-ecological zone in total land area we find 34% of land in the tropics, 41% in temperate zones and 25% in boreal zones. Computing the shares of AEZs in crop areas we the percentages change since little crop cultivation occurs in the colder regions, reflected by only accounting for 5% of crop area. Most cropland is located in the temperate regions, accounting for 60% of cropland.

Apart from total area available for cultivation the productivity of the land in crop production affects the agricultural potential of different regions in the world. The agro-maps database contains harvested area and production allowing us to compute a yield by crop and agro-ecological zone. Ignoring for now the difference between countries we can establish for each crop the agro-ecological zone with the highest yield. Normalizing the yields to range from 0 to 1 for the highest yield provides an overview of potential of each AEZ for the eight crops distinguished in the GTAP database (figure 3.13.1).

The first thing to note in figure 3.1 is the importance of water availability. Especially for the temperate and boreal zones more humid AEZs (AEZ 10 through 12 and AEZ 16 though 18) are more productive. The arid AEZs (AEZ 1, 7 and 13) show a clear dip in productivity for all crops. Another noteworthy aspect is that for most crops the lower productivity AEZs are concentrated in the tropical AEZs (exceptions are sugar crops and oil seeds). The data on the productivity thus indicate that developing countries have less productive land endowments.

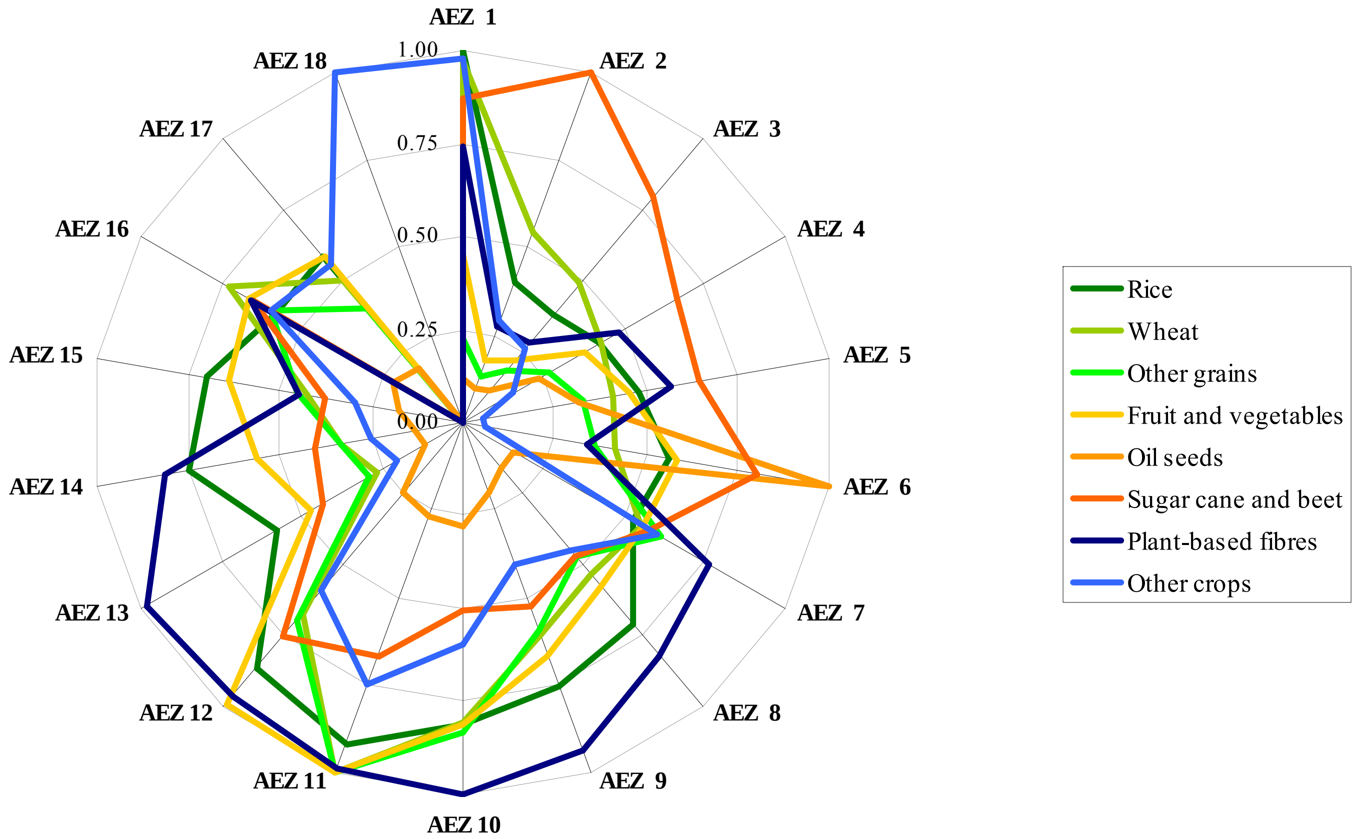
The dataset clearly reflects the correlation between climate and income group (figure3.2). Graphing the share of the AEZs by country income group we find the least developed and low income countries predominantly located in the tropics, while high-income countries are located in temperate and boreal zones. The middle income countries are more dispersed over tropical and temperate zones.

Table 3.6: Definition of agro-ecological zones in GTAP

Climate	Moisture	Length of growing period (days)	Zone	Share of world area (%)	Share of crop area (%)
Tropical	Arid	0-59	AEZ 1	7.06	1.64
	Dry semi-arid	60-119	AEZ 2	2.31	3.40
	Moist semi-arid	120-179	AEZ 3	3.89	7.50
	Sub-humid	180-239	AEZ 4	5.12	7.45
	Humid	240-299	AEZ 5	6.25	7.14
	Humid, year-round growing season	>300	AEZ 6	9.79	7.96
				34.42	*35.08*
Temperate	Arid	0-59	AEZ 7	17.76	7.02
	Dry semi-arid	60-119	AEZ 8	5.45	12.02
	Moist semi-arid	120-179	AEZ 9	4.74	11.50
	Sub-humid	180-239	AEZ 10	5.93	15.55
	Humid	240-299	AEZ 11	3.24	7.39
	Humid, year-round growing season	>300	AEZ 12	3.82	6.11
				40.95	*59.59*
Boreal	Arid	0-59	AEZ 13	4.72	1.82
	Dry semi-arid	60-119	AEZ 14	10.38	1.13
	Moist semi-arid	120-179	AEZ 15	8.97	2.22
	Sub-humid	180-239	AEZ 16	0.49	0.17
	Humid	240-299	AEZ 17	0.04	0.00
	Humid, year-round growing season	>300	AEZ 18	0.02	0.00
				24.63	*5.33*

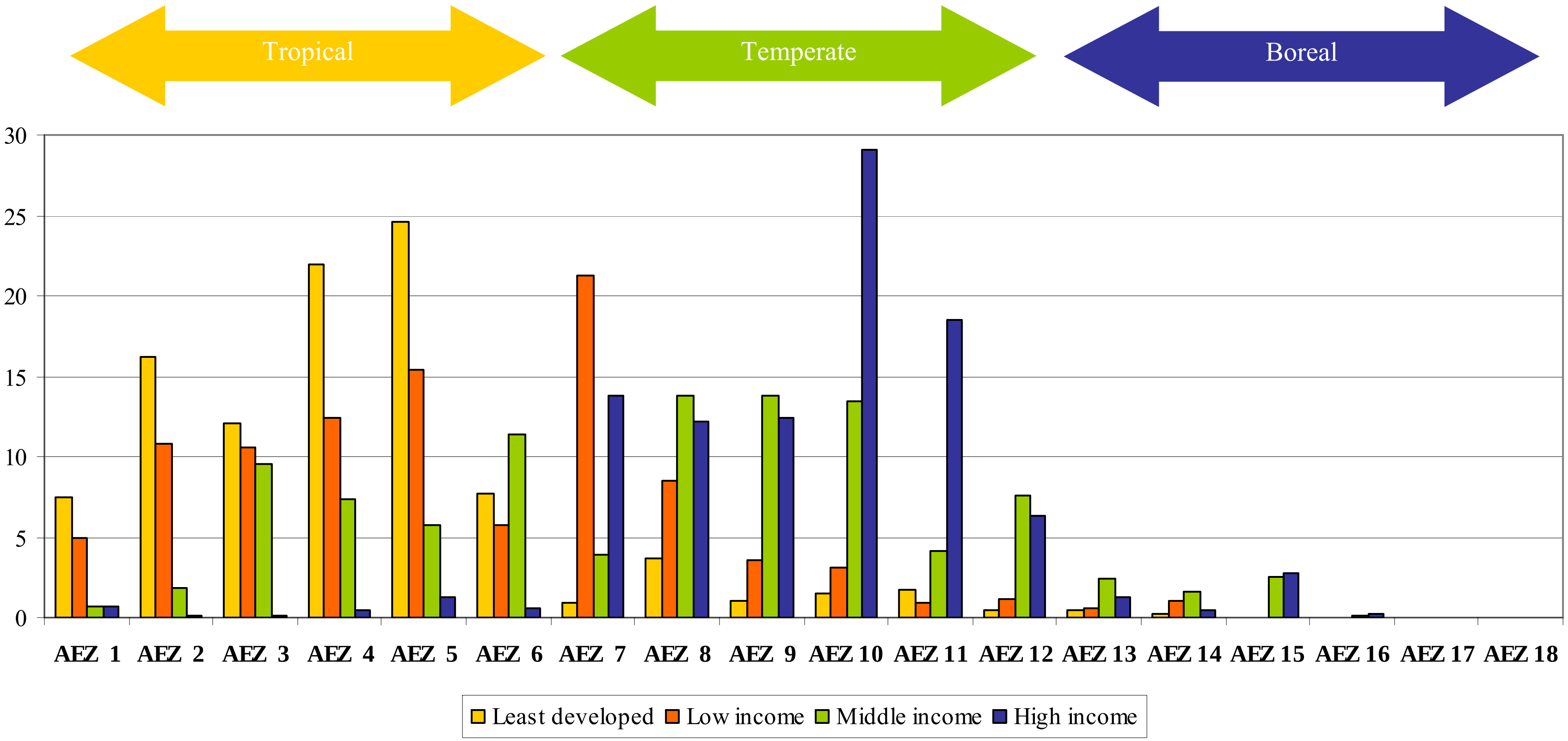
Source: Agro-maps as documented in Monfreda et al. (forthcoming), authors' calculations

Figure 3.1: Productivity index of AEZs by GTAP crop



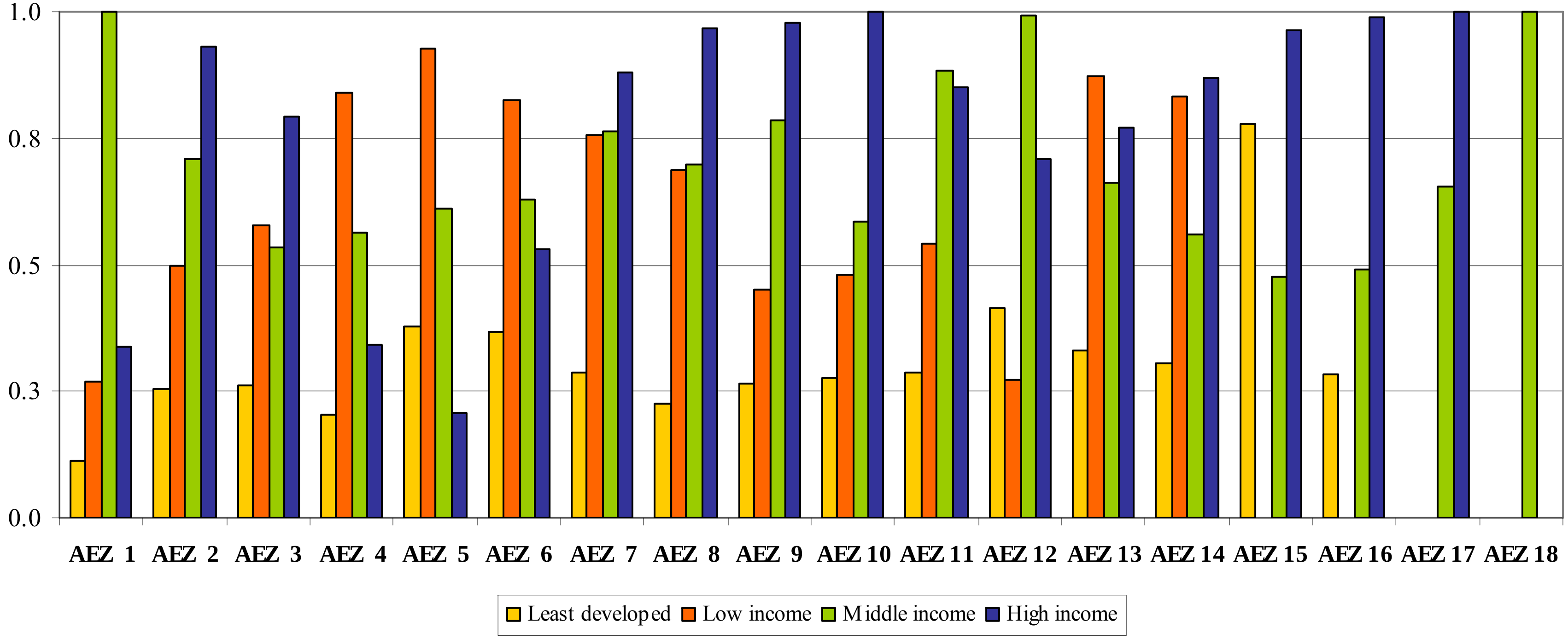
Note for description of AEZ see table 3.63.6 (Tropical AEZ 1 - 6; Temperate: AEZ 7 - 12; Boreal: AEZ 13 - 18). Source: agro-maps as documented in Monfreda et al. (forthcoming), authors' calculations.

Figure 3.2: Agro-ecological zones by country group (percentage of total land by country group)



Note for description of AEZ see table 3.6 (Tropical AEZ 1 - 6; Temperate: AEZ 7 - 12; Boreal: AEZ 13 - 18). Source: agro-maps as documented in Monfreda et al. (forthcoming), authors' calculations.

Figure 3.3: Average productivity by agro-ecological zones by country group (average productivity index)



Note: for description of AEZ see table 3.6 (Tropical AEZ 1 - 6; Temperate: AEZ 7 - 12; Boreal: AEZ 13 - 18). Source: agro-maps as documented in Monfreda et al. (forthcoming), authors' calculations. The average productivity by AEZ is computed as the simple average of the productivity index by crop and country (the country with the highest yield of a crop gets a index of one).

The lower productivity on tropical AEZs even holds for paddy rice, an archetypical tropical crop. This points to the importance of other factors than biophysical determining yields. The yields in the land use dataset are observed yields. This implies that the indirect impact of for instance limited infrastructure on the use of fertilizers is included in the yield (which may account for part of the lower yields observed in developing countries). Differences in yields by AEZ across countries thus include differences in biophysical differences not captured by the AEZs (like differences in soil nutrients not captured by the AEZ definition) as well as socio-economic differences affecting production decisions. These socio-economic differences include variation in labour, capital and intermediate input use since there are no data on inputs besides land in the land use dataset. In case of paddy rice it may well be that tropical AEZs are best suited from a bio-physical point of view, but that the availability of external inputs and large machinery in countries located in temperate zones results in a higher yield.

To get a feel for the impact of non-biophysical factors on observed yields we compared average productivity indexes by AEZ for the country groups (figure 3.4). This provides a rough indication of the relative productivity of the AEZs by country group. Figure 3.4 provides the clearest pattern for the least developed countries. Their productivity is about a third of that of most productive country. With the exception of AEZ 15 (of which these countries have nearly nothing according to figure 3.2) the least developed countries harvest much less than the other three country groups. The low income countries clearly perform better, even having the highest average productivity on the humid tropical land (AEZ 4 to 6). The high income countries mainly have AEZs 7 to 12 (see figure 3.2) and by far attain the highest yields on these. Although a rough indication, the average productivity by AEZ does indicate that factors other than bio-physical constraints hamper the production in especially the least developed countries.

In SEAMTAP we use a country, crop and AEZ specific productivity index. The AEZ with the highest production potential in one country is therefore not necessarily the same as in another country.

3.3 Data on harvested areas by crop and AEZ used in SEAMTAP

The AEZ database is for the year 2000. The most recent version of GTAP however reflects the state of the world economy in 2004. We therefore update (part of) the data on agro-ecological zones using FAO data. Because of data availability we only update the harvested areas. Apart from a lack data needed for such an update we do not expect major shifts in availability of land nor productivity that would show at the level of the model regions between 2000 and 2004.

For the harvested areas we use data from the FAO. Although the AEZ database stems from the FAO data it undergoes a whole series of consistency checks and modifications. Furthermore, the FAO data do not distinguish harvested areas by AEZ. We therefore do not want to fully replace the 2000 harvested areas with those from the FAO. Instead we compute a change in areas by crop between 2000 and 2004and use this to update the 2000 data to 2004. Harvested areas in both years are computed as a three year average (1999-2001 and 2003-2005) to reduce the impact of an unusual year on the results.

Another modification of the data is to consolidate the harvested areas and total available area. The data on harvested areas include the multiple cropping, i.e. if an area is harvested twice it will be counted twice in the harvested area. This implies that the total harvested area of an AEZ can exceed the available area of AEZ, which violates the land constraint in SEAMTAP (that does not account for multiple cropping). Lacking further data on multiple cropping we opt for a pragmatic solution of scaling the total harvested area to the total available area. Note that although we satisfy the constraint on available land we overestimate the area of crops for which multiple cropping occurs.

Table 3.7 presents the total crop area (computed as the sum of area occupied by the eight crops for which we have AEZ data) and the shares of each type of AEZ in this total. The grey marking of three largest AEZs by region already indicate quite some variation within each region despite the grouping on availability of water. For the LDCs with dry land, for example, we find that although dry land (computed as the sum of AEZ 1, 2, 7, 8, 13 and 14) is comprises the largest area (49.6 percent) the second and third largest areas are in found in AEZ 4 (sub-humid) and AEZ 5 (humid).

To get some more insight in the variability within and between regions we take a closer look at the productivity by region (figure 3.4). In terms of model results the area weighed productivity index is the most relevant indication of average productivity. The closer this measure is to one the more productive the land is in a region. Note that we do not compare yields between regions, the productivity index is computed for each combination of crop and region. The figure thus gives no information on which regions are most productive. The figure does provide an indication of the variability in productivity within a region first of all by the difference between the area weighed and simple average productivity. Secondly, we included the lowest productivity index found for each region (excluding zeros for crops that are not grown in a specific region. In the figure we also indicate the number of countries or GTAP regions included in each of the 12 model regions. Generally one would expect more diversity if more countries and regions are comprised in a model region.

The three model regions comprising more than 20 countries or regions from the GTAP database to not seem to have a higher variation in productivity than the other regions. Comparing area weighed and simple average productivity we find for all regions the area weighed productivity to exceed the simple average productivity. Cropping thus seems to concentrate on areas most suited for agriculture. The only exception is the LDCs with dry land, which may indicate use of marginal lands in these regions and limited expansions of productive areas.

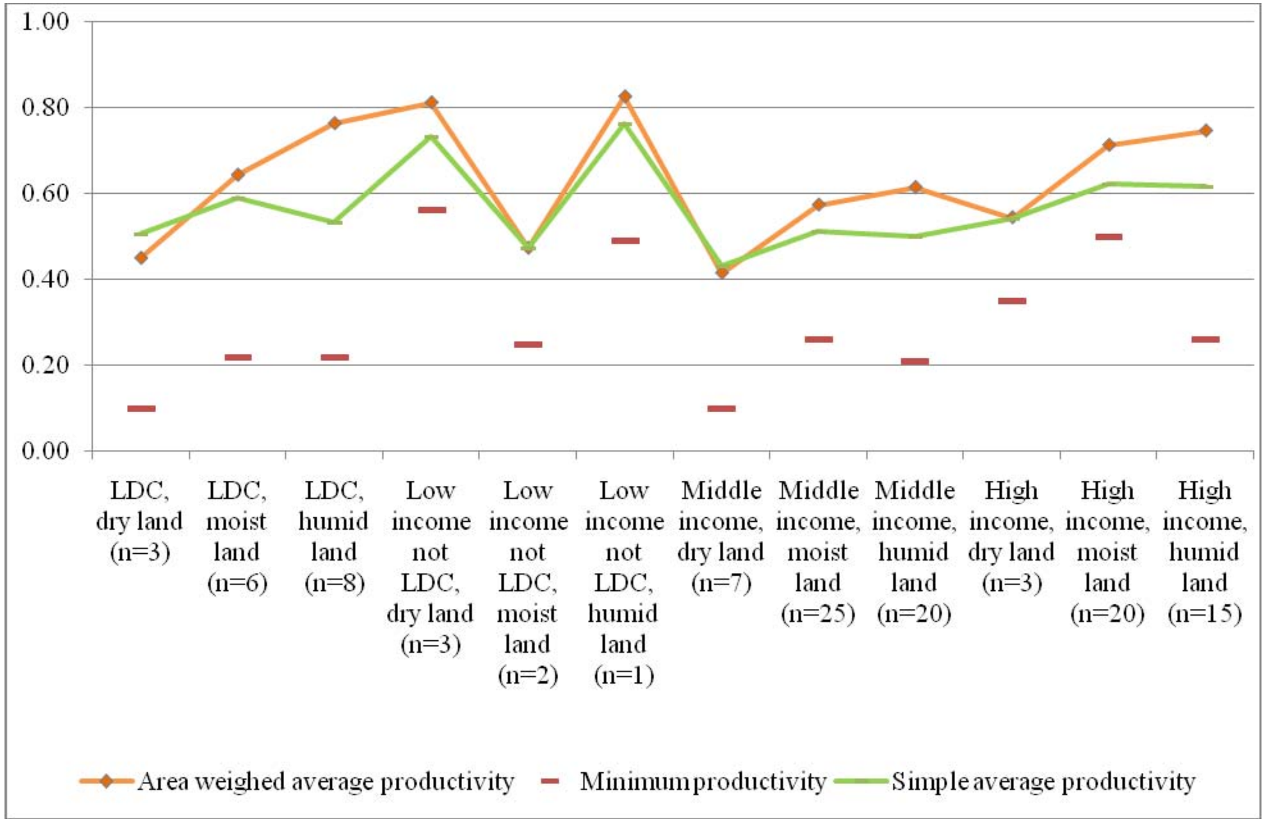
The group of low income regions displays the widest variation between regions which can probably be attributed to the small number of countries in each group. This limits the variation within each model region but also makes the totals for each model region depending on the specific features of the few countries comprising it.

Table 3.7: Agro-ecological by region in SEAMTAP

Region	**Crop area** *(million ha)*	**Share of agro-ecological zone in total crop area (%)**															
			Tropical						*Temperate*						*Boreal*		
		AEZ 1	AEZ 2	AEZ 3	AEZ 4	AEZ 5	AEZ 6	AEZ 7	AEZ 8	AEZ 9	AEZ 10	AEZ 11	AEZ 12	AEZ 13	AEZ 14	AEZ 15	AEZ 16
LDC - dry	82	13.2	25.9	11.8	15.8	14.9	5.5	1.8	7.2	0.1	0.7	1.1	0.4	1.0	0.5	0.0	0.0
LDC – moist	30	2.2	12.4	22.7	37.4	8.9	0.8	0.0	0.6	4.8	4.8	4.8	0.6	0.0	0.0	0.0	0.0
LDC – humid	65	1.3	2.9	5.4	22.5	51.4	12.7	0.0	0.1	0.3	0.6	1.9	0.8	0.0	0.0	0.0	0.0
Low inc. – dry	33	9.2	0.0	0.0	0.0	0.0	0.0	51.7	19.3	4.4	7.3	2.1	2.0	1.5	2.6	0.0	0.0
Low inc. – moist	40	2.4	22.0	21.4	24.8	20.1	3.5	0.6	1.3	3.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Low inc. – humid	8	0.0	0.0	0.0	1.0	54.9	40.3	0.0	0.0	0.0	0.0	0.1	3.7	0.0	0.0	0.0	0.0
Middle inc. – dry	47	5.3	0.5	0.1	0.1	0.3	0.9	17.6	27.4	4.4	0.9	0.5	0.2	34.5	5.2	1.3	0.7
Middle inc. – moist	502	0.7	3.0	15.9	10.3	3.2	2.2	3.9	16.4	17.6	18.7	0.8	0.3	0.7	2.1	4.1	0.1
Middle inc. – humid	332	0.0	0.3	1.7	3.6	8.2	27.1	2.3	8.5	9.8	7.7	9.6	19.7	0.5	0.2	0.6	0.2
High inc. – dry	229	1.1	0.1	0.1	0.1	0.0	0.0	19.5	17.9	11.8	23.6	17.1	7.6	0.8	0.1	0.0	0.0
High inc. – moist	106	0.0	0.0	0.0	0.0	0.0	0.0	8.2	5.8	19.7	46.2	5.0	0.2	2.9	1.4	9.9	0.8
High inc. – humid	53	0.0	0.0	0.0	2.7	9.1	4.2	0.0	0.0	0.2	18.3	51.8	12.6	0.0	0.1	0.6	0.5
World	*1528*	*1.6*	*3.4*	*7.5*	*7.4*	*7.1*	*8.0*	*7.0*	*12.0*	*11.5*	*15.6*	*7.4*	*6.1*	*1.8*	*1.1*	*2.2*	*0.2*

Note: AEZ 17 and AEZ 18 are excluded from the table since shares do not exceed 0.0 percent, the three largest AEZs are marked in grey for each region, for a description of AEZ see table 3.6 (Tropical AEZ 1 - 6; Temperate: AEZ 7 - 12; Boreal: AEZ 13 - 18). Source: agro-maps as documented in Monfreda et al. (forthcoming), authors' calculations.

Figure 3.4: Area weighed, simple average and minimum productivity index by region.



Source: agro-maps as documented in Monfreda et al. (forthcoming), authors' calculations.

3.4 Baseline parameters for SEAMTAP

In SEAMLESS two different baselines are used. One reflects the world in 2013 aimed at medium term assessments of mainly economic policies and one reflects a longer time horizon reflecting the world in 2020. Given the phasing in of the WTO agreement we will use 2020 as baseline year. This will allow us to assume that all reductions have been implemented which greatly simplifies the scenario definitions.

When constructing the baseline we need to extrapolate autonomous developments of key variables occurring during the year of our database (2004) to the reference year of 2020. Our baseline focuses on replicating projected changes in GDP and population in the 2004 and 2020 period from the ERS (table 3.8).

Table 3.8: GDP and population projections (2004 – 2020) and projected technical change (%)

	ERS projections		**Projected changes in factor augmenting technical change**	
	GPD	*Population*	*Labour*	*Natural resources*
LDC, dry land	108.3	46.0	54.6	27.3
LDC, moist land	123.9	37.8	70.8	35.4
LDC, humid land	132.9	41.4	89.8	44.9
Low income not LDC, dry land	141.5	33.1	97.6	48.8
Low income not LDC, moist land	133.3	42.6	154.7	77.3
Low income not LDC, humid land	195.5	16.6	198.8	99.4
Middle income, dry land	115.6	20.0	105.8	52.9
Middle income, moist land	136.7	18.5	111.9	55.9
Middle income, humid land	191.6	13.6	168.8	84.4
High income, dry land	59.9	22.0	32.2	16.1
High income, moist land	44.2	1.8	42.2	21.1
High income, humid land	47.8	3.1	43.6	21.8

Source: ERS (data of 17 December 2007) authors' calculations, technical change projections with SEAMTAP

In our baseline projection we set the growth of the labour force equal to the population growth projections. We furthermore assume that capital endowments grow at the same rate as GDP. We then run a baseline scenario with SEAMTAP whereby we set GDP exogenous to the projected increase while making technological change endogenous. We furthermore assume that technological change only occurs for labour (both skilled and unskilled). We capture growth in availability of natural resources (for example due to oil explorations) through natural resource augmenting technical growth that is an (arbitrary) halve of the growth in labour productivity.

The aim of our baseline is to capture three stylized facts on economic growth. *Capital grows strong relative to labour*, which is attained by having capital growing at the rate of GDP growth. *Capital grows at about the same rate of output* which is also attained by having capital growing at the rate of GDP growth. *Labour and capital shares in GDP are approximately constant with real wages growing and capital returns remaining constant.* To attain this last stylized fact we need to make technical change more rapidly labour saving than capital saving which is attained by setting the technical change for capital to zero. Table 3.9 presents for the baseline real wages by labour type and returns to capital as well as the ratio between labour and capital contributions to GTAP. There are some minor changes for capital but these are insignificant compared to the large increases real wages in all regions. The ratio between labour and capital in GDP also remains the same with changes limited to 5.6 percent.

Table 3.9: Real wage, capital return and ratio of contribution to GDP in 2020 baseline (% change compared to 2004)

	Real factor prices			**Ratio labour/capital**
	Unskilled labour	*Skilled labour*	*Capital*	
LDC, dry land	23.8	41.7	-2.0	-2.8
LDC, moist land	47.4	68.9	0.2	-2.9
LDC, humid land	48.9	56.6	-6.1	1.8
Low income not LDC, dry land	73.9	79.2	-2.8	0.3
Low income not LDC, moist land	21.5	98.4	-2.2	5.6
Low income not LDC, humid land	122.1	126.6	-8.0	-1.5
Middle income, dry land	70.2	75.4	-5.1	2.4
Middle income, moist land	94.3	100.9	-1.4	-0.1
Middle income, humid land	153.7	157.6	-0.9	-0.6
High income, dry land	32.0	32.5	0.2	0.2
High income, moist land	42.6	44.1	1.2	-0.2
High income, humid land	44.6	46.0	1.4	-0.2

Source: SEAMTAP

4 Simulations results

Having developed a model which accounts for differences in land productivity and developed a baseline simulation of the situation in 2020 keeping all policies as they are in 2004 we are now ready to analyze the impact of multilateral trade liberalization. We first define a scenario that can be analyzed in SEAMTAP. We then explore the impact on the global economy with a special focus on developing countries with the standard assumption of full employment. In this assessment we compare the results of SEAMTAP to results obtained with GTAP-AGR on which SEAMTAP is based to assess the impact of explicitly accounting for productivity differences between agro-ecological zones. We focus the comparison on changes in agricultural production where we expect the main impact of the inclusion of AEZs.

The last part of this chapter assesses the impact of accounting for unemployment in all but the high-income regions. We compare the results of SEAMTAP with full employment to the results of a version of SEAMTAP with unemployment focussing on changes in income and employment.

4.1 Multilateral trade liberalization scenario

The trade liberalization scenario is based on the December 8th 2008 modalities for trade liberalization. These consist of two main parts: agricultural and non-agricultural trade liberalization. There are also negotiations ongoing for liberalization of services but these negotiations are in a much less advanced stage than those for agriculture and manufacturing goods. We therefore do not include services liberalization in our scenario.

4.1.1 Reduction of agricultural tariffs

The agricultural modalities consist of three main parts: domestic support, market access and export competition. Our scenario only addresses the latter two parts. Although impressive cuts on *domestic support* are proposed in the modalities (with reductions up to 85 percent) these cuts are expected to have a limited effect on the EU and the United States which are the two key players in terms of domestic support. For the EU the use of a historic reference point (1995 - 2000) combined with a string of CAP reforms since implies that no additional changes in agricultural policy would be needed to satisfy WTO commitments (Jean et al., 2008). The agricultural modalities would in principle limit United States policies (Blandford, 2008). There are however specific provisions for the United States included in the agricultural modalities and notified levels of support may be decreased by labelling policies as non-trade distorting. Given their recent agricultural policies which maintain farm support and reluctance to adhere to the WTO ruling on cotton support we expected that a WTO agreement will only be acceptable to the United States if it does not require a change in policy.

The reductions in agricultural tariffs in our scenario are derived from the *market access* part of the modalities. We account for the difference between bound tariffs (the maximum tariffs a WTO member is allowed to levy on imports from other WTO members) and actually applied tariffs. Especially in the case of developing countries there is a generally a large gap between bound and applied tariffs implying that a reduction in the bound tariff does not affect the tariffs actually applied on imports. In addition the December 6th modalities describe a large set of exceptions for specific products (sensitive products, special products, tropical products, tariff escalation provisions) or specific regions (least developed, recently acceded WTO members, small and vulnerable economies). Exceptions are defined at very detailed level (tariff line level for most product exceptions which are very detailed descriptions of specific products) whereas in our modelling exercise we model most countries as regional aggregates and we do not distinguish products at tariff line level. We ignore these exceptions which provides a simplified representation of the actual proposal and overestimates the impact of the tariff reductions.

The third component of the modalities (*export competition*) consists of eliminating export subsidies, subsidized export credit, food aid used to dispose of surplus production and privileged treatment of parastatal export. Of these only exports subsidies are reflected in the GTAP database which we eliminate in our scenario.

Agricultural tariff reductions are based on tiered formulas with four bands. This means that the tariffs are placed in four groups based on their initial size and each of these groups has a different reduction percentage. The main idea is that tariffs that are high will be cut more than tariffs that are low and thus not very trade distorting. The WTO formula's work with tariffs expressed in ad valorem equivalents (AVEs) expressed in percentages. In case of ad valorem tariffs (tariffs expressed as a percentage of the price of the product) the AVE is equal to the ad valorem tariff. Non-ad valorem tariffs, like for example a tariff stipulating that a 100 euro is levied on each ton of imported product, are converted to AVEs using a formula negotiated among the WTO members.

Having established all AVEs the application of the tariff reduction is a straightforward reduction of the AVEs with the level of the cut depending on the initial level of tariff. Table 4.1 presents the cuts for each tier for both the G20 and WTO proposal. Also keep in mind that the reductions are applied to bound tariffs and may have a very limited impact on actually applied tariffs.

Table 4.1: Tiered formula for agricultural tariff reductions

Reductions for developed countries (in %)		**Reductions for developing countries (in %)**	
Thresholds for tariffs[1)]	WTO	*Thresholds for tariffs*[1)]	WTO
0 ≤ 20	50	0 ≤ 30	33.33
20 ≤ 50	57	30 ≤ 80	38.00
50 ≤ 75	64	80 ≤ 130	42.67
>75	70	>130	46.67

[1)] Tariffs are translated to Ad Valorem Equivalents (AVEs) to determine which reduction percentage applies. Note: least developed countries do not reduce their tariffs while receiving duty-free access to other WTO members' markets.

Note that different threshold for the four tiers apply for developed (rich OECD countries) and developing countries (the rest of the world). This is typical for WTO agreements and referred to as special and differential treatment (SDT). Within the group of developing countries the least developed countries (LDCs) are treated differently. LDCs are not required to make any tariff reductions while all tariffs on imports from these countries by developed and other developing countries are reduced to zero. We implement this as a complete removal of all tariffs on imports from LDCs thereby ignoring limitations posed by rule of origin provisions and exception for sensitive products like sugar imports for the EU.

4.1.2 Reduction of non-agricultural tariffs

The scenario is based on the modalities of non-agricultural market access (NAMA) as of December 6th, 2008. These modalities describe in detail the reductions in tariffs for different groups of countries. The non-agricultural or NAMA market access negotiations are based on a "Swiss formula" for reducing tariffs (to be applied to bound tariffs):

$$t_f = [M{\cdot}t_i] / [M + t_i]$$

where t_f, t_i are the final and initial bound rate of duty; M is the coefficient determining the maximum tariff after applying the formula. In order to apply the Swiss formula the coefficient M needs to be determined. In the December 2008 package ranges for final numbers are presented as described in table 4.2. For developing countries there are three options of which two imply a stronger default cut but with room for reducing cuts on specific products. Since these exceptions are hard to implement without the choices of each developing country known we implement the coefficient of 25 without further flexibilities for developing countries. Least developed countries are exempted from making tariff reductions, their obligations are limited to increasing the number of bound tariffs in ad valorem terms. This does not affect applied tariffs and therefore does not affect the scenario definition. Least developed countries shall have duty free and quota free access to developed countries for at least 97% of products from LDCs. The current text however is not clear on which products will be included and what the rules of origin are that will apply and we therefore implemented it for all non-agricultural products.

Several exceptions to the default cuts in non-agricultural tariffs are included in the draft modalities. *Exceptions for members with low binding coverage.* Developing countries with less than 35% of their NAMA tariffs bound do not have to make reductions but are required to bind 75% of their tariffs in case less than 15% of tariff lines has bindings or else bind 80% of their NAMA tariffs. The average bound tariff shall not exceed 30%.

Exceptions for small and vulnerable economies. Small and vulnerable economies are defined as those with less than 0.1% of world 1999-2001 NAMA trade. These economies can opt for an alternative reduction schemes with a value of M between 18 and 30 depending on the average level of their bound tariffs. Lacking information on these levels we implement an average coefficient of 27 for small and vulnerable economies.

*Exceptions for recently acceded members (RAMs).*Two groups of recently acceded members can be distinguished. One group does not have to reduce tariffs beyond the reductions that remain to be implemented following their accession to the WTO: Albania, Armenia, Former Yugoslav Republic of Macedonia, Kyrgyz Republic, Moldova, Saudi Arabia, Tonga, Viet Nam and Ukraine. Of the remaining RAMs China, Taiwan, Oman and Croatia have an extended implementation period of 3 to 4 years. The other RAMs (Ecuador, Georgia, Jordan, Kyrgyz republic, Mongolia and Panama) qualify as small and vulnerable economies and can apply those flexibilities. Since we do not include timing of reductions in our scenario, i.e. we consider the impact of a full implementation of the NAMA reductions, the latter extended implementation period is not accounted for.

Preference erosion. To counter the impact of preference erosion tariff reductions are delayed for a number of products defined in Annex 2 for the EU and Annex 3 for the US to the NAMA text. This delay may affect developing countries that do not benefit from the preferences. For products defined in Annex 3 the reductions are therefore immediately implemented on products originating in developing countries that do not currently benefit from preferential access. Again, not accounting for phasing in of reductions our scenario does not include these delays in implementation.

Next to these key exceptions there are more flexibilities and exceptions included in the NAMA modalities for specific groups of developing countries that we could not include due to lack of conclusiveness of the modalities and/or because countries have various options and we cannot determine which choice will be made.

Table 4.2: Parameters of the Swiss formula for non-agricultural market access

Countries	*July 2008 text*	*Additional flexibilities*	*Scenario*	*Phasing*
Developed	8	-	8	5 years (6 equal rate reductions)
Developing	20	(i) less than formula cuts for up to 14 percent of non-agricultural national tariff lines provided that the cuts are no less than half the formula cuts and that these tariff lines do not exceed 16 percent of the total value of a Member's non-agricultural imports; or (ii) keeping, as an exception, tariff lines unbound, or not applying formula cuts for up to 6.5 percent of non-agricultural national tariff lines provided they do not exceed 7.5 percent of the total value of a Member's non-agricultural imports.	-	-
	22	(i) less than formula cuts for up to 10 percent of non-agricultural national tariff lines provided that the cuts are no less than half the formula cuts and that these tariff lines do not exceed 10 percent of the total value of a Member's non-agricultural imports; or (ii) keeping, as an exception, tariff lines unbound, or not applying formula cuts for up to 5 percent of non-agricultural national tariff lines provided they do not exceed 5 percent of the total value of a Member's non-agricultural imports.	-	-
	25	No flexibilities	25	10 years (11 equal rate reductions)
Least developed	-	-	-	-

Note: Reductions to be applied to bound tariffs, in case of unbound tariffs the 2001 applied MFN rate + 25 percent points shall be used; non-ad valorem duties shall be converted to ad valorem equivalents based on method in document TN/MA/20 using 1999-2001 import data; implementation of reductions shall start January 1st of the year following the entry into force of the DDA (NAMA text, p3).

4.1.3 Implementation of reductions in SEAMTAP

The tariff reduction components of the NAMA scenario are constructed using a data detailing bilateral trade at 6-digit product and country level, the MAcMap dataset Version 2.1 with data for 2004 (Bouët et al., 2004). We implement the formulas at this detailed level and the resulting changes in tariffs are then aggregated to SEAMTAP sectors and regions to be implemented in the model[1].

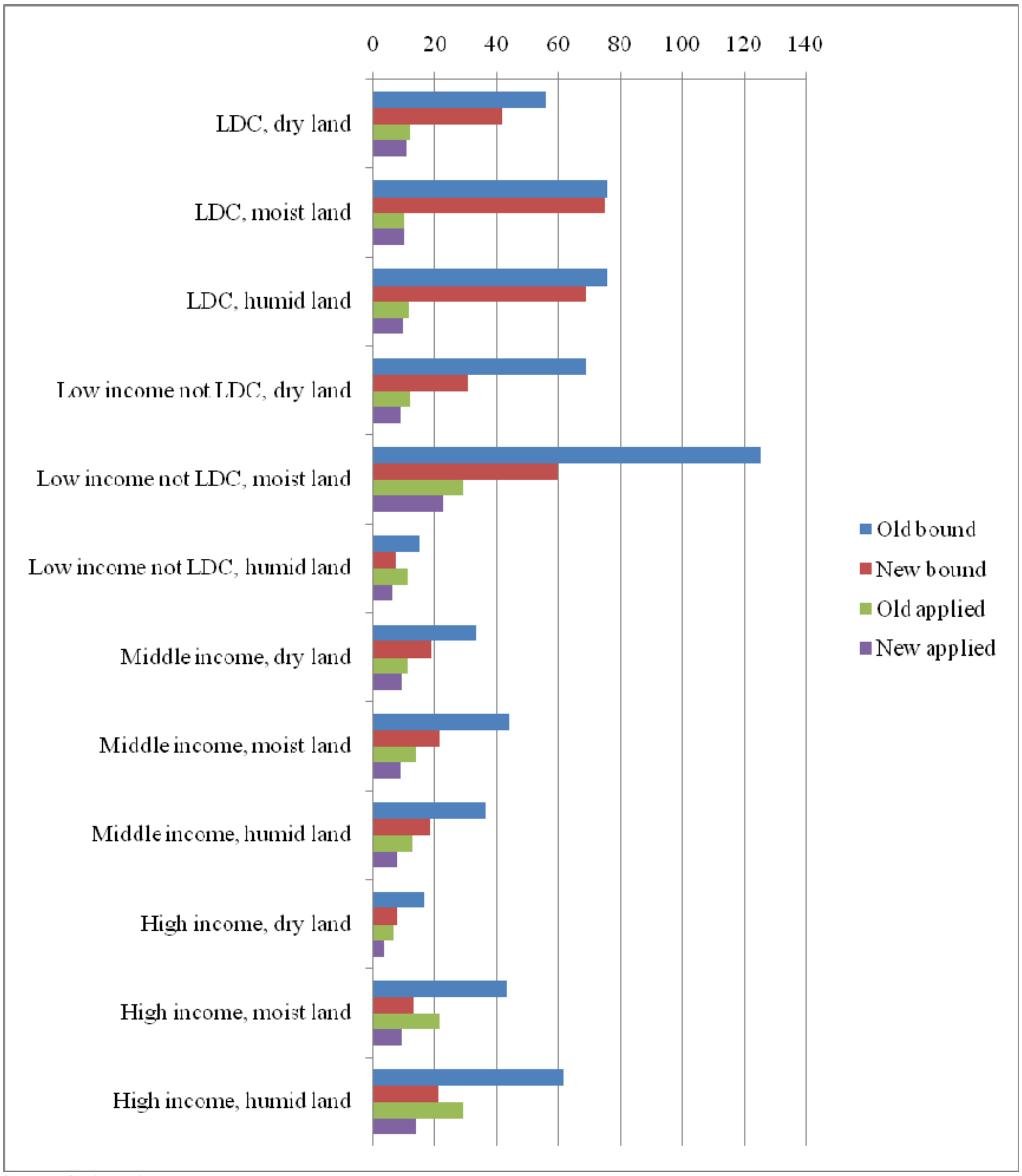
SEAMTAP models all trade flows bilaterally, i.e. for each product all bilateral trade and thus tariffs are traced. For readability we averaged all tariffs over regions and products to get the average bound and applied tariff levied by region (figure 4.1). The first thing to note is that for the LDCs and low income countries there is a wide gap between the old bound tariffs and old applied tariffs. There is thus significant water in the tariffs minimizing the impact of tariff reductions on applied rates. Although LDCs are fully exempt from making tariff reductions in the Doha round figure 4.1 still shows small declines in tariffs. This is due to the fact that some aggregate GTAP regions comprising also non-LDCs are included in the LDC model regions. The largest reductions in applied tariffs are found for the high income countries this is due to limited water in the tariffs and the higher reductions applicable for developed countries.

Whereas figure 4.1 presents the reductions countries have to make on their own tariffs the other side of the coin is the increased access to third country markets. Figure 4.2 presents a similar average as figure 4.1 but now focuses on tariffs faced by the regions. First of all note the difference in scale which runs up to 140% with tariffs levied and only up to 70% for tariffs faced in figure 4.2. This reflects that the limited contributions of the LDCs and low income countries to global trade. Most trade is directed at the middle and high income countries which have lower tariffs. Since we weigh all tariffs by trade flows in the aggregation procedure this dominance of trade with high and middle income countries is reflected by the much lower level of tariffs faced compared to tariff levied. As expected LDCs have the strongest reductions in applied tariffs since they benefit from special and differential treatment providing them with duty free access to third markets.

The second component of our trade liberalization scenario is an abolition of export subsidies. Again the subsidies are traced for all bilateral flows but for the sake of readability table 4.3 presents the average reduction in export subsidies for the regions imposing these subsidies. With the EU being a major user of export subsidies as part of its common agricultural policy it is not surprise that the major changes in subsidies are found among the high income regions (note that because of differences in climate EU member states belong to different model regions).

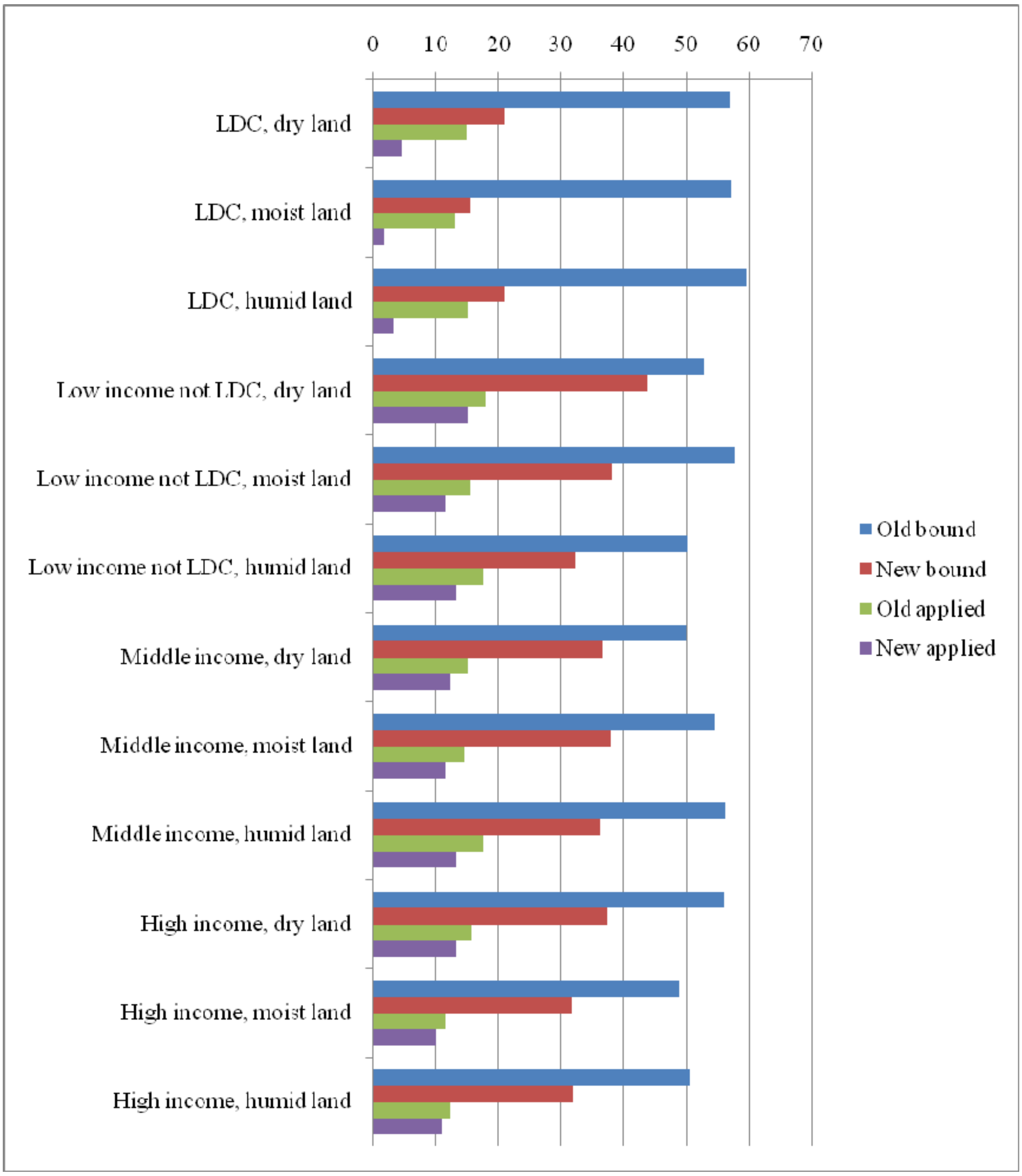
[1] The aggregation is done with the TASTE program developed by Mark Horridge and David Laborde available at http://www.monash.edu.au/policy/taste.htm.

Figure 4.1: Simple average of bound an applied tariffs levied on imports from third countries, before and after the applying tariff reductions by region (%)



Source: SEAMTAP

Figure 4.2: Simple average of bound an applied tariffs faced on exports to third countries, before and after the applying tariff reductions by region (%)



Source: SEAMTAP.

Table 4.3: Average change in export subsidies by sector and region (%)

	Cereal grains nec	*Vegetables, fruit, nuts*	*Cattle, sheep, goats, horses*	*Meat: cattle, sheep, goats, horse*	*Meat products nec*	*Dairy products*	*Processed rice*	*Sugar*	*Food products nec*	*Beverages and tobacco*	*Manufacturing*
LDC - dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LDC – moist	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LDC – humid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low income – dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low income – moist	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
Low income – humid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Middle income – dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
Middle income – moist	0.0	0.0	0.0	-0.1	-0.1	-1.0	0.0	-1.8	0.0	0.0	0.0
Middle income – humid	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
High income – dry	0.0	0.0	0.0	0.0	0.0	-1.8	0.0	0.0	0.0	0.0	0.0
High income – moist	-0.8	-5.2	-8.7	-1.1	-0.4	-6.1	-2.2	-18.0	-0.7	0.0	0.0
High income – humid	-1.0	-0.1	0.0	-1.1	-0.4	-3.1	-1.2	-16.7	-0.3	0.0	0.0

Note: Changes in export subsidies for sectors not included in the table are zero. Source: SEAMTAP

4.2 Welfare impacts of trade liberalization

In order to assess the impact of accounting for agro-ecological zones when assessing trade liberalization we compare results of SEAMTAP and GTAP-AGR. The macroeconomic effects of changes in policies are typically assessed by the well-established welfare economic compensation measure which is the measure that is used in this study. The so-called equivalent variation (EV) measures '*what change in income would be equivalent to the proposed policy change*'. In other words, the EV is the amount of income that should be given to (or taken away from) households to achieve a welfare that is similar to that which occurs when a certain policy change comes into effect. This measure always informs us about the potential welfare change and it does not inform us about distributive effects. In fact, if the EV is positive, we know that enough resources are mobilized such that the winners from the policy move can potentially compensate the losers. The EV is firmly grounded in the welfare economic literature, and provides the ultimate measure of how well an economy is doing when implementing a policy change[2]. In this study we will assess the four main drivers of the total welfare impact: allocative efficiency effects, terms of trade effects, endowment effects and technical efficiency effects.

Allocative efficiency gains arise when, due to the removal of distortions, the factors of production (capital, labour and land) move more easily to their most efficient use, resulting in a (better approximation of the) optimal allocation of resources. The related productivity growth transfers into declining producer and consumer prices, and demand and supply expansion. In the process, global patterns of specialisation and trade change, as factors of production move in and out of countries and sectors. Estimated efficiency gains are useful indicators of the current depth of distortions per sector.

Terms of trade effects provide a summary measure that indicates the change in the ratio of prices received for exports and prices paid for imports. Declining terms of trade, i.e. a drop of export prices relative to import prices, often account negatively in the welfare evaluation. The intuition is that declining terms of trade represent a loss in the purchasing power of export. Note that in the model, we assume perfect markets, so that we do not allow for any flaws in price transmission.

Terms of trade effects are a macro-economic phenomenon, which ultimately reflect the changes in the country's real exchange rate. A negative terms of trade effect generally, but not always, reflects a drop in factor prices (land, labour and capital) relative to a worldwide average of factor prices. To appreciate this fundamentally macro-economic phenomenon, it is useful to recall the basic definition of the economy's external equilibrium, the balance of payments:

$$(X-M) - (S-I) = BoT + BoKA = BoP = 0.$$

The sum of the balance of trade, BoT, which is the difference between exports, X, and imports M, plus the balance of capital, BoKA, which is the difference between savings, S, and investments, I, must always be equal to zero. The balance of payments, BoP, always balances. If a tariff cut is undertaken imports will rise and this leads to a disequilibrium that must be resolved. Either exports must rise, or investments must rise, or savings must decline to restore the balance of payments. For ease of explanation we assume that investments and savings are fixed (although in the model this is not really so), so that adjustments have to occur by an expansion of exports. The basic mechanism through which exports can be

[2] While the EV takes the new situation as a reference, the alternative measure known as Compensating Variation (CV) takes the old situation as the reference. It asks the hypothetical question: 'what is the minimum amount of compensation after the price change in order to be as well off as before the change?'

increased is a drop (or a less rapid rise) in export prices, which makes the country's products more attractive than other suppliers'. Generally it will be the domestic prices of primary production factors, land, labour and capital that will bring about this fall in export prices. A depreciation of domestic factor prices then restores the balance of payments.

Another mechanism through which the balance of payments (under certain circumstances) may be restored is through prices of intermediate inputs. If initial levels of border protection are high lowering border protection leads to price drops for imported intermediate inputs, and consequent substitution towards imported goods. The price drop for inputs, in turn, leads to lower production cost, which ultimately translates into lower prices for exported goods, hence depressing their terms of trade, but at the same time boosting export volumes. In these circumstances primary factor prices may rise as economic expansion leads to more demand for labour and other factors, while the drop in costs of imported intermediate inputs assure a maintaining the balances of payments.

The allocative efficiency and terms of trade effects are the main welfare components for GTAP-AGR. For SEAMTAP there is an additional *endowment effect* from changes in the endowments of land and labour (when accounting for unemployment). In SEAMTAP land is treated as a composite commodity derived from the use of AEZs in production. This implies that the amount of land is not fixed as it is in GTAP-AGR (which therefore does not have a land endowment effect). Instead the composite 'production' of land from AEZs can shrink or grow depending on the changes occurring at AEZ level. These effects show as endowment effects in the decomposition of welfare. In the case of the SEAMTAP model with unemployment there is, next to the land endowment effect, also a labour endowment effect for all regions with unemployment. In this case the labour supply is also not fixed but instead follows demand while its real wage remains fixed.

Finally, we include the AEZs through a change in technical efficiency of land (see D3.8.7 for an elaborate technical description of SEAMTAP). This allows us to assess the impact of the AEZs on total welfare through the *technical change* welfare contribution to total welfare changes. This measure, jointly with the endowment effects of land, signals the impact of including agro-ecological zones on the overall assessment of trade liberalization.

The impact of trade liberalization is assessed against a baseline or reference scenario for the 2004- 2020 period in which policies remain as they are in 2004. We run separate baselines for GTAP-AGR and SEAMTAP since the differences between the models will also be reflected in their baseline projections. Before we delve into the differences between the model versions relative to their respective baselines we first take a quick look at the welfare results of the GTAP-AG and SEAMTAP baselines (table 4.4). In terms of total welfare changes the two models have similar results which is not surprising since they both target the same GDP projections. For SEAMTAP we also present the direct contribution to welfare changes form the inclusion of the AEZs. Compared to total changes in welfare the impact of the AEZs is modest. Only for the humid middle income countries we find a significant positive contribution amounting to 2.6% of total welfare. The largest contribution is made by the change in productivity of land, in other words AEZs are reallocated to the sectors where they are most productive thus raising the overall productivity of land. There are also two cases where there is a minor decline in productivity of land (moist low income countries and dry high income countries). For these prices of certain crops rise to such an extent that it warrants to use AEZS that are less productive for these crops.

Table 4.4: Changes in welfare by region and model version for 2004-2020 baseline (billion US $ 2004)

Region	**GTAP-AGR**	**SEAMTAP**			
	Total EV	*Total EV*	*Direct effects of including AEZ*		
			Endowment	Technical change	Total AEZ contribution
LDC - dry	109.2	105.4	1.4	0.0	1.3
LDC – moist	43.1	42.6	0.6	0.0	0.6
LDC – humid	162.2	164.1	2.4	0.0	2.4
Low income – dry	147.5	150.9	5.0	0.0	5.0
Low income – moist	88.7	88.7	0.6	-0.1	0.5
Low income – humid	65.6	63.6	1.5	0.0	1.5
Middle income – dry	321.5	324.5	1.4	0.1	1.5
Middle income – moist	4017.7	4055.4	44.7	0.0	44.7
Middle income – humid	5578.7	5602.8	37.5	109.9	147.4
High income – dry	7178.8	7212.1	-2.3	-0.1	-2.4
High income – moist	2850.0	2878.6	-2.2	0.0	-2.2
High income – humid	5692.1	5757.7	-0.6	0.1	-0.5
World	*26255.2*	*26446.5*	*89.9*	*110.0*	*199.9*

Source: model simulations.

Table 4.5: Changes in welfare by region and model version with trade liberalisation (billion US $ 2004)

Region	**GTAP-AGR**			**SEAMTAP (full employment)**				**SEAMTAP (unemployment)**				
	Total welfare	*Allocative efficiency*	*Terms of trade*	*Total welfare*	*Allocative efficiency*	*Terms of trade*	*AEZ*	*Total welfare*	*Allocative efficiency*	*Terms of trade*	*AEZ*	*Employment*
LDC - dry	1.3	0.5	0.8	3.1	0.7	1.7	0.4	8.9	2.5	1.5	0.8	3.9
LDC – moist	1.1	0.3	0.7	1.4	0.3	0.8	0.1	3.2	0.7	0.8	0.2	1.3
LDC – humid	2.0	0.5	1.7	2.6	0.5	1.7	0.5	5.6	1.2	1.7	0.7	2.2
Low income – dry	0.4	0.5	0.0	0.4	0.5	-0.1	0.1	2.4	0.9	-0.1	0.2	1.6
Low income – moist	-0.3	-0.1	-0.4	-0.2	0.0	-0.3	0.0	-0.1	0.0	-0.3	0.0	0.1
Low income – humid	2.0	0.4	1.5	2.0	0.4	1.5	0.1	4.2	0.9	1.3	0.2	1.8
Middle income – dry	0.7	1.3	-0.9	0.5	1.3	-1.2	0.1	3.6	1.8	-1.4	0.1	2.7
Middle income – moist	-1.4	3.3	-5.5	-2.0	3.3	-5.7	-0.3	19.1	10.3	-5.6	-0.1	13.8
Middle income – humid	15.4	7.2	9.3	18.9	6.2	11.8	1.8	69.4	16.5	10.2	2.6	40.8
High income – dry	-5.3	1.1	-4.7	-6.9	1.2	-6.4	0.1	-6.5	1.3	-6.1	0.0	0.0
High income – moist	0.4	4.9	-5.1	2.8	9.2	-6.0	-1.1	3.0	9.1	-5.6	-1.2	0.0
High income – humid	20.5	17.1	2.6	24.3	24.5	2.1	-3.0	25.6	24.7	3.5	-3.1	0.0
World	*36.7*	*36.8*	*-0.1*	*46.8*	*48.1*	*-0.1*	*-1.2*	*138.2*	*70.0*	*-0.1*	*0.3*	*68.0*

Source: model simulations.

We then turn to assessing the impact of trade liberalization relative to the baseline. We combine the endowment and technical change effect of land in a single column AEZ for both SEAMTAP models and separate the labour endowment effect in the unemployment model from the land endowment effect for the SEAMTAP model with unemployment (table 4.5).

In all model versions trade liberalization increases total welfare of the world. Welfare increases are considerably higher when unemployment is accounted for. In this model there is a multiplier effect whereby lowering of trade barriers promotes specialization in line with the comparative advantages of each region. Increased production possibilities are promoted by fixed real wages in regions with unemployment which limits production costs and increases employment. The increase in employment on its turn increases labour income which increases demand and results in additional demand for products. As a result the welfare increase in the SEAMTAP model with unemployment is about three times welfare increase when assuming full employment in all regions.

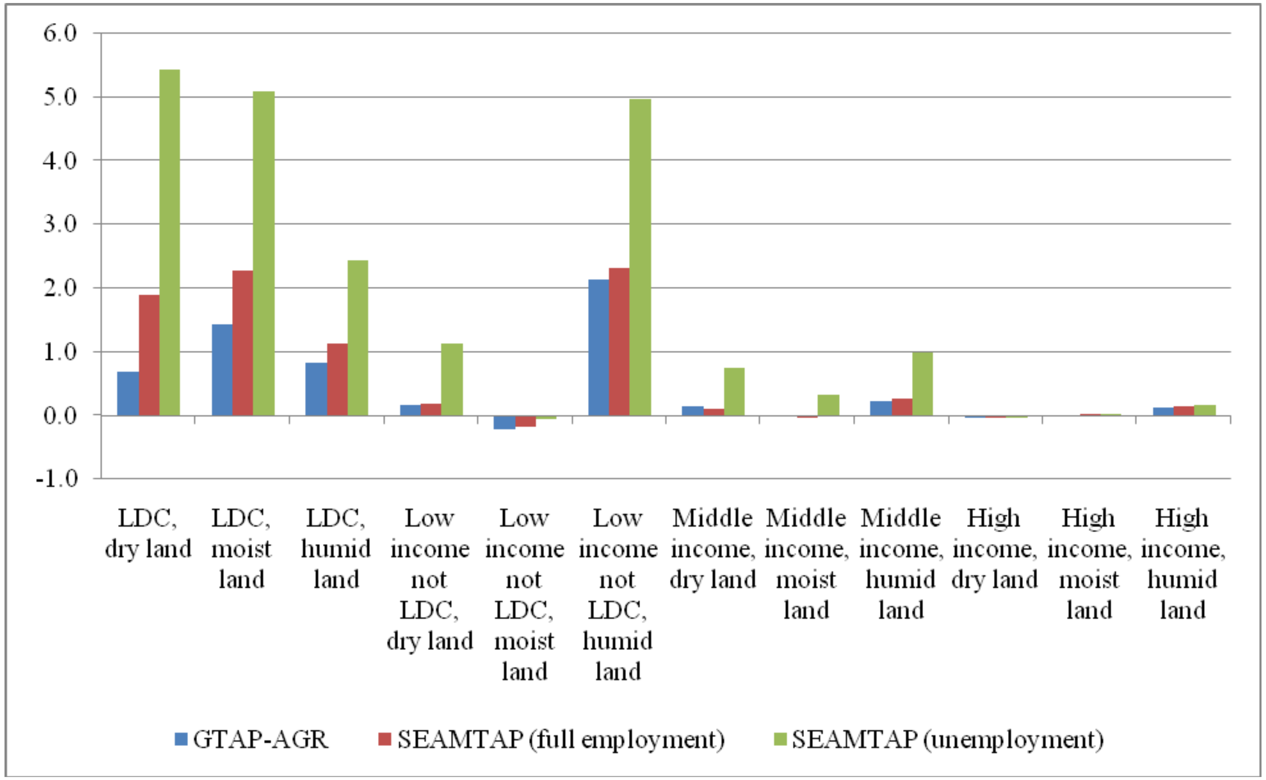
The impact of including AEZs on total welfare are limited, as in the baseline scenarios the strongest positive impact is found for the humid middle income countries (1.8 billion US $). The strongest impact however is found for the dry high income countries (-3.0 billion US $), suggesting that the availability of water is limiting their possibilities for expansion. Moist middle and high income regions are the other cases where the direct effects of the inclusion of AEZs lead to a reduction in the total welfare.

Although the total welfare effects for the world are positive not all regions gain from trade liberalization. In GTAP-AGR and SEAMTAP with full employment regions that lose are moist low and middle income regions as well as dry high income regions. Accounting for AEZ decreases the losses of the moist low and middle income regions but increases the losses for the dry high income region. Accounting for unemployment further reduces the losses for the moist low income region, results in net gains for the moist middle income region and slightly reduces the losses in the dry high income region. The latter is an indirect effect since for the high income regions full employment is assumed in all model versions.

So far we have discussed welfare gains in levels. The relative gains and losses for the regions may differ considerably since the levels of GDP vary considerably. We therefore assess the change in total welfare relative to the baseline GDP (figure 4.3). Due to their low initial income the relatively modest gains in welfare for the LDCs translates into the largest gains relative to GDP. Their gains are furthermore larger when including AEZs and even more so when adding unemployment to the model. Only for the moist low income countries the positive impact of accounting for unemployment is limited, although reducing the losses from trade liberalization it does not result in a net gain from trade liberalization.

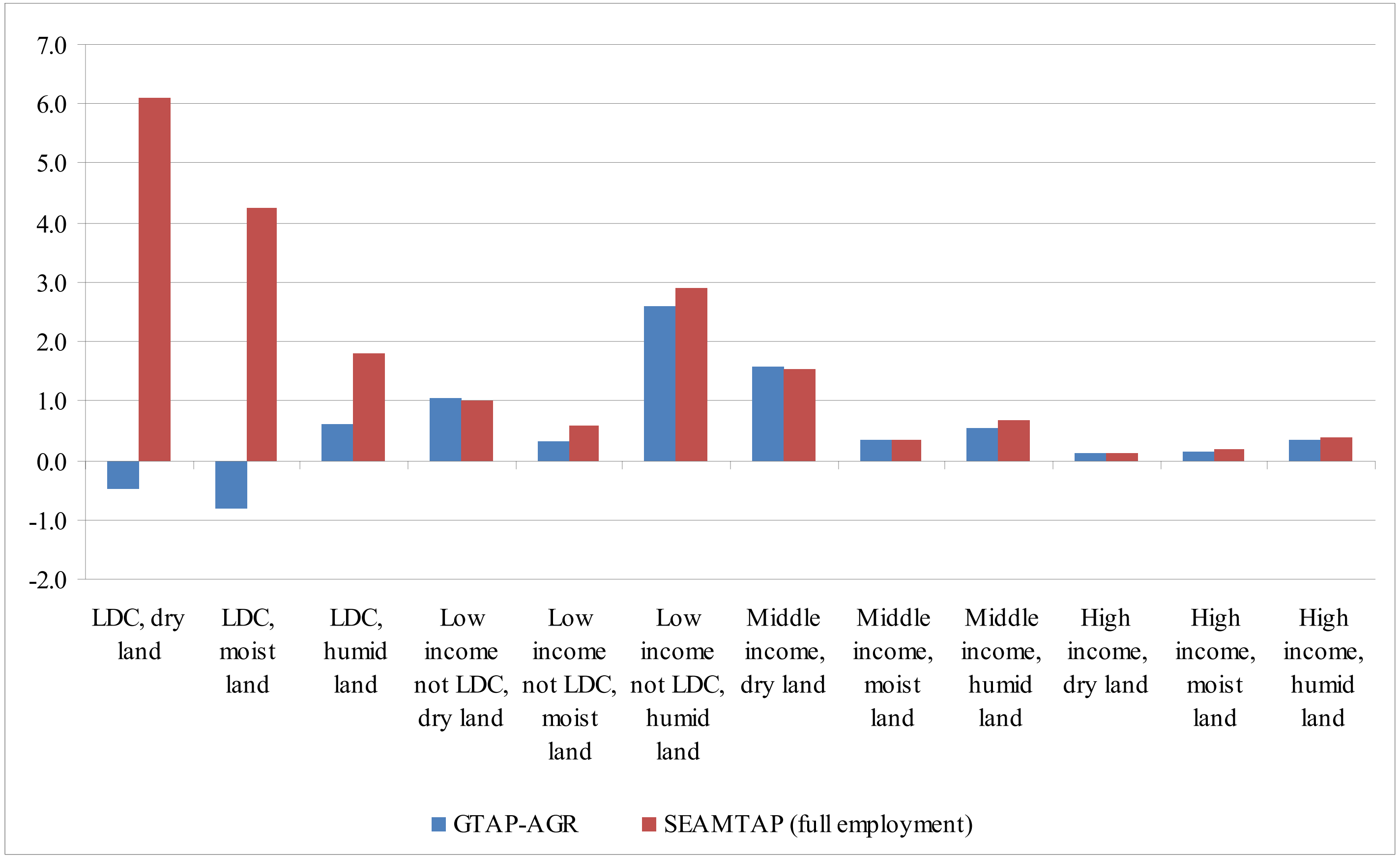
The welfare assessment provides a measure of the aggregate impact on the economy, summing over all consumers and producers. The distribution of the gains or losses over specific groups in society cannot be determined from the welfare changes. In fact the presence of a single household for each region does not allow us to assess the impact on different types of households, like for example the poor. By looking at the changes in the returns to factors we can get a rough estimate of distributional impacts. In the context of assessing poverty changes in the returns to unskilled labour are relevant since most poor have limited (formal) education. Figure 4.4*4.4* presents the changes in real wages for unskilled labour for the two models where wages are endogenous. In SEAMTAP with unemployment the real wage is fixed and employment increases in cases where wages would increase in the other two models. Due to the stronger supply response in SEAMTAP for LDCs (discussed more below) wages for unskilled labour increase more than in GTAP-AGR and for dry and moist LDCs even reverse the pattern in wages. SEAMTAP thus suggests a more beneficial impact on the poor than GTAP-AGR does.

Figure 4.3: Welfare (EV) increase relative to baseline GDP (%)



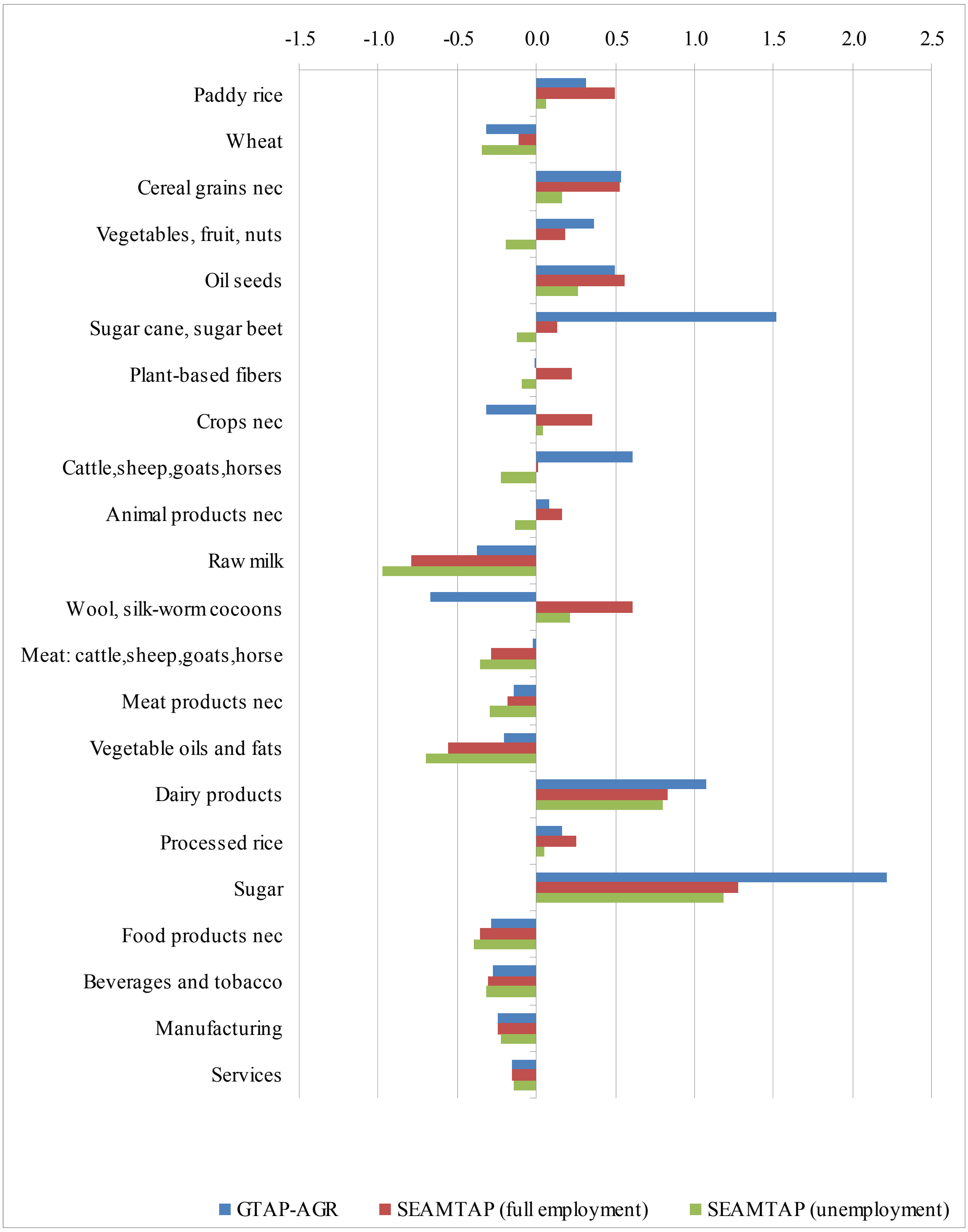
Source: model simulations

Figure 4.4: Changes in real wages of unskilled labour with trade liberalization (%)



Source: model simulations.

Figure 4.5: Changes in world market prices with trade liberalization (%)



Source: model simulations..

4.3 Price impacts of trade liberalization

The variation in welfare impacts is to a large extent determined by the changes in prices following trade liberalization. Countries where the majority of sectors benefit from a price increase will experience a welfare gain whereas countries with the majority of sectors experiencing a price decrease will experience a welfare loss. Figure 4.54.5 explores the price changes for each model version.

Generally price increases are lower with SEAMTAP while price decreases are stronger. Manufacturing and services are an exception to this general pattern although here the differences between the model versions are marginal. Since price increases signal scarcity, the inclusion of AEZs in the model seems to increase the production possibilities and thereby production potential. It should be noted that we ran the model with a high substitution elasticity between AEZs of 20, i.e. assuming no barriers to substituting AEZs with each other when producing the land composite. We furthermore assume AEZs can move freely between sectors without adjustment costs. This exacerbates the impact of the AEZs since now only the punishment through the productivity of the land composite is constraining the shift of AEZs among crops.

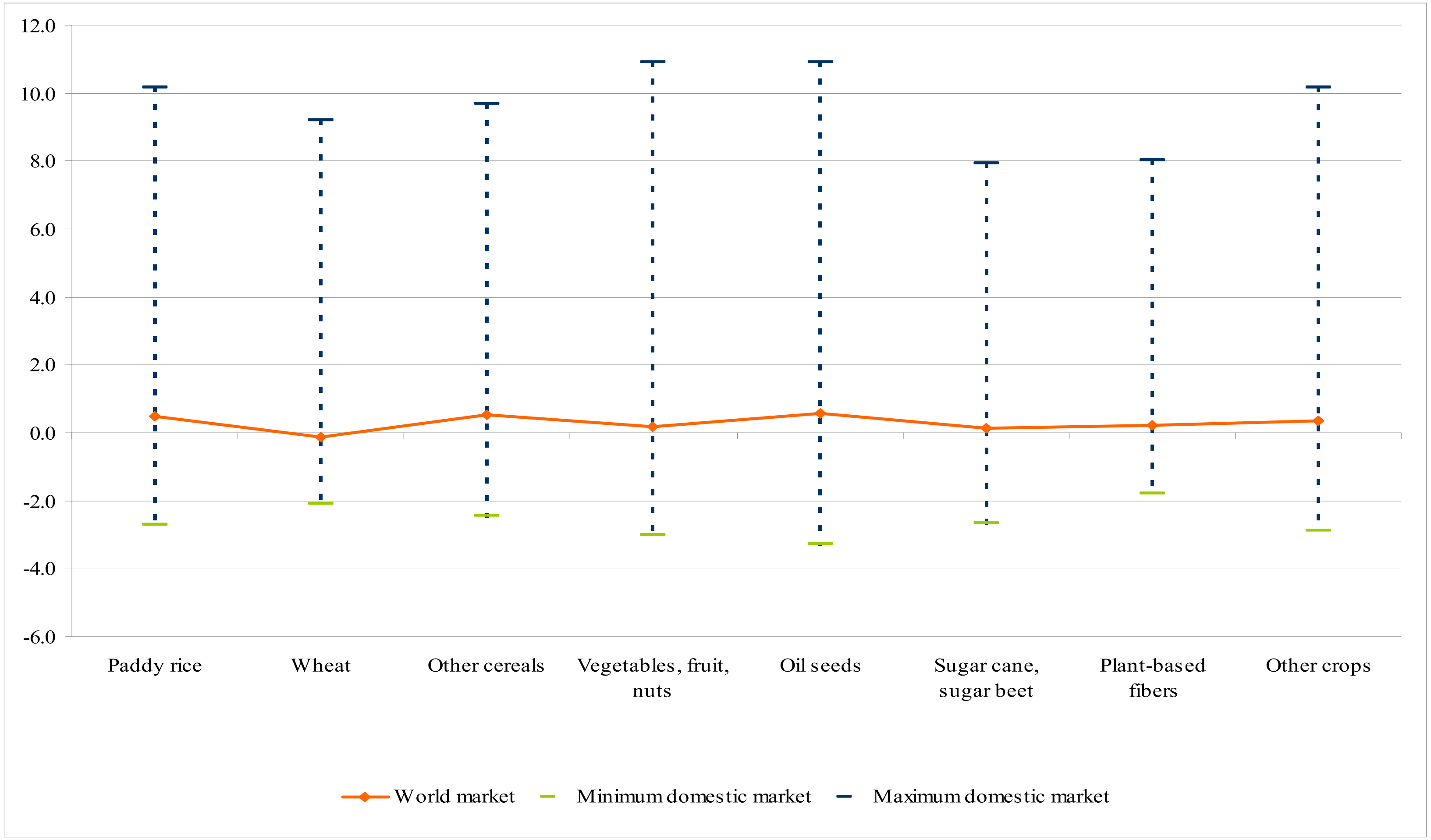
The increase in production possibilities with the AEZs is not surprising. In GTAP-AGR limited suitability of land for a specific crop is reflected in a lower initial value-added and thus lower initial endowment of land. This endowment of land (measured in dollar terms) is fixed in the remainder of the model. SEAMTAP on the other hand constrains AEZs in level terms, i.e. accounts for the total amount of hectares available for agricultural production. By shifting AEZs to crops to which they are more suited the productivity of the land composite increases. Intuitively this can be seen as an increase in the amount of land available for production which will increase the supply response to price changes.

Although SEAMTAP only includes AEZs for the eight crop sectors price differences with GTAP-AGR are also found in non-crop sectors due to the relationships between sectors. The most obvious example is the price increase for sugar which is the main user of the sugar can and beet production.

Focusing on the eight crop sectors difference between GTAP-AGR and SEAMTAP especially stand out for fibre crops and other crops where prices decrease in GTAP-AGR while increasing in SEAMTAP with the full employment. Assuming unemployment the price of plant based fibers decreases in SEAMTAP and to a much larger extent than in GTAP-AGR.

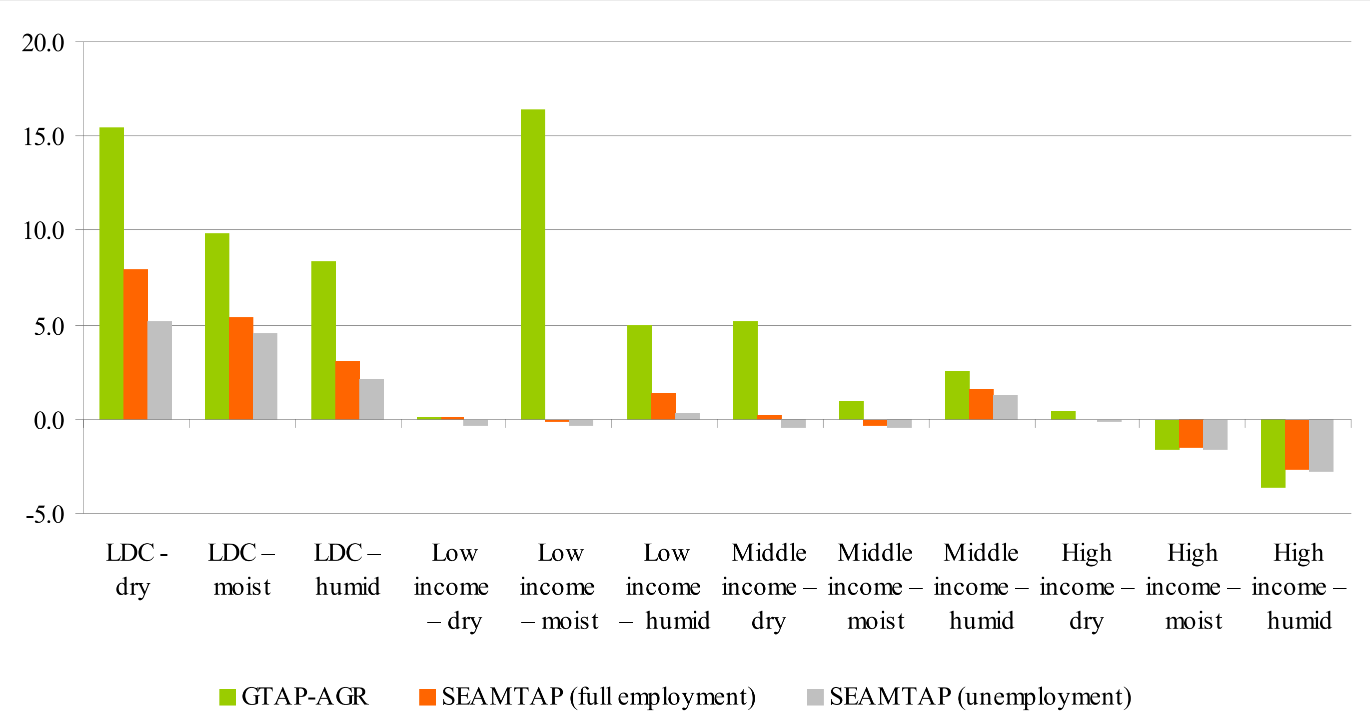
So far we have discussed world market prices, price changes in the domestic markets of the regions may differ considerably from this world market price due to remaining trade barriers. Figure 4.6 explores this variation between regions for the SEAMTAP model with full employment. From the figure it is obvious that the rather modest changes in world market prices mask wide range of price changes within the regions. The deviation from the world market price is highest in the upward direction. These much higher price increases are mostly occurring in the LDCs. Due to their limited economic size these price increases are not reflected in the world market prices. The main reason for the price increases in the LDCs is their special and differential treatment. Recall from figure 4.1*4.1* and figure 4.2 that the LDCs do not have to lower their own tariffs while facing much lower tariffs in the rest of the world. The maintenance of their tariffs shields the domestic producers while offering increased scope for exports for products with a comparative advantage. The production of sugar cane provide an illustration of this effect (figure 4.7). Across the regions domestic market prices increase most for the LDCs, significantly less for the low and middle income countries and generally decrease for the high income countries. This pattern holds in general terms for the eight crop sectors and across the three model versions and can ascribed to the special and differential treatment of LDCs.

Figure 4.6: World market and domestic market price changes in SEAMTAP (full employment) by sector (%)



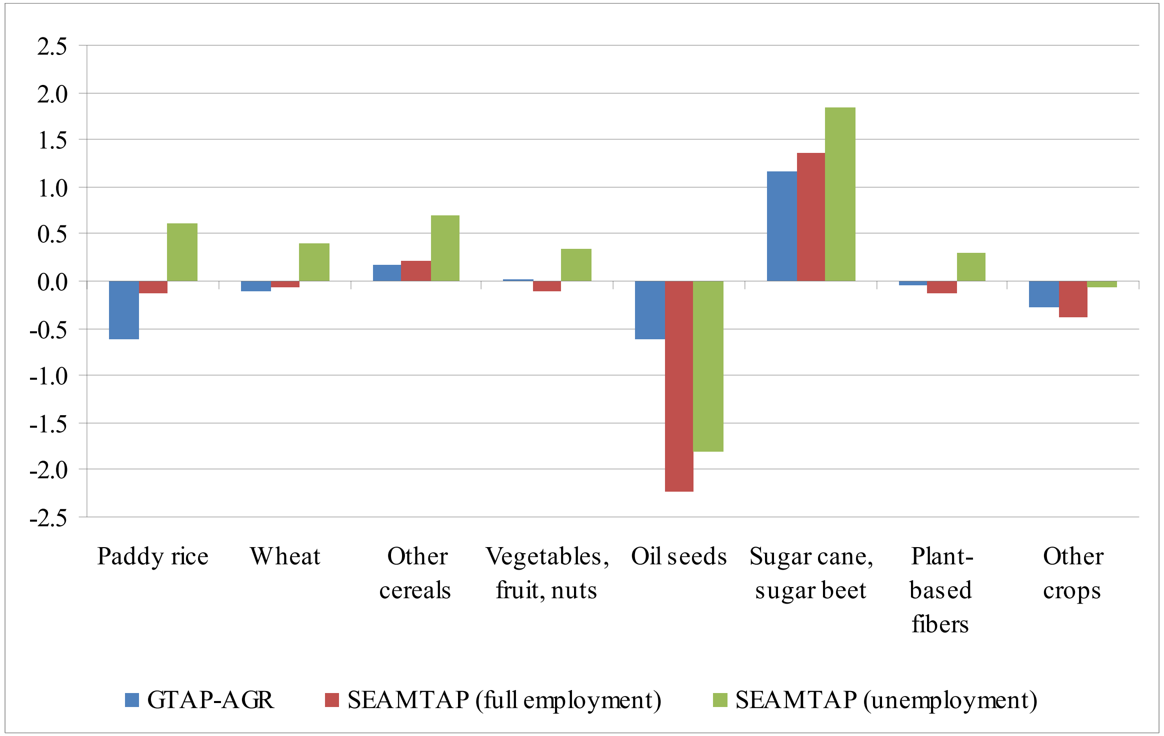
Source: model simulations.

Figure 4.7: Changes in domestic market prices for sugar cane and beet (%



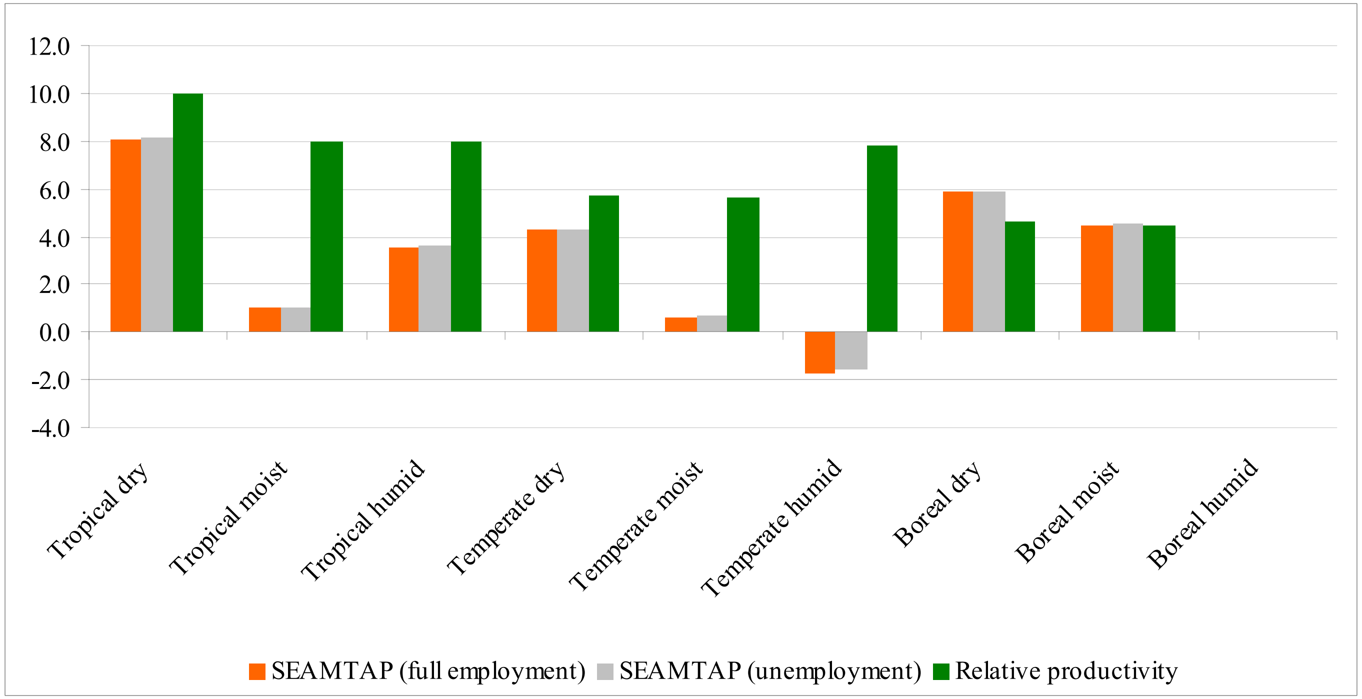
.Source: model simulations.

Figure 4.8: Changes in production by crop sector with trade liberalization (%)



Source: model simulations.

Figure 4.9: Changes in production by of sugar cane and sugar beet crop sector by agro-ecological zone with trade liberalization (%) and productivity index of agro-ecological zones for sugar cane and beet (0 -10).



Source: model simulations .

Note that in contrast to the general pattern above for sugar cane and beet the price increase in SEAMTAP is less than the price increase in GTAP-AGR instead of being stronger. Looking at the productivity indices sugar cane and beet is the crop best suited for humid tropical areas (which seems to point to production of sugar cane and not sugar beet which is produced in the temperate regions). Prices of sugar increase dramatically as a result of a severe reduction in the protection of the EU sugar market[3] stimulating the production of sugar cane and beet. The more modest price increase in SEAMTAP suggest that accounting for the exceptional suitability of humid tropical regions for sugar cane leads to a much stronger specialization in LDCs in sugar cane and therefore to a more modest price increase.

The concentration of production in sugar cane in LDCs implies less area available for other crops which will put an upward pressure on their prices. This explains the price increase found for wheat in LDCs despite a decline in world market prices and LDCs being a net importer of wheat (see table 3.5).

4.4 Production impacts of trade liberalization

Being general equilibrium models there is a close relationship between price and production in all three models. In these models a price increase signals an increase in demand that will be met by an increase in production until demand and supply are in equilibrium again at a higher price level (and vice versa for price decreases). Given the increases in sugar cane and beet it thus comes at no surprise that the production of sugar cane and beet increases (figure 4.8). Comparing production changes between the models we find that SEAMTAP with unemployment shows more increases (or smaller decreases) in production for all crops. This is due to the stimulating effect of having labour available at a fixed wage in most of the model regions.

The case of sugar cane and beet proves to provide a good illustration of the impact of AEZs on production. Prices of sugar cane and beet increase considerably in the LDCs and low income regions (figure 4.7). From the distribution of AEZs over the regions (figure 4.7) we know that most of the tropical AEZs are located in the LDC and low income countries (figure 3.2). In these tropical regions sugar cane[4] is the crop with the highest productivity (figure 3.4). The combination of a high increase in prices with the suitability of tropical AEZs for sugar cane results in an increased use tropical AEZs for sugar cane (figure 4.9). This figure also includes the (global) productivity index for sugar cane and beet (scaled by a factor 10 to highlight the differences in productivity between AEZs). The tropical dry AEZ is best suited (productivity of 10, or 1 in the index used in the model), while the tropical moist and humid AEZs are equally well suited to sugar cane and beet (productivity of 8, or 0.8 in the index used in the model). Despite its suitability there is only a minor increase in use of moist tropical for sugar cane and beet. This is due to competition for this AEZ by other crops which also experience a considerable price increase. With the endowment of LDCs predominantly in tropical AEZs the increase in other crops competes with sugar cane. The productivity of other crops on humid tropical AEZs is however much lower than on moist AEZs and therefore the increase in other crop production occurs on moist AEZs.

[3] The huge price increase is sugar may not materialize in practice due to ongoing reforms of the European sugar policy that are not accounted for in the baseline. Furthermore, in case large effects would still be anticipated with trade liberalization one may expect that the EU will denote sugar as a sensitive product in order to limit the reduction in tariffs.

[4] Since sugar beet is produced in the temperate regions we can deduce that the productivity index for sugar cane and beet for tropical regions refers to sugar cane.

5 Conclusions

Our aim was in this deliverable was to explore the impact of accounting for heterogeneity in land when assessing the impact of trade liberalization on developing countries. Starting from an existing global general equilibrium model (GTAP-AGR) we developed a model in which land used in crop production is composed of 18 different agro-ecological zones dubbed SEAMTAP. The main contribution of SEAMTAP is a direct link between suitability of a type of land for a specific crop through productivity indices. These productivity indices are derived from a detailed database containing the yields and harvested areas at detailed crop and country level. This approach allows us to include 18 AEZs in the model without and 'explosion' in model size and with no significant impact on model performance.

The variation in suitability of land for specific crops and adjustment costs when shifting use is implicitly included in GTAP-AGR by restricting the movement of land between sectors. In SEAMTAP we replace this by a direct connection between crops sectors and types of land by making the productivity of land in a sector dependent upon the suitability of the AEZs used in that sector. To analyze the way in which this productivity link functions we abstract from the presence of adjustment costs and assume that AEZs can move freely between sectors with no further costs incurred apart from the impact on productivity of land. We furthermore fix the available amount of land at the initial crop area.

We analyzed the impact of multilateral trade liberalization using three model (versions): GTAP-AGR, SEAMTAP with full employment and SEAMTAP with unemployment. The SEAMTAP model with unemployment differs from the 'standard' SEAMTAP by assuming unemployment in all but the high income regions. This is translated in a fixed real wage with the total size of the labour force adjusting to balance supply and demand of labour.

Trade liberalization raises global welfare with all three models, which is the common finding of this type of analysis. Gains are higher when introducing AEZs and even higher again when introducing unemployment. In SEAMTAP with unemployment there is a multiplier effect whereby lowering of trade barriers promotes specialization in line with the comparative advantages of each region. Increased production possibilities are promoted by fixed real wages in regions with unemployment which limits production costs and increases employment. The increase in employment on its turn increases labour income which increases demand and results in additional demand for products. As a result the welfare increase in the SEAMTAP model with unemployment is about three times welfare increase when assuming full employment in all regions in the SEAMTAP model with full employment.

The introduction of AEZs with the assumption of no adjustment costs of moving AEZs between sectors apart from the impact on aggregate land productivity increases the supply response of agriculture, thereby reducing price changes compared to GTAP-AGR.

In terms of distributional impacts between regions we find that the LDCs experience a larger welfare gain when accounting for AEZs. This gain is mostly driven by a strong increase in the price of sugar (related to a reduction in the strong protection of the EU sugar market). The LDCs are well placed to benefit from this price increase since the crop with the highest productivity on the tropical land (which constitutes the major part of the LDCs' land endowment) is sugar cane. The connection with the change in sugar price implies that if the EU would denominate sugar as a sensitive product in order to avoid a strong reduction in tariffs (which is an option in the current WTO negotiations) this positive impact on the LDC economies may not materialize.

The impact of the suitability of AEZs for specific crops is illustrated by an analysis of the changes in AEZ use by sugar cane. Expansion on tropical moist AEZs is limited despite their suitability for sugar cane. This is due to a price increase for other crops which do not grow well on humid tropical soils, whereas this poses no problem for sugar cane. Other crops are thus allocated to moist tropical soils whereas sugar cane expands on dry and humid AEZs. This illustrates that the model not only assess the suitability of a soil for a specific crop but also takes into account the suitability of the AEZ for other sectors.

Our aim was to assess the impact of including a direct link between AEZs and their suitability for specific crops ignoring adjustment costs of shifting AEZs between sectors. Future applications may consider extensions by accounting for such costs by making the movement of AEZs between sectors sluggish (identical to the treatment of land in GTAP-AGR) or introducing the possibility of an expansion of crop land by adding a land supply module to the model. This would be a straightforward extension of the model since SEAMTAP already includes market clearing conditions in level terms at AEZ level. Introducing land supply would thus imply that instead of the currently fixed amount of crop land by AEZ a function is specified which determines the availability of AEZs as is done in van Meijl et al.(2005) for land.

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Glossary

Closure — The closure describes which variables are endogenous and which are exogenous in a general equilibrium model. The total number of endogenous variables needs to equal the number of equations to solve the model. Apart from its mathematical role the choice of closure summarizes the way the economy is functioning and therefore has a fundamental impact on model results.

Appendix A: model aggregations

Table A1: Region aggregation

Code	Description	Original GTAP regions
LDC_DRY	LDC, dry land	Rest of South Asia; Rest of Western Africa; Rest of Eastern Africa.
LDC_MST	LDC, moist land	Senegal; Ethiopia; Malawi; Mozambique; Tanzania; Zambia.
LDC_HUM	LDC, humid land	Cambodia; Lao People's Democratic Republic; Myanmar; Bangladesh; Central Africa; South Central Africa; Madagascar; Uganda.
LIC_DRY	Low income not LDC, dry land	Pakistan; Kyrgyzstan; Rest of Former Soviet Union.
LIC_MST	Low income not LDC, moist land	Nigeria; Zimbabwe.
LIC_HUM	Low income not LDC, humid land	Viet Nam.
MIC_DRY	Middle income, dry land	Peru; Kazakhstan; Armenia; Iran Islamic Republic of; Egypt; Botswana; Rest of South African Customs .
MIC_MST	Middle income, moist land	Rest of East Asia; Thailand; India; Mexico; Bolivia; Chile; Rest of Central America; Latvia; Lithuania; Poland; Albania; Bulgaria; Belarus; Romania; Russian Federation; Ukraine; Rest of Eastern Europe; Azerbaijan; Georgia; Turkey; Morocco; Tunisia; Rest of North Africa; Mauritius; South Africa.
MIC_HUM	Middle income, humid land	Rest of Oceania; China; Indonesia; Malaysia; Philippines; Rest of Southeast Asia; Sri Lanka; Argentina; Brazil; Colombia; Ecuador; Paraguay; Uruguay; Venezuela; Rest of South America; Costa Rica; Guatemala; Nicaragua; Panama; Croatia.
HIC_DRY	High income, dry land	Australia; United States of America; Rest of Western Asia.
HIC_MST	High income, moist land	Canada; Rest of North America; Austria; Cyprus; Czech Republic; Denmark; Estonia; Finland; Germany; Greece; Hungary; Malta; Portugal; Slovakia; Spain; Sweden; Switzerland; Norway; Rest of EFTA; Rest of Europe.
HIC_HUM	High income, humid land	New Zealand; Hong Kong; Japan; Korea; Taiwan; Singapore; Caribbean; Belgium; France; Ireland; Italy; Luxembourg; Netherlands; Slovenia; United Kingdom.

Table A2: Sector aggregation

Code	*Description*	*Original GTAP sectors*
pdr	Paddy rice	Paddy rice.
wht	Wheat	Wheat.
gro	Cereal grains nec	Cereal grains nec.
v_f	Vegetables, fruit, nuts	Vegetables, fruit, nuts.
osd	Oil seeds	Oil seeds.
c_b	Sugar cane, sugar beet	Sugar cane, sugar beet.
pfb	Plant-based fibers	Plant-based fibers.
ocr	Crops nec	Crops nec.
ctl	Cattle,sheep,goats,horses	Cattle,sheep,goats,horses.
oap	Animal products nec	Animal products nec.
rmk	Raw milk	Raw milk.
wol	Wool, silk-worm cocoons	Wool, silk-worm cocoons.
cmt	Meat: cattle,sheep,goats,horse	Meat: cattle,sheep,goats,horse.
omt	Meat products nec	Meat products nec.
vol	Vegetable oils and fats	Vegetable oils and fats.
mil	Dairy products	Dairy products.
pcr	Processed rice	Processed rice.
sgr	Sugar	Sugar.
ofd	Food products nec	Food products nec.
b_t	Beverages and tobacco	Beverages and tobacco products.
mnfs	Manufacturing	Forestry; Fishing; Coal; Oil; Gas; Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Petroleum, coal products; Chemical,rubber,plastic prods; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec.
srvs	Services	Electricity; Gas manufacture, distribution; Water; Construction; Trade; Transport nec; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Educat; Dwellings.