Transportation costs and bilateral trade in the global land use model MAgPIE - DRAFT

Anne Biewald*, Christoph Schmitz, Hermann Lotze-Campen

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Abstract

MAgPIE (Model of Agricultural Production and and its Impact on the Environment) is a spatially explicit model covering the most important crop and livestock production types in 10 economic regions worldwide. Until now, trade in MAgPIE is simulated by defining minimum self-sufficiency ratios for each region, and letting the model allocate the rest according to comparative advantages. This paper presents an advanced version of MAgPIE, in which bilateral trade between each of the ten regions is possible and controlled through the transport costs in the cost minimization goal function. The transport costs for each route and for each of the traded agricultural goods are calculated from transport margins from the GTAP database and FAO producer prices. Data which are flawed (because of reporting errors or similar) are filtered out by using the minimum percentage of transport costs of the total costs of each good as validation threshold. Resulting data gaps are first filled in by data mirroring the reversered route and if not possible by data derived through interpolation from the correct transport costs. In this paper we will show how global trade patterns can be reproduced using MAgPIE

*The author works as a Postdoctoral Researcher at the Potsdam Institute for Climate Impact Research (mail: biewald@pik-potsdam.de, phone: +49-331-288-2668, address: Telegrafenberg A51, 14473 Potsdam, Germany).

1 Introduction

Trade in agricultural products has seen a tremendous growth during the past 150 years. Whereas the trade/gross output ratio was 5% in 1870 and around 16% in 1940, it is now estimated to be more than 30% [6]. The World Bank calculated the share of agricultural exports in agricultural GDP to be 45% for the years 1996-2000 [1]. Consequentially, trade plays a significant role in the agricultural modelling community. For our purpose we concentrate on partial equilibrium models, which have incorporated trade to different extents.

The World Trade Model (WTM) minimizes factor usage and introduces trade according to the concept of comparative advantages. However, the main limitation of the model is the absence of trade barriers and transportation costs [5]. The AGLINK-COSIMO model from FAO and OECD simulates trade mainly as the residual of a supply-utilization identity equation under consideration of export or import limits. In some exceptional cases, trade quantities are fixed exogenously. However, no other trade costs are included [11]. The Common Agriculutral Policy Regionalised Impact (CAPRI) model incorporates trade barriers, like import tariffs or export subsidies, endogenously via a price transmission function. Transport, processing and other marketing costs are added with a fix margin, which is added to the consumer price [2]. The World Agricultural Trade Simulation Model (WATSIM) works similar but has already implemented some kind of transportation costs. However, according to their model description the implementation is still in its infancy. They assume only three different freight rates (for crops, livestock and other commodities) and the costs are not dependent on the distance between regions [8]. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) calculates producer and consumer support estimates as well as a fixed marketing margin, which includes transportation and marketing costs [12].

So, to us no model is known, which has incorporated transportation costs explicity as an determinant for trade flows between regions. In order to deal with this research gap, we have calculated transportation costs between ten world regions based on the GTAP database and have implemented these in our economic land-use model MAgPIE (”Model of Agricultural Production and its Impact on the Environment”).

2 Implementing trade in MAgPIE

MAgPIE is a global, spacially explicit landuse model which has been developed at Potsdam Institute for Climate Impact Reseach and is extensively described in [9]. The model works in a dynamic, recursive mode and covers on the demand side ten world regions (see table 1) and on the production side 2178 grid cells[1]. The core of the model is a cost minimization function, which minimizes the production cost for 10 demand categories for each of the regions. The required calories in the demand categories are produced by 16 cropping and 5 livestock activities (see table 2). 3 categories of costs arise for the production: factor requirement costs; yield increasing technical change costs (as described in [3] [4]) and land conversion costs. One special feature of MAgPIE is the fact that it is coupled to the grid-based dynamic vegetation model LPJmL, which simulates the potential crop yields on which the production in MAgPIE is based. The model simulates time steps of 10 years and uses in each period the optimal land-use pattern from the previous period as starting point.

In the original MAgPIE version, trade is simulated endogenously by giving each region a minimum self sufficiency ratio and letting the model allocate the rest of the production to other regions according to comparative advantages. This version of MAgPIE implements bilateral trade by including transport costs into the cost minimization function.

In the following the extensions made in order to implement bilateral trade are described in detail. The goal function minimizes the total costs of producing the exogenously given demand of every region, including the bilateral transport costs from one region to another.

$$\sum_{i}\sum_{j}\sum_{inp}\sum_{act} x_{i,j,inp,act} \cdot c_{i,inp,act} + \sum_{e}\sum_{i}\sum_{good} y_{e,i,g} \cdot t_{e,i,g} \tag{1}$$

[1] These cells cover the terrestrial part of the globe and have each an approximate size of 300 by 300 km.

where i are the economic regions, j are the single cells in each region, inp are the inputs (factor requirements, technical change and land conversion costs), act are the production activities, $x_{i,j,inp,act}$ are the levels of the different production activities (livestock and crops), $c_{i,inp,act}$ are the costs for these activities, $y_{e,i,g}$ is the amount of each good shipped from export region e to import region i and $t_{e,i,g}$ are the transport costs per ton and traded good specific to each route (transport costs inside one region are zero).

The first constraint requires that incoming shipments from all export regions to one import region (there is of course the possibility that a country imports its own products) should be greater or equal than the exogenously given demand of food calories $d\_food_{i,g}$.

$$\sum_e y_{e,i,g} \geq d\_food_{i,g} \text{ for all } i \text{ and all } g \tag{2}$$

Outgoing shipments from one export region to all import regions are not allowed to exceed the production in the export region region.

$$\sum_i y_{e,i,g} \leq \sum_j \sum_{inp} x_{e,j,inp,act} \cdot y\_food_{e,j,inp,act} \quad \text{for all } e \text{ and all } act \tag{3}$$

where $y\_food_{e,j,inp,act}$ is the food energy delivery for each cell and production activity.

In the first period the production of each region is fixed to exogenously given subsistence levels. In the following periods all goods can be traded freely between all regions.

3 Transport data

The bilateral transport costs between the ten world regions and for each of the goods at stake are derived by combining transport margins from GTAP (Global Trade Analysis Project) [10] and producer prices from the FAOSTAT statistics database, both for the year 2005.

The transport margin, that means that part of the total cost of a good which is needed for transportation, is calculated by subtracting the bilateral exports at world prices FOB (Free On Board) from the bilateral imports at world prices CIF (Cost Insurance and Freight).

transport margin ($) =
bilateral exports ($) - bilateral imports ($)

The bilateral export volume in tons[2] is calculated by using bilateral exports at market prices and dividing it by the producer price for each good taken from FAOSTAT.

bilateral export (ton) = export ($)/producer prices ($ /ton)

Unfortunately many of the GTAP data are flawed, mostly because of reporting errors, which cannot only be seen by impossible transport prices per ton of zero but also by the unrealistic share in the imported value of goods. Korinek and Sourdin [7], using data from the Maritime Transport Costs Database, find ad valorem transport costs for agricultural goods of 10.89 percent. The category of goods with the lowest value is crude oil which has ad valorem transport costs of 4 %. To filter out flawed data from the GTAP database we have now defined a rule, that only transport margins which are at least 4% of the import value and at most twice as high as the ad valorem rate given by Korinek and Sourdin (that is 20%) pass the test of not being flawed. We

[2]The export values are used rather than the import values since they do not include taxes, insurance and the transport margin and are therefore closer to the actual traded values

are aware that the different agricultural goods in MAgPIE have partly different ad valorem rates, but the filter used is very generous and works well as a first approximation. To fill the resulting gaps in the transport cost data we apply two consecutive methods. First we use, when available, mirror data, that means that missing transport margins are substituted with the transport margin from the return route[3]. This is of course not the perfect solution since there are differences in transport costs on different directions of the same route depending on the regions being import or export regions, but it is nevertheless a good approximation. The resulting data gaps are now filled with interpolated values, which are interpolated on the base of all the goods on a specific route.

4 Simulation results

4.1 Trade in 2005, Comparison with GTAP data

In the following trade patterns calculated with MAgPIE are compared with global trade patterns from GTAP[4]. For a soft calibration the production of each of the agricultural good for each region is fixed in 1995, the trade is not constrained. In 2005 trade and production are free.

The graphs show import shares for each region and each of the agricultural categories: cereals, rice and oilseeds, for MAgPIE and GTAP. Looking at all goods, the following observations can be made. The GTAP-data show a more diversified import behavior, demand is met through import from many regions, wheras in MAgPIE fewer regions export in a single import region. This tendency to specialize in MAgPIE has several reasons, the most important being that for an optimization model price is the only criteria to import from a certain region, whereas in reality several factors beside price might play a role. First, the quality of a product from a certain region might be better compared to one from another region. Second, there is demand for several kinds of rice, cereals and oilseeds, which are only produced in certain regions. Third, long established and trustfull trade relations between regions will continue, despite a higher price. So in contrast, the trade patterns which

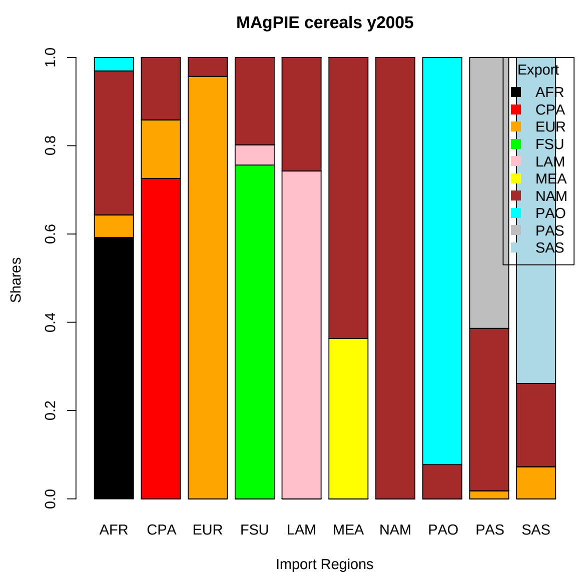
[3]This method is widely used to resolve data gaps, e.g. by the United Nations

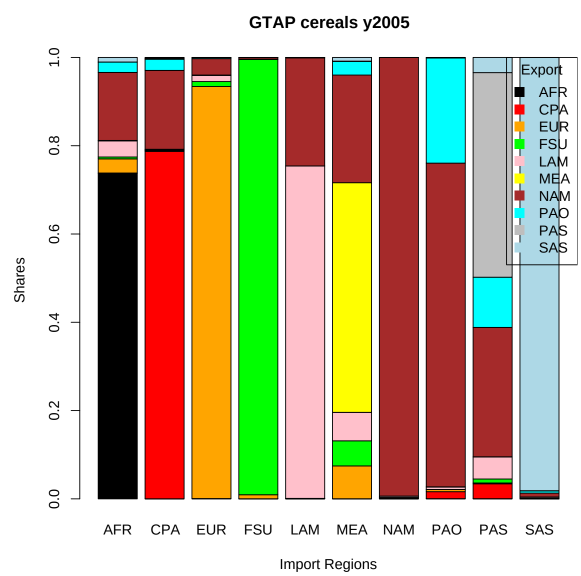
[4]In order to make the values from GTAP comparable to MAgPIE results, the values are converted into tons by dividing the values by producer prices taken from the FAO.

can be seen in the MAgPIE results are the patterns derived only from a cost minimization perspective.

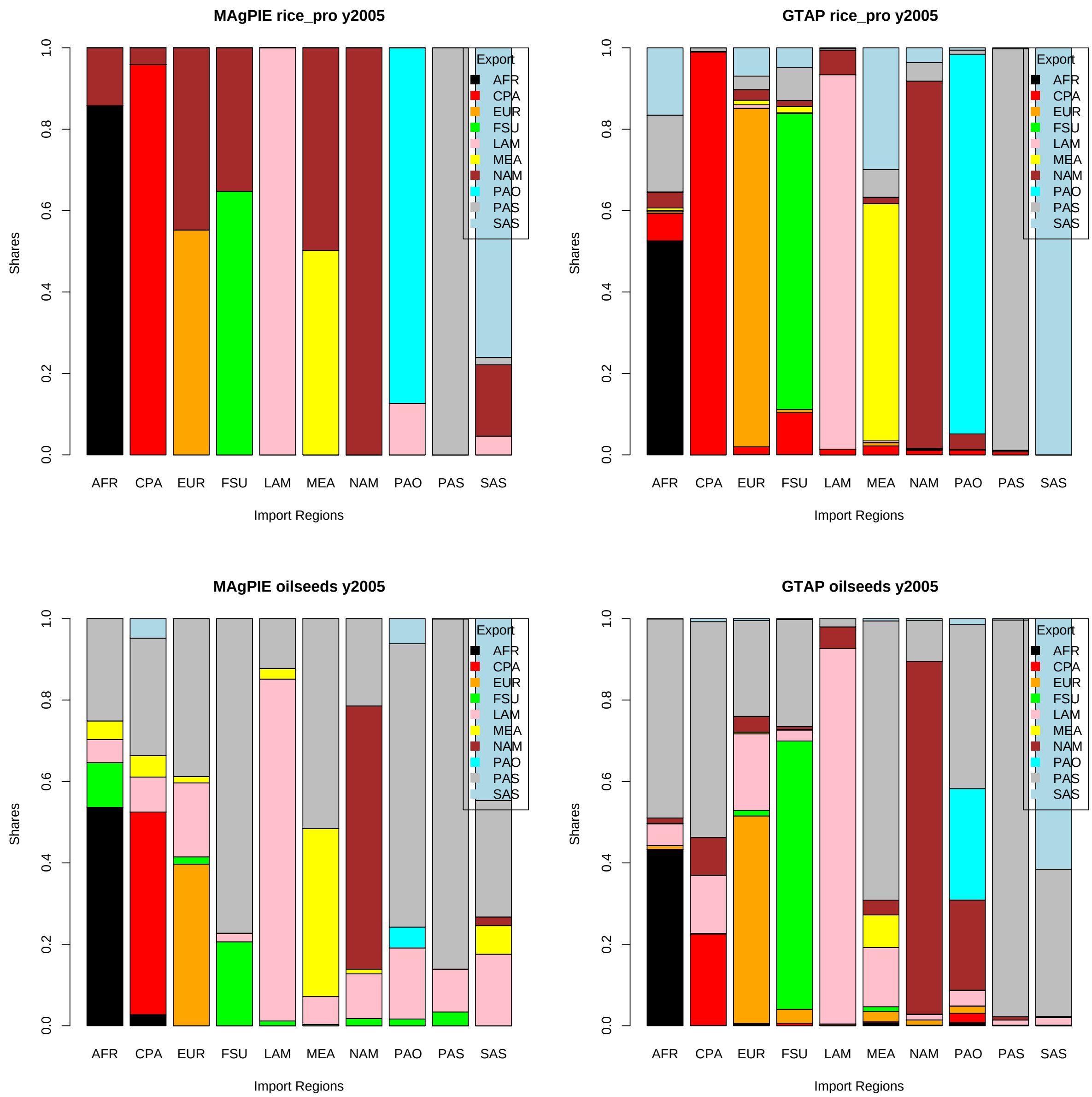
A second general observation concerns the share which is imported from each region. In the data the share of imports is often smaller for each region than in the model results. This can be explained by lack of tariffs and subsidies in MAgPIE[5]. Due to the small size and heterogenous composition of the region, Pacific OECD (which consists of Australia, New Zealand and Japan) the model results for this region are less satisfying for each of the three goods. However, for the other regions the comparison between model results and GTAP data shows a good quality.

For cereals the main exporteur is North America, which is in line with GTAP data. Almost all regions in MAgPIE as well as in the data produce the largest part of their demand themselves. In the GTAP data a high percentage of rice is produced by the regions themselves, whereas the model results show a higher import share. This is probably due to the lack of tariffs. The main exporter in oilseeds is Pacific Asia, followed by Latin America, which is well reproduced by MAgPIE.





[5]There is work in progress to endogenize customs and subsidies in MAgPIE.



5 Outlook

This paper is a draft and the following steps are planned to improve it. First, the model is supposed to be calibrated by fixing the trade patterns in the first period and deriving endogenously customs and subsidies. Second, a sensitivity analysis will be made to see how transport costs influence model output.

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Appendices

Regions	Description
AFR	Sub-Saharan Africa
CPA	Centrally planned Asia (including China)
EUR	Europe (including Turkey)
FSU	Former Soviet Union
LAM	Latin America
MEA	Middle East/ North Africa
NAM	North America
PAO	Pacific OECD (Japan, AUS, NZL)
PAS	Pacific Asia
SAS	Southern Asia (incl. India)

Table 1: Description of the different economic regions

Production activities	**Demand categories (Traded goods)**
temperate cereals maiz tropical cerals	cereals
rice	rice
soybean rapeseed groundnut sunflower oilcrop	oilcrops
pulses	pulses
potato cassava	roots
sugar_beet sugr_cane	sugar
vegetables, fruits,nuts	vegetables, fruits, nuts
cotton	fiber
bio_fuel	biof_ener
ruminant meat	ruminant meat
nonruminant meat	non-ruminant meat
milk	milk

Table 2: Production activities and their relations to the demand categories