What if not all land is created equal? The role of heterogeneous land when assessing the impact of trade liberalization on developing countries

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Abstract

Land is a key input in agriculture, which is the most important sector in terms of employment and foreign exchange earnings in many developing countries. The way in which land is modeled is therefore crucial for understanding the impact of trade liberalization in developing countries. Our objective is to assess if the expected impact of trade liberalization on developing countries, which plays a central role in the current Doha development round, is affected by differences in land endowments. Our analysis relies upon a recent GTAP-compatible land use dataset containing data on land endowments, harvested area and yields by crop, agro-ecological zone and country. Given the prominent role of agriculture in our analysis we start from the GTAP-AGR model. Instead of defining production by AEZ we maintain a single production function by crop (as in GTAP-AGR) but redefine the single type of land as a land aggregate composed of land of different AEZs. We then add a nest to the production function to determine the composition of this land aggregate. By assuring that this land nest captures the productivity differences of land across AEZs we incorporate the same amount of information in the model as with defining production by AEZ (differences in yields across AEZs) without having an explosion of the model's dimensions. The aim of this study is to assess whether heterogeneity of land affects the expected impact of trade liberalization on developing countries. We therefore compare the results of the model including the productivity differences across AEZs (GTAP-AEZ) with the findings of GTAP-AGR. First tests with a full trade liberalization scenario resulted in modestly lower gains from trade liberalization found in the first tests of the impact of heterogeneous land.

1. Introduction

The impact of trade liberalization on developing countries has become a central topic in discussions on international trade. The growing importance of developing countries within the WTO is reflected in the current round being dubbed the "Development Round", placing the impact on developing countries firmly on the trade agenda. Although the WTO negotiations have come to a standstill, there is no shortage of bilateral and regional trade agreements involving developing countries. The impact of trade liberalization on developing countries (being it multilateral, regional or bilateral) therefore remains a key policy issue subject to considerable public debate.

The GTAP database plays a prominent role in this debate by providing the basis for the great majority of international trade models. In this paper we focus on one aspect of GTAP-based models: the modeling of land. Land is a key input in agriculture, which is the most important sector in terms of employment and foreign exchange earnings in many developing countries. In addition to the importance for developing countries, agriculture is also the most contested area in the current WTO negotiations. One reason is the relative high levels of current protection in agriculture compared to manufactured goods. This relatively high current level of protection also implies that global gains from liberalization of agriculture will be high (Hertel, Keeney *et al.*, 2007). The way in which land is treated in trade models therefore appears crucial for understanding the impact of trade liberalization in developing countries.

The GTAP database distinguishes one type of land, next to two types of labor (skilled and unskilled), capital and natural resources. A casual look at the map already suggests that having a single type of land may not be well-suited for analyzing the impact on developing countries. Most rich countries are located in the temperate zones, whereas developing countries are predominately found in the tropics. Various explanations exist for this correlation between climate and income level, for example related to the presence of diseases like malaria, possibilities to transfer knowledge between different climate zones and so on. In this paper we do not attempt to explain the reason for the correlation between climate and income levels, but limit ourselves to assessing the impact of observed differences in the productivity of land on the agricultural response of (developing) countries to trade liberalization.

Our objective is to explore whether the expected impact of trade liberalization on developing countries is affected by differences in land endowments. We hypothesize that developing countries have less productive land, implying that benefits from trade liberalization are less than expected based on currently used models with a single type of land.

2. Data

A major limitation for a global analysis (which is essential for international trade) is the availability of data. The role of GTAP in the international trade debate can be directly attributed to this scarcity of global datasets. In the context of another global concern, global warming, 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. These data provide the first global dataset on land use and land endowments compatible with the GTAP database.

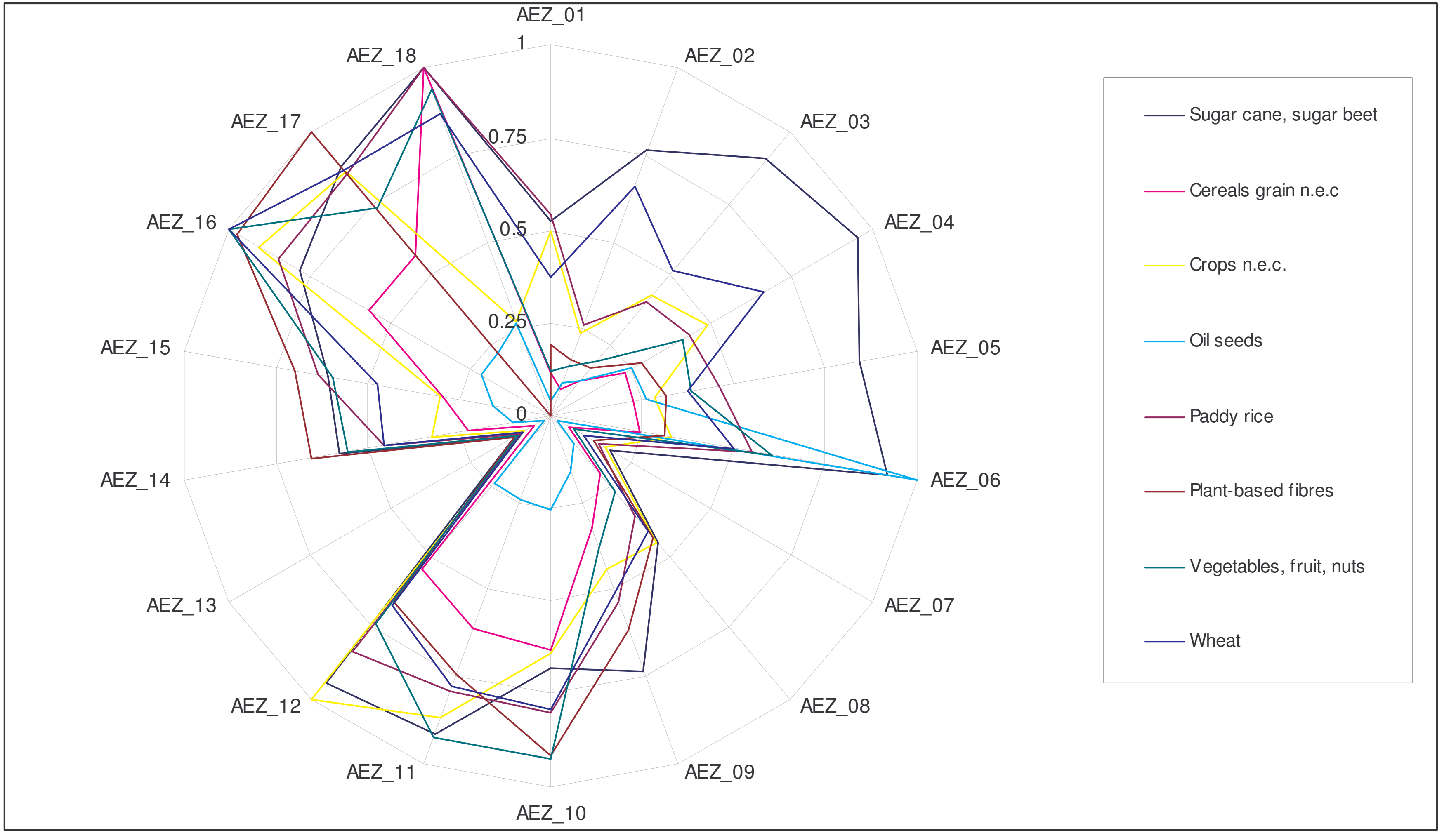
Our analysis relies upon these land use and land endowment data by country to include differences in land quality in a GTAP model. In the current analysis we limit the analysis to land quality differences in the eight crops distinguished in the GTAP database: paddy rice, wheat, cereals, vegetables and fruits, oil seeds, sugar cane and beet, plant-based fibers, other crops. Although land quality may indirectly affect livestock production through pasture quality, for the sake of simplicity we limited our analysis to the crop sectors.

Table 1: Definition of agro-ecological zones in GTAP

Climate	Moisture	Length of growing period (days)	Zone	Share of world area (%)
Tropical	Arid	0-59	AEZ 1	7.06
	Dry semi-arid	60-119	AEZ 2	2.31
	Moist semi-arid	120-179	AEZ 3	3.89
	Sub-humid	180-239	AEZ 4	5.12
	Humid	240-299	AEZ 5	6.25
	Humid, year-round growing season	>300	AEZ 6	9.79
				34.42
Temperate	Arid	0-59	AEZ 7	17.76
	Dry semi-arid	60-119	AEZ 8	5.45
	Moist semi-arid	120-179	AEZ 9	4.74
	Sub-humid	180-239	AEZ 10	5.93
	Humid	240-299	AEZ 11	3.24
	Humid, year-round growing season	>300	AEZ 12	3.82
				40.95
Boreal	Arid	0-59	AEZ 13	4.72
	Dry semi-arid	60-119	AEZ 14	10.38
	Moist semi-arid	120-179	AEZ 15	8.97
	Sub-humid	180-239	AEZ 16	0.49
	Humid	240-299	AEZ 17	0.04
	Humid, year-round growing season	>300	AEZ 18	0.02
				24.63

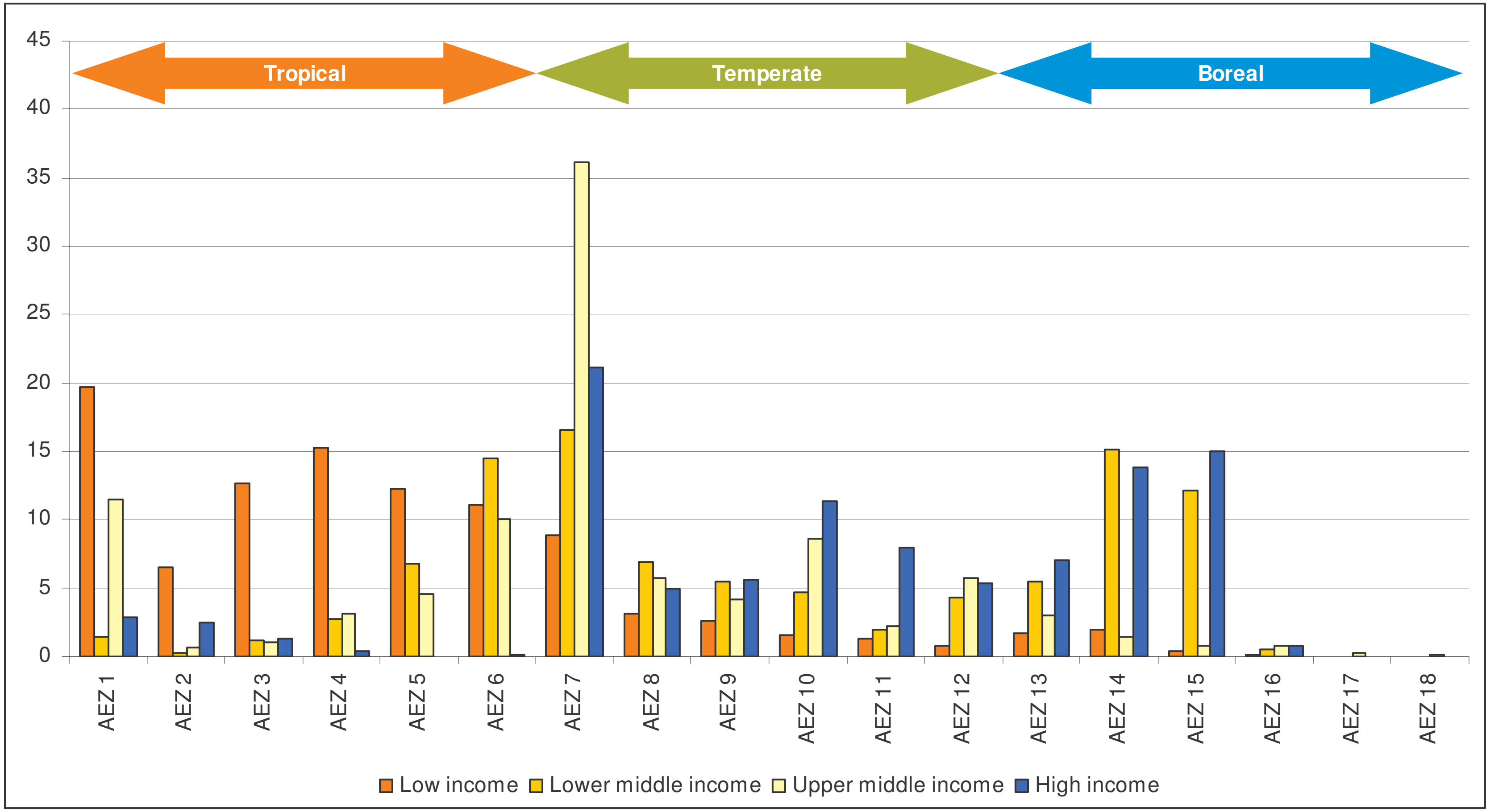
Source: Lee et al. (2005:17), authors' calculations

Figure 1: Productivity index by AEZ and crop (index is 1 for the AEZ where the crop has the highest yield)



Note for description of AEZ see Table 1 (Tropical AEZ01-06; Temperate: AEZ 07-12; Boreal: AEZ13-18). Source: Lee et al. (2005), authors' calculations

Figure 2: Agro-ecological zones by country group (percentage of total land by country group)



Source: Lee et al. (2005), authors' calculations

The land use dataset contains the land endowments for 159 countries by agro-ecological zone (AEZ). Combing six different rainfall regimes (arid, dry semi-arid, moist semi-arid, sub-humid, humid, humid year round growing season) and three climate zones (tropical, temperate, boreal) 18 AEZs are defined (Table 1). The dataset also contains harvested areas and yields for 19 crops (which can be mapped to the eight GTAP crops) for each of the countries by AEZ. We thus have data on land endowments, harvested area and yields by crop, AEZ and country[1].

It should be noted that 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 labor, capital and intermediate input use since there are no data on inputs besides land in the land use dataset.

To illustrate the different productivity of the agro-ecological zones Figure 1 presents a productivity index[2] for each of the eight GTAP crop sectors. The first thing to note in Figure 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

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[1] When constructing the databases for the model we found that in several instances the land use data indicated that a crop was not harvested whereas according to the GTAP databases there were very small areas of these crops. In these cases we used yield data of similar regions in order to limit our modifications of the standard GTAP data as much as possible.

[2] The productivity index is computed by dividing (for each crop) the yield attained at an AEZ b y the maximum yield over all AEZs. The most productive AEZ thus has an index of 1.

AEZs (AEZ 1, 7 and 13) show a clear dip in productivity for all crops. Another noteworthy aspect of Figure 1 is that for most crops the lower productivity AEZs are concentrated in the tropical AEZs. The data on the productivity thus support the hypothesis that developing countries have less productive endowments. This even holds for paddy rice, an archetypical tropical crop. This illustrates the point made above that the observed yields are the result of both bio-physical and socio-economic potential. 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. This is illustrated in Figure 2 by the distribution of the AEZs by country income group: low income countries are predominantly located in the tropics and high-income countries in the temperate and boreal zones.

3. Model

Given the prominent role of agriculture in our analysis we start from the GTAP-AGR model (Keeney and Hertel, 2005). GTAP-AGR is based on the standard GTAP model, with adjustments to better capture the agricultural sector and agricultural policies. Main modifications to the standard GTAP model are: segmented factor markets for agricultural and non-agricultural labor; substitution possibilities between factor and intermediate inputs in agricultural production; and substitution between different types of feed in livestock production. The GTAP-AGR model is used as the reference model in our study, representing the impact of trade liberalization with a single type of land.

The challenge we face is to incorporate differences in land quality as measured by the AEZs in agricultural production. The method of choice appears to be defining AEZ-specific production functions. This would greatly increase the dimensions of the model since instead of eight crop sectors by region, reach region would potentially have 144 crop sectors (8 crops specified for 18 AEZs). The extent to which a production function can be defined for each AEZ is limited by the available data. The land use dataset only contains the amount of land by AEZ used in each crop, but does not contain data on the variation in use of labor and capital by crop and AEZ. This reflects a lack of global data on the use of factors of production in agricultural production. The GTAP database therefore assumes that the distribution of value-added across land, labor and capital is the same across all agricultural activities in a country. Value-added shares thus differ across countries but are identical for all agricultural activities within a country.

With the available data we do not have an empirical basis to differentiate production by AEZ in terms of value-added, factor prices or substitution elasticities. This implies that when calibrating a CES production function for the value-added composite of crops, there will be no difference in the distribution parameters (which are identical for all crops in a country), nor substitution elasticity (also identical for all crops in a country). When calibrating the production function to the available data the efficiency parameter will completely capture the differences in production across AEZs by shifting the production function to capture differences in yields by AEZ. In other words, if a less productive type of land is used, the lower production will be completely captured by the efficiency parameter shifting the production function down compared to a more productive type of AEZ. Defining production by AEZ thus results in an explosion of the dimensions of the model while the additional production functions are identical apart from the efficiency parameter.

The variation in efficiency parameters (measuring factor productivity) is due to variation in land productivity across AEZs in the absence of data on other differences in production by AEZ. Instead of defining production by AEZ we therefore maintain a single production function by crop as in GTAP-AGR but redefine the single type of land as a land aggregate composed of land of different AEZs. We then add a nest to the production function to determine the composition of this land aggregate. By assuring that this land nest captures the productivity differences of land across AEZs we incorporate the same amount of information in the model as with defining production by AEZ (differences in yields across AEZs) without having an explosion of the model's dimensions.

We account for the productivity differences across AEZs by introducing standardized hectares of AEZs in the land composite nest[3]. We compute a (country-specific) productivity index for each crop by dividing the yield attained at an AEZ by the maximum yield across all AEZs. This index takes value for the most productive AEZ and is less than one for the other AEZs. If we then multiply the actual area of an AEZ by the productivity index we obtain a cultivated area in standardized hectares which is used in the nest determining the land composite.

The standardization procedure implies that the endowment of land measured in standardized hectares changes when the cropping pattern changes, even though the total land endowment measured in actual cultivated hectares is fixed. In case there would be no differences in AEZ productivity between crops there would also be no need to account for the productivity differences of AEZs. The differences in productivity across crops depicted in Figure 1 indicate that shifting between crops may imply that land is shifted to crops to which it is less suited. This implies a loss of productivity not accounted for by having a single type of land, but which can be captured by introducing eth standardized hectares.

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[3] Note that the land composite nest is not necessary for introducing the standardized areas. These could also be included directly in the value-added nest. However, since substitution between different types of land may be easier than substitution between land and labor or capital we add a land nest to the value-added nest.

4. Scenarios

The aim of this study is to assess whether heterogeneity of land affects the expected impact of trade liberalization on developing countries. We therefore compare the results of a model including the productivity differences across AEZs (GTAP-AEZ) with the findings of GTAP-AGR. To compare the results of the models we use a free trade scenario which is straightforward to implement and results in a large adjustment highlighting the differences between the two models.

In the current first version of the model we employ a similar aggregation (using Version 6 of the GTAP database) as Keeney and Hertel (2005) in their development of GTAP-AGR. We thus maintain full disaggregation of the farm and food sector while aggregating manufacturing and services in seven sectors. We maintain forestry and fisheries as separate sectors to allow the introduction land transformation from forestry to other uses at a later stage of the research, resulting in a total of 31 sectors. The regional aggregation in the current version of the model is also the same as in Keeney and Hertel (*ibid.*). This rather disaggregated model structure is possible because by adding the nest for land to capture productivity differences across AEZs we keep the dimensions of the model limited.

As a reference scenario we use the base data in the 2001 database, we thus do not develop an updated reference scenario to capture policy changes that have occurred between 2001 and 2007. Again, given our focus on comparing models model scenarios are kept as simple as possible.

5. Results

Some first results are presented in Table 2 and 3. The hypothesis driving the development of the AEZ model was that the single type of land in the standard GTAP database overestimated the production possibilities in developing countries and therefore their gains from trade liberalization. The first tests of the model do not find strong support for this hypothesis. For all regions except Brazil we find less than one percent difference in equivalent variation (EV) of the two models (Table 2). Focusing on the direction of the differences we find for the majority (16 out of 23 regions) that the GTAP-AEZ model results in a smaller welfare gain that the standard GTAP-AGR model. Among these are the African regions for which generally limited or negative impacts of trade liberalization are found. Of the regions with a higher welfare gain in the GTAP-AEZ model Korea stands out in being a relatively small country. Other regions which experience a larger gain are either large countries (like Brazil) or aggregates like the EU.

Table 2: Welfare changes by region for GTAP-AGR without and with AEZs (billion US$ 2001)

	GTAP-AGR	*GTAP-AEZ*	*Difference (%)*
Oceania	2.76	2.76	-0.12
China	7.49	7.52	-0.36
Japan	29.35	29.35	0.00
Korea	9.46	9.42	0.34
Taiwan	1.19	1.19	-0.22
Indonesia	0.93	0.93	0.34
South East Asia	2.86	2.84	0.60
India	1.77	1.78	-0.59
South Asia	0.29	0.29	-0.29
Canada	7.85	7.86	-0.06
United States	4.80	4.83	-0.51
Mexico	0.94	0.95	-0.52
Latin America	-1.37	-1.36	0.56
Argentina	0.81	0.81	0.32
Brazil	4.66	4.55	2.28
European Union	15.64	15.60	0.30
European Free Trade Area	5.38	5.39	-0.08
Russia	1.28	1.29	-0.24
EU New Entrants (2004)	0.96	0.96	-0.24
Other Eastern Europe and FSU	1.02	1.02	-0.08
Middle East and North Africa	2.73	2.73	-0.24
Sub-Saharan Africa	-1.33	-1.33	-0.19
South African Customs Union	1.40	1.40	-0.28

Table 3: Crop production with trade liberalization for GTAP-AGR without and with AEZs (% change)

	Model	*Paddy rice*	*Wheat*	*Cereal grains nec*	*Vegetables, fruit, nuts*	*Oil seeds*	*Sugar cane, sugar beet*	*Plant-based fibers*	*Crops nec*
Oceania	AGR	78.5	-19.0	16.7	-1.1	-27.0	22.2	-7.6	-5.2
	AEZ	86.1	-17.2	17.9	-0.5	-25.4	22.3	-5.6	-4.4
China	AGR	24.5	-0.6	0.9	0.1	-19.3	-0.7	10.6	-10.5
	AEZ	24.4	-0.5	0.8	0.0	-19.5	-0.8	10.6	-11.2
Japan	AGR	-77.9	-72.6	-21.6	5.9	19.6	-15.9	8.0	0.9
	AEZ	-77.9	-72.6	-21.6	5.9	19.6	-15.9	6.9	0.8
Korea	AGR	-71.0	23.8	-51.7	3.7	-51.7	13.1	24.9	17.5
	AEZ	-70.6	24.6	-51.8	4.4	-51.1	12.9	8.1	19.6
Taiwan	AGR	-1.8	-2.4	-1.9	-3.0	14.9	-52.4	14.7	-7.9
	AEZ	-1.8	-2.4	-1.9	-3.0	15.1	-52.5	9.2	-8.2
Indonesia	AGR	-2.4	-8.2	-0.8	0.4	5.2	-3.3	5.5	-3.9
	AEZ	-2.3	-4.7	-0.6	0.6	5.5	-3.2	6.0	-3.4
South East Asia	AGR	0.0	-0.4	-0.4	0.2	-2.6	7.7	1.8	-6.8
	AEZ	0.4	-0.5	-0.3	0.3	-2.1	7.8	2.1	-6.4
India	AGR	0.3	0.7	-0.2	-2.1	-4.5	0.4	4.0	-1.0
	AEZ	0.4	0.7	-0.1	-2.1	-4.4	0.5	4.0	-0.9
South Asia	AGR	-1.0	-1.2	-2.8	-0.8	-8.0	-5.5	7.0	-0.3
	AEZ	-1.0	-1.3	-2.8	-0.7	-8.1	-5.5	7.0	-0.4
Canada	AGR	51.7	11.5	6.6	12.2	-12.0	-25.2	-1.7	-2.2
	AEZ	50.1	10.7	6.4	11.9	-12.3	-25.4	-1.8	-2.4
United States	AGR	91.4	0.6	3.6	-0.1	10.2	-3.4	-3.1	0.7
	AEZ	86.4	0.7	3.7	0.0	9.8	-3.5	-3.3	0.6
Mexico	AGR	29.6	-8.2	-0.3	1.7	7.2	-0.1	6.2	-0.7
	AEZ	30.9	-8.3	-0.3	1.6	7.0	-0.1	6.2	-0.8
Latin America	AGR	2.7	-8.3	-1.7	11.6	-1.4	12.1	-2.3	-5.5
	AEZ	2.4	-8.4	-1.8	11.3	-1.8	12.0	-2.6	-5.9
Argentina	AGR	0.7	-0.1	3.8	1.6	6.5	3.3	-6.3	2.1
	AEZ	-0.2	-0.2	3.7	1.5	6.2	3.3	-6.4	2.0
Brazil	AGR	-3.2	-9.3	8.1	-9.8	-10.9	-1.0	-15.8	-15.7
	AEZ	-1.9	-6.7	8.9	-8.2	-8.9	-0.4	-14.4	-13.1
European Union	AGR	-54.2	2.2	-7.7	-4.4	3.1	-34.5	10.0	3.5
	AEZ	-54.0	2.0	-7.7	-4.5	2.6	-34.5	9.8	3.3
European Free Trade Area	AGR	-4.4	-35.4	81.3	-14.7	-14.0	-11.0	21.1	-2.4
	AEZ	-5.8	-37.0	78.2	-15.4	-15.6	-11.1	19.3	-3.9
Russia	AGR	-9.0	2.7	-0.3	-0.7	-2.8	0.0	3.0	-4.3
	AEZ	-9.1	2.7	-0.3	-0.8	-3.1	0.0	2.8	-4.4
EU New Entrants (2004)	AGR	-8.1	3.5	2.4	-3.4	-1.8	0.7	-2.2	-7.5
	AEZ	-7.9	3.8	2.5	-3.2	-1.9	0.7	-2.2	-7.4
Other Eastern Europe and FSU	AGR	0.0	3.8	-0.3	-1.5	2.1	-0.1	-0.2	-1.4
	AEZ	-0.1	3.7	-0.4	-1.5	2.0	-0.2	-0.2	-1.4
Middle East and North Africa	AGR	2.9	-6.0	-4.2	-0.9	14.8	-0.7	-1.8	-0.4
	AEZ	2.6	-5.9	-4.1	-0.9	14.8	-0.7	-1.8	-0.7
Sub-Saharan Africa	AGR	-17.0	-10.4	-1.3	0.4	5.1	6.9	12.4	0.2
	AEZ	-17.1	-10.5	-1.3	0.4	5.1	6.8	12.2	0.0
South African Customs Union	AGR	0.1	-13.1	1.9	-4.8	5.7	63.4	-13.4	-1.4
	AEZ	0.0	-13.0	1.9	-4.5	5.8	63.4	-13.3	-1.2

The main effect of the AEZs is expected to be in the agricultural supply response. Table 3 therefore presents the change in production of the eight crop sectors for which we introduced the AEZs. For each region and crop we present the change with the GTAP-AGR model (as developed by Keeney and Hertel) and the modified model including the AEZs. Comparison across the different regions indicates a varied pattern. In several cases there are no, or only very marginal, differences between the two models, most notably for the three African regions in the model (Middle East and North Africa, for Sub-Saharan Africa and the South African customs union). In other cases there are several percentage point differences for several crops (Oceania, Indonesia). There is no obvious pattern appearing in these results.

6. Preliminary conclusions

The objective of this paper is to explore the extent to which a difference in the type of land endowments across countries affects the impact of trade liberalization. We hypothesize that developing countries have less productive land, implying that benefits from trade liberalization are less than expected based on currently used models with a single type of land.

We exploited a recently made available dataset on agro-ecological zones which is compatible with the GTAP database. The available data are limited to harvested areas and yields by crop and country, no data are available on differences in labor and capital use by AEZs (or by crop). We added the AEZs through a land composite in the value-added nest of the standard GTAP-AGR model. By accounting for the productivity differences across AEZs through the use of standardized hectares we can include 18 AEZs without having an explosion of the model dimensions.

As a first test we compared result of a full liberalization scenario with the standard GTAP-AGR and GTAP-AEZ model developed in this paper. This first test indicates limited differences between the two models. One reason for this may be that the same low elasticity for the supply of sluggish land endowments in used in both models. This low elasticity limits the possibilities for shifting land between sectors and will therefore mute the difference between the two models. Given that the introduction of AEZs captures more of the differences in suitability of land, introducing higher supply elasticities seems warranted. A second reason for the limited differences may be the current regional aggregation which is not based on AEZ endowments. Grouping regions which similar endowments may better elicit the impact of heterogeneous land endowments on the impact of trade liberalization. We will explore whether these changes to the model will reinforce the modestly lower gains from trade liberalization found in the first tests of the impact of heterogeneous land.

7. References

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