Decomposing Land Use Changes in GTAP-BIO-W Model

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Background

What are the drivers of land use changes? This paper develops a comprehensive decomposition for assessing changes in regional and global land use. Although the decomposition is done based on the GTAP-BIO-W model, the methodology can be applied to any other general equilibrium or partial equilibrium land use model. The change in hectares of land used is divided into significant component parts. The main components are rain-fed substitution, crop switching, relocation, irrigation technical change, water intensity, price effects, domestic scale, and global scale. Each component represents a channel of transmission from shocks to change in land use pattern. The module embeds systemic sensitivity analysis too. This helps comparing and ranking the significance of each component and checking the robustness of ranking. Decomposing land use changes can improve policy making in mitigation policies too. It helps finding which component parts lead to higher/lower emission of air pollutant due to land use changes (Searchinger et al., 2008; Hertel et al., 2010)

Methods

This paper decomposes land use changes for GTAP-BIO-W model (Taheripour et al., 2013). For decomposing changes in land use, we take the accounting relationship and totally differentiate it. Land use in each region obtained by summation of land use in production of various crops in different AEZs in all river basins of the region. Then, corresponding variables for each of the component parts are introduced. Finally, these pieces are assembled according to the methodology developed by Huff and Hertel (2000) for welfare decomposition. Then any individual component is explored deeply to find out where the results are coming from.

To include spatial features of land use changes, the units of study are river basin AEZs (Agro Ecological Zones) around the world. Each region is divided into several river basins; and in each river basin several AEZs exist. This gives us around 7000 pieces of land on the earth surface. As an empirical example, we will apply the decomposition on the results from Liu et al. (2014) which studies the impacts of changes in water availability. The model includes 8 crops, 19 regions, up to 18 AEZs and 20 river basins in each region, and 126 river basins globally.

Results

The finding suggests that although crop mix, rain fed substitution, and water intensity imply decrease in irrigated land, the relocation effect offsets those effects and leads to increase in irrigation land. In other words, crop mix will change towards a pattern with lower share of water-intensive crops; rain fed substitutions demonstrate how irrigated lands are converted to rain fed lands; and relocation shows how crop production moves towards AEZs and river basins with lower water scarcity and/or lower water intensity. In china total irrigated land is increased by 3.00% of which -1.92% is due to crop mix changes; -4.76% is due to rain fed substitution; -0.64% is due to water intensity; and +10.33% is due to relocation. India faces similar direction of changes while in Brazil the direction of changes is opposite. The sensitivity analysis with respect to parameters demonstrates the robustness of this ranking.

Prices are important part of the decomposition in regional and global level. In regional level, relative prices of land, water, and crops determine land allocation across AEZs. In global level, relative price of crops is the main determinant of changes in export and imports which affects the global land use pattern. The following table shows the initial calculations for main component parts of change in irrigated cropland by region. Final paper will discuss these component parts in more details.

Table 1: main decomposition of irrigated cropland by region, Changes in irrigated crop land use in percentage

	1 CRP_MIX	2 RFD_SUB	3 WL_INTN	4 RELOCAT	5 LU_TOT
1 USA	0.432	-0.105	-0.102	-0.425	-0.200
2 EU27	0.755	0.679	-0.138	-2.731	-1.435
3 BRAZIL	0.339	1.557	0.003	-5.016	-3.117
4 CAN	0.678	-3.254	-0.137	5.253	2.540
5 JAPAN	0.494	-0.458	-0.042	0.007	0.001
6 CHIHKG	-1.922	-4.761	-0.641	10.327	3.003
7 INDIA	-1.115	-5.880	-0.569	14.852	7.288
8 C_C_Amer	0.402	0.247	-0.076	-2.925	-2.352
9 S_o_Amer	0.106	-0.772	-0.098	1.619	0.855
10 E_Asia	0.338	-0.606	-0.154	0.890	0.468
11 Mala_Indo	0.179	-0.022	-0.211	0.095	0.041
12 R_SE_Asia	-0.863	-4.624	-0.474	11.429	5.468
13 R_S_Asia	-7.554	-9.212	-1.104	32.366	14.496
14 Russia	0.400	-2.175	-0.132	3.862	1.955
15 Oth_CEE_CIS	-0.185	-3.014	-0.162	7.077	3.716
16 Oth_Europe	0.748	-2.612	-0.103	3.963	1.996
17 MEAS_NAfr	-1.473	-2.587	-0.153	7.598	3.385
18 S_S_AFR	0.238	-11.096	-0.127	20.979	9.994
19 Oceania	0.629	-0.519	-0.174	0.365	0.301

Note:
RELOCAT: relocation; WL_INTN: water intensity; RFD_SUB: rain fed substitution; CRP_MIX: crop mix
Source: research findings

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