Effects of environmental and energy policies on long run patterns of land use

by

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Draft April 30, 2012

Introduction

In light of higher fossil fuel prices, concerns about energy security and global warming, considerable attention has been devoted to biofuels over the past decade. Stimulated by policies which are designed to deal with these three global problems, production and use of biofuels has grown, and much bigger volumes are expected to be produced to meet future US and European policy targets. The large scale production of biofuels may have dramatic impacts on patterns of land use, resulting in expansion of cultivated lands and deforestation. In the same time, there is a significant interest in international agricultural and forestry based carbon sequestration and greenhouse gas (GHG) mitigation, which could be inexpensive, and provide revenue to developing countries and farmers. Changes in land-use induced by the land-based GHG mitigation policies run counter to the changes induced by biofuels, further heightening competition for land driven by increasing world population and improving diets.

The goal of this work is to analyze land-use change at the global scale over the long run in the context of environmental and energy policies, taking into account fundamental drivers of supply and demand for land, including population and technical change drivers. The policies we focus on are 1) greenhouse gas (GHG) mitigation, including land-based mitigation through shift to cleaner agricultural production practices and increased forest carbon sequestration, and 2) expanded production of biofuels. To accomplish the goal this study develops a new dynamic global computable general equilibrium (CGE) model GDyn-E-AEZ.

Analytical Framework

The new model is based on several existing CGE platforms - the dynamic GTAP model GDyn (Ianchovichina and McDougall, 2001) and static GTAP-BIO (Birur et al., 2008) and GTAP-AEZ-GHG (Golub et al., 2009) models. The data base used in this study integrates several independent components: GDyn data base (McDougall et al. 2012), GTAP data base with liquid biofuels and their by-products (Taheripour et al. 2011), non-CO2 emissions data for all sectors of the economy (Rose and Lee, 2009), forest carbon stock data by species, vintage and AEZ (Sohngen *et al.*, 2009), and the fossil fuel CO2 emissions database developed by Lee (2007).

GDyn is a multi-sector, multi-region, recursive dynamic applied general equilibrium model that extends the standard GTAP model to include international capital mobility, endogenous capital accumulation, and an adaptive expectations theory of investment. The distinguishing feature of the model is its disequilibrium mechanism for determining the regional supply of investments, which is critical for analysis of carbon leakages due to unilateral climate policies. This model was used to analyze the role of global economic integration, population and income growth in determining land use change with special attention paid to consumer demands and technological progress in agriculture as drivers for supply and demand for land. The previous work, however, had not incorporated land use related GHG mitigation mechanisms in agriculture and forestry and land use impacts of biofuels programs. This project builds on static GTAP-BIO and GTAP-AEZ-GHG frameworks to incorporate the detailed model of land use into GDyn model.

The GTAP-BIO model is modification of GTAP-E (GTAP-energy and environment model, Burniaux and Truong, 2002) with standard GTAP sectors dissaggregated to handle first generation biofuels and their by-products. Production and consumption structure of GTAP-E are modified to incorporate these new products. Grain-based ethanol, sugar cane ethanol and oilseeds biodiesel substitute for petroleum products in liquid fuel consumption. In the data base used for this work, soybean is separated from other oilseeds; soybean oil is separated from other vegetable oils and fats, and soybean biodiesel from other types of biodiesel (Tyner et al. 2011). Biofuels co-products (Dried Distillers Grains with Solubles (DDGS) and oilseed-meals) compete with other feedstock in livestock feed use. To estimate the climate effects of land use changes resulting from biofuels expansion, land use change results are combined with assumptions about the types of ecosystems affected, and the carbon fluxes from changes to those ecosystems. A version of this model is used by California Air Resource Board in the assessment of Low Carbon Fuel Standard assessments of biofuels.

The GTAP-AEZ-GHG model is also based on GTAP-E. As in GTAP-BIO and earlier work with GDyn, regional land in GTAP-AEZ-GHG is split into Agro-Ecological Zones to reflect heterogeneity of land. In addition to carbon dioxide (CO_2) emissions, the model includes detailed non-CO_2 GHG emissions in agricultural and other sectors, and forest carbon sequestration. Land-based GHG mitigation options are based on a variety of partial equilibrium approaches. In the agricultural sectors, the model is calibrated to non-CO_2 GHG mitigation possibilities derived from detailed engineering and agronomic studies developed by the US Environmental Protection Agency. In the case of forest carbon sequestration, estimates of optimal sequestration responses to global forest carbon subsidies are derived from partial equilibrium forward looking global forestry model. This includes both the extensive margin (increased forest land cover) and intensive margin (increased carbon stocks on existing forest lands).

Baseline assumptions

The starting point of the analysis is the world economy in 2004, as depicted in the version 7.0 of GTAP data base. 36 sector and 19 region aggregation of the modified GTAP data base is employed in this analysis. In the baseline simulations from 2004 to 2030, labor force and population are all exogenous to the model. Historical and projected population and labor force (skilled and unskilled labor) growth rates for 2004 – 2030 are taken from Chappuis *et al*. (2011). The population growth rates are highest in Sub Saharan Africa region, and lowest (negative) in Japan and Russia. Skilled and unskilled labor cumulative 2004-2030 growth rates are presented in Table 1. Historical real GDP growth rates are taken from Chappuis *et al*. (2011). The real GDP path for 2012 − 2030 is driven by assumptions about productivity growth in various sectors of the economy. Productivity growth rates in non-land using sectors are based on our assumptions about economy-wide labor productivity growth in each region (reported in Table 1, column 4). These rates are adjusted for productivity differences across sectors using estimates reported in Kets and Lejour (2003). For detailed description of the productivity growth in non-land using sectors the reader is referred to Hertel et al. (2006).

Land using sectors include agricultural sectors and forestry. Agricultural sectors include seven crops, ruminants, dairy and non-ruminants. Non-ruminants sector does not use land directly to reflect the fact that production of non-ruminants does not involve grazing land and is largely undertaken in confined settings. For the agricultural sectors, the projected productivity growth rates are taken from Ludena (2005). These productivity growth rates take into account the productivity of all inputs, not just value-added. Productivity growth rates in forestry are assumed to be equal to the average of productivity growth rates in crops and ruminants, weighted by the share of their output in total output of crops and ruminants. This is a “neutral” assumption that does not have an effect on the allocation of land between agriculture and forestry.

Baseline cumulative GDP growth rates are shown in column 5. Fastest GDP growth is achieved by China, closely followed by India. The assumed productivity growth rate in China is higher than in India (8 and 7 percent per year, respectively) to respect recent historical development of GDP growth rates in these countries. However, due to slowdown in China's labor force growth and continued strong growth of labor supply in India, by 2030 India almost catch up to China by the cumulative GDP growth.

Table 1 Cumulative growth rates in endowments and GDP and annual productivity, by region (%)

Region	Unskilled labor	Skilled labor	Productivity (growth rate per year)	Capital	GDP
1	2	3	4	5	6
USA	32	1	2	83	75
EU27	17	1	2	68	53
BRAZIL	26	95	3	300	226
CANADA	29	0	2	108	80
JAPAN	-9	-24	2	27	27
CHIHKG	-12	32	8	987	753
INDIA	45	122	7	982	745
C_C_Amer	31	73	3	72	125
S_o_Amer	36	53	3	320	198
E_Asia	-12	25	4	485	232
Mala_Indo	29	136	5	552	387
R_SE_Asia	33	103	4	250	273
R_S_Asia	74	99	5	424	358
Russia	24	49	4	494	190
Oth_CEE_CIS	24	60	3	276	197
Oth_Europe	23	0	2	111	72
MEAS_NAfr	34	125	3	414	249
S_S_AFR	66	106	4	436	319
Oceania	57	32	2	146	118

Summary

The dynamic framework proposed in this work allow us to capture the intertemporal opportunity costs of agricultural and forestry land-use decisions, generate projections of land use changes and associated GHG emissions, and allow comparison to historic land use changes over the last decade. With the new model, we evaluate potential future global land-use patterns. We will consider futures with expanded biofuels policies, climate change mitigation policies, and combinations of the two. The framework is more sectorally, regionally, and temporally disaggregated than other models, and allows us to offer more detailed perspective on potential land-use management and land conversion. In addition, we will explore interactions between biofuels and climate change mitigation policies to identify potential synergies and competition between the policies. By modeling bioenergy and climate policies separately and simultaneously, we also uncover the net comparative advantages regions have in meeting these two sets of goals.

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