A LAND DEMAND AND SUPPLY SYSTEM WITH ENDOGENOUS LAND PRICES IN THE CAPRI AGRICULTURAL SECTOR MODEL

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Abstract

Questions about land use change induced by policies impacting the agricultural sector such as bio-fuel mandates have clearly raised the interest of understanding to which extent changes in agricultural productions stem from the extensive margins – expansion of agricultural land cover – or from the intensive margin – changes in the special intensity which increase yields or stocking rates. Agricultural sector models being able to answer these questions in a consistent manner are still rare. In this paper, we develop a land demand and supply system with endogenous land prices in the CAPRI agricultural sector model[1].

Keywords

Land use change, CAPRI, agricultural sector modelling, land market

1. Introduction

The CAPRI market model has driven before the extension discussed in the paper supply quantities by behavioural equations depending on prices. It did not distinguish between an area and a yield response. Consequently, it could also not simulate effects on the area used by agriculture and on returns to agricultural lands. In the context of the GLUES (http://nachhaltiges-landmanagement.de/en) project, it is envisaged to introduce explicit land allocation in the global market model of CAPRI. One medium term goal of the initiative is to improve interaction with plant growth models world-wide. Equally, the project aims to develop an approach to model agricultural land use change which is as far as possible empirically based and, if possible, allows taking differences in agricultural land quality into account.

As a first step in that direction the changes discussed in the following are implemented in CAPRI as they allow using at least parameters derived from other models or studies respectively later from a separate module. The reader should note, however, from the beginning that the discussed solution does not endogenously allocate land to individual crops. The approach presented here can be understood as a meta-model for a more complex and explicit tool which allocates land to agricultural activities and models land use cover change.

2. Empirical Method

The basic extension in the market module of CAPRI consists of treating land as a netput in the normalized quadratic (NQ) profit function which so far was used for agricultural outputs, only. The related equations are extended by the additional element land:

$$y_{i,r} = as_{i,r} + \sum_j bs_{i,j,r} \frac{p_{j,r}}{p_{index.r}}$$

The difference to the former formulation is the fact that the left hand side now comprises total land demand meaning that the index i now includes land and not only agricultural outputs. Consequently the land price is now taken into account on the right hand side. Accordingly, changes in output prices of agricultural commodities change total agricultural land demand and changes in land prices change production quantities.

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[1] www.capri-model.org

In order to parameterize the function, information about yield and supply elasticities is used. The marginal reaction of land to a marginal change in one of the prices is defined as the total supply effect minus the yield effect:

$$dLand_r / dp_{i,r} = \sum_j dQ_{j,r} / dp_{i,r} \; 1/ yield_{j,r} - ela_{i,r} \; Q_{i,r} / p_{i,r} \; 1/ yield_{i,r}$$

where Q denotes quantities and p prices. The calibration requires prices for land which is set to 0.3 of the crop revenues. For fodder area demand from animals it was set lower (cp. page 56 in Golub et.al. 2006). The summation term over all products j defines the "land demand change" if the price *i* changes. The quantity change of each product j is translated into a land demand change based on its yield. The reciprocal of the yield can be interpreted as the land demand per unit produced.
The last term translates first the yield elasticity (an endogenous variable) into a marginal quantity effect and, then again, based on the yield, in a changed land demand. The land demand change is subtracted as the land demand for product i per unit decreases if yields increase due to a positive own price yield elasticity. This formulation assumes, as conventionally done in multi-commodity models, that cross-price yield effects are zero.
The CAPRI market model does not handle explicitly non-tradable crop outputs such as grass, silage or fodder maize. However, the land demand for these products is also taken into account in order to allow closing an overall land balance. This is achieved by deriving per unit land demands for animal products.

The link to land supply is straightforward: if the land supply curve is known, a market balance equilibrates the simulated land demand based on the behavioral equation derived from the NQ profit function with that land supply curve. The land price is the equation multiplier attached to the land market clearing equation. If the land supply curve collapses to a constant, any output price induced change in land demand is leveled out by a change in the land price. That solution is equivalent to the behavior of programming model with a fix land endowment.
If the market balance equation is dropped and the land price fixed, totally elastic land supply to agriculture is assumed. This assumption should be of little empirical value as agriculture is typically the major demander for land suitable to agriculture. The current solution incorporates a land supply curve with exogenous given elasticities (similar to Tabeau et.al. 2006). The parameterization of the land supply curve is currently chosen similar to the land elasticities e.g. reported in GTAP (Amer Ahmed et. al. 2008). Generally, land supply is rather inelastic so that price increase of agricultural commodities rather increase land prices and not so much land use.
Although the profit function approach does not allocate areas to individual crops, it captures in a dual formulation how product and land price changes impact on *total* agricultural land use. The estimated yield elasticity is however used in a post model analysis to derive an allocation which is consistent with the assumptions used during parameter calibration. Basically, for each crop product, the yield elasticity is used to derive from the simulated quantity change the implied land change. The resulting land demands are then scaled to match the simulated change in total land.

3. Results

The implemented changes are illustrated with a simulation, where we assume that the EU removes the biofuel targets defined in the Renewable Energy Directive (RED). The simulation results for 2020 are compared to a baseline which is based on the OECD/FAO Agricultural outlook 2011. In this baseline it is assumed that the RED is not completely, but to a large extent met (ca 9.5% if total transport fuel filled with biofuels).
Table1 and figure 1 summarize the results. Globally about 3.5 million hectare leave production. In relative terms this only accounts to 0.1 %, but the absolute amount must be noticed. The strongest area effects can be found in South America and there especially in Brazil followed by Argentina. This is not surprising given the importance of these two countries on biofuel markets. In the USA (another global biofuel player) the area effects are less strong, since the US biofuel policy remains in

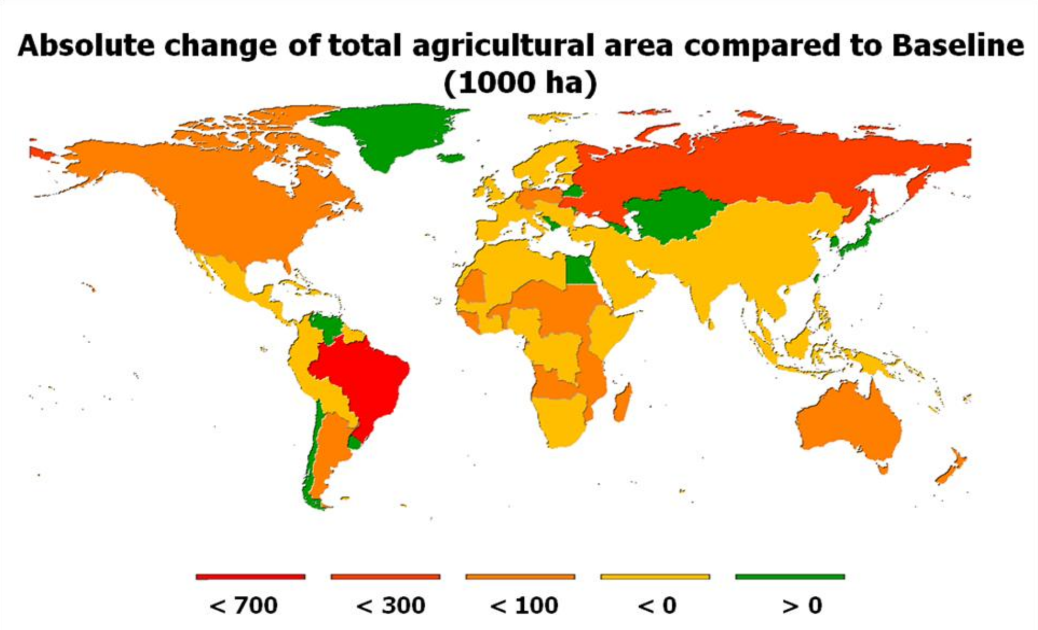
place. In Russia and the Ukraine we observe the second largest area reduction (both are allocated to Europe, Non EU, although geographically not perfect), although they play only minor roles in biofuel markets. But as they are important player in grain markets they will be affected by less feedstock demand of the EU27 for grain ethanol. The area effects in the EU27 are comparably low, although the scenario alters an EU policy. In relative terms EU agricultural area is reduced by 0.3% which is the largest relative effect, but in absolute terms this policy impacts stronger on area use in extra EU27 regions.

Table 1: Area effects of RED removal

Total agricultural area (2020)

Mn ha	Baseline	Scenario	Δ
EU27	180.46	179.98	-0.48
Europe, Non-EU	571.73	571.03	-0.70
Africa	1650.75	1650.59	-0.16
North America (USA, Canada, Mexico)	662.16	661.64	-0.52
Middle and South America	689.67	688.61	-1.06
Asia	1470.65	1470.41	-0.24
Australia and New Zealand	454.25	453.98	-0.28

Figure 2: Area effects of RED removal



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