Land Use in Computational General Equilibrium Models

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Paper outline

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  - 2.3. Land allocation using extreme value distribution functions
  - 2.4. Land allocation with explicit costs of land conversion
- 3. Numerical analysis for CET based approaches
- 4. Simulation results
- 5. Suggestions and conclusions
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- Appendix B: Land allocation using extreme value distribution functions
- Appendix C: Numerical analyses using CET, MCET, and Fréchet stylized models

Introduction

- Covers background of modeling land use in CGE models
- Introduces main approaches in modeling land use in CGE:
  - CET approach
  - Extreme value distribution functions
  - Other approaches such as land transformation matrices, cost of land conversion, and Simple market clearing conditions
- Main messages:
  - CET approach considers heterogeneity in land quality and takes into account implicit costs of land conversion, but it fails to maintain area of land in balance
  - Various scaling methods were used to maintain area of land in balance with CET approach
  - Some CGE models have used extreme value distribution function to maintain land in balance

Theoretical background: CET

- This section analyzes the theory of land allocation in CGE models using CET approach and shows why it fails to maintain area of land in balance. The main findings are:
  - **There is no way to remain on the CET frontier and hold the physical land constraint**
  - **Heterogeneity in land prices and the curvature of the CET land frontier affect the size of imbalance**
- This section introduces adjustment approaches to maintain area of land in balance:
  - *Ex post* scaling methods: Post simulation adjustments in land use results to maintain area of land in balance **with no welfare implication**
  - *Ex ante* scaling: Impose a physical land constrain to maintain area of land in balance during the simulation process **with some welfare implications due to shifts in CET frontier**
- Two *ex ante* methods are introduced: Modified CET (MCET) and Additive CET (ACET)
- The ACET land supply can be decomposed to a shift factor and a CET land supply

Theoretical background: Fréchet distribution function

- This section explains properties of this approach, reviews the most recent papers that used this approach, and then compares this approach with CET and MCET using a set of numerical examples
- The most important take away messages are:
  - If welfare is of concern, the Fréchet and CET generate equivalent predictions
  - If land related parameters such as rent, yield, and area of land are of concerns, then the CET and Fréchet approaches provide different outcomes
  - Unlike CET, the Fréchet approach maintains area of land in balance, but this approach has two important limitation: 1) it requires equal land rents across uses in the benchmark data and 2) the calibration process must take into account yields across uses.
  - The implementation of these requirements in a typical CGE model that employs the GTAP Data Base is not trivial. The GTAP Data Base shows heterogeneous land rent across uses.

Theoretical background: Land allocation using costs of land conversion

- CET approach implicitly takes into account the opportunity cots of land conversion: 1) Losses in value added in current use and 2) costs of land conversion due to the curvature of CET. The Fréchet distribution function does the same
- The land transformation elasticity for CET imposes the second type of opportunity costs:
  - The larger the size of land transformation elasticity the smaller the opportunity costs
  - A linear CET (a simple market clearing condition) neglects the second type of opportunity costs
- The CET and Fréchet both ignore the explicit costs of moving land from one type to another type
- To allocate land across uses, in a CGE model one can take into account the explicit costs of land transformation: for example, the MIT Economic Projection and Policy Analysis (EPPA) model.
- This approach need side information on costs of land conversion.

Numerical Analyses

- Using a simplified version of the GTAP-BIO model which represents a one-nest CET land allocation, as set of numerical analyses have been made to support the findings of our analytical analyses
- All examined simulations targeted an expansion in the US corn ethanol by 747% (12.56 billion gallons)
- Simulations were made with various land transformation elasticities for CET approach
- Simulation were made to compare CET, MCET, ACET, and Physical Area Market Clearing (PAMC)

Numerical Analyses: Size of imbalance with CET

Table 1. Percent imbalances in US land area for CET1, CET2, and MARKET experiments

AEZ	CET1: $\sigma = -0.5$	CET2: $\sigma = -10$	MARKET
AEZ7	-2.00	-1.62	-1.54
AEZ8	-1.96	-1.34	-1.24
AEZ9	-2.36	-1.87	-1.79
AEZ10	-4.54	-4.60	-4.55
AEZ11	-4.32	-4.26	-4.20
AEZ12	-0.88	-0.52	-0.47
AEZ13	0.34	2.12	2.38
AEZ14	-0.45	0.75	0.93
AEZ15	0.18	1.37	1.53
AEZ16	0.02	0.05	0.06

Notes: In this table, percent imbalance for each AEZ under each experiment equals:

$$\frac{(Area\ after\ simualtion - Area\ before\ simualtion)}{Area\ before\ simualtion} \times 100.$$

The size of imbalance in each AEZ does not change largely with the size of land transformation elasticity

Numerical Analyses: Size of imbalance and land heterogeneity in land price

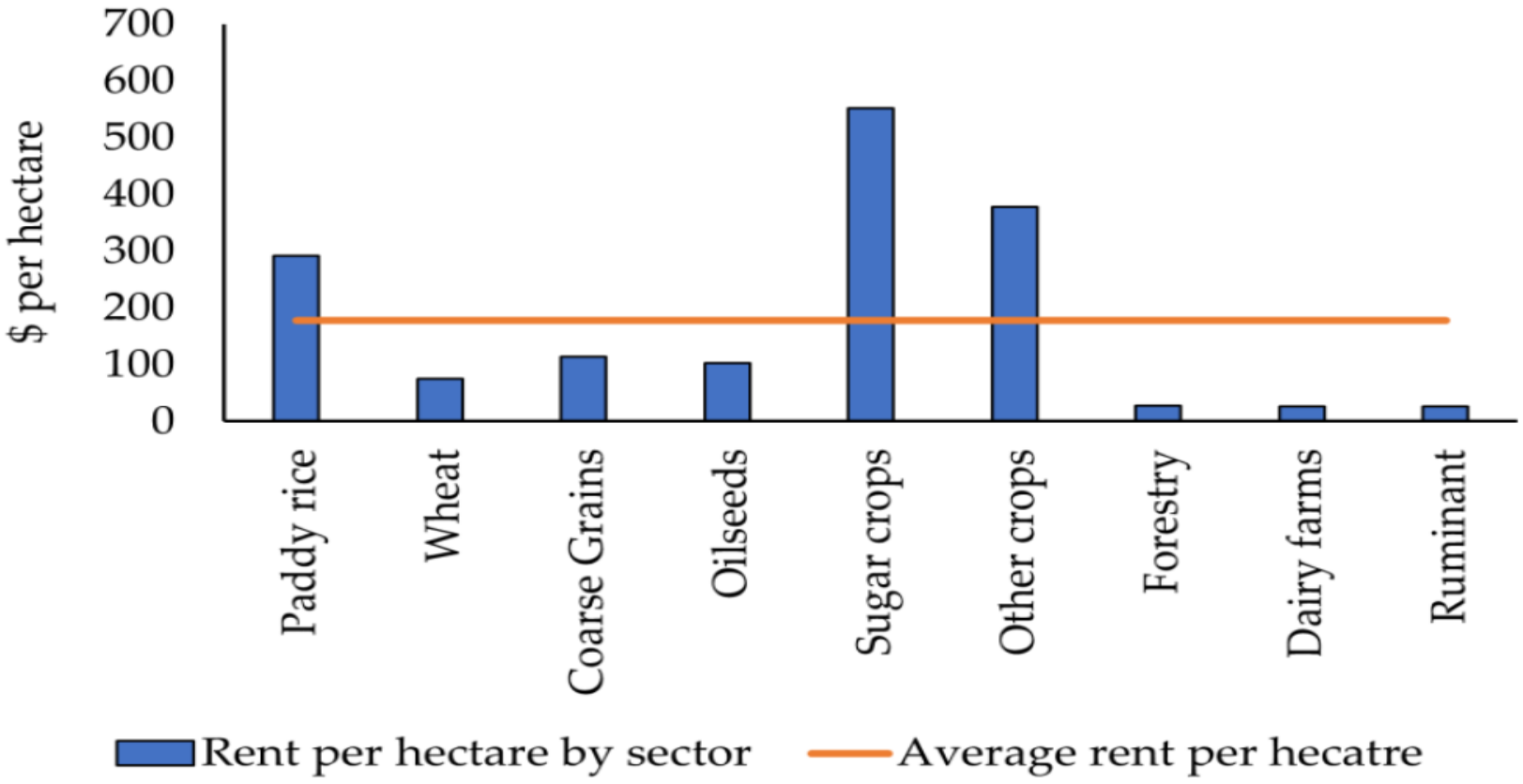


Figure 4. Rental rate of land in US AEZ10 by sector in 2011.

Heterogeneity in land price is the main source imbalance in CET approach

Numerical Analyses: Land allocation for alternative methods

Table 2. Land allocation from examined experiments for US economy

Land use	Area of land (million hectares)				Land shares (%)			
	Initial data	CET1	MCET or ACET	PAMC	Initial data	CET1	MCET or ACET	PAMC
Paddy rice	1.3	1.3	1.3	1.3	0.2	0.2	0.2	0.2
Wheat	22.6	21.1	22.1	21.2	3.8	3.7	3.7	3.6
Coarse Grains	36.3	42.1	43.1	45.8	6.2	7.3	7.3	7.8
Oilseeds	32.6	30.7	31.9	31.6	5.5	5.3	5.4	5.4
Sugar crops	1.0	1.0	1.0	1.0	0.2	0.2	0.2	0.2
Other crops	38.3	36.5	37.7	37.4	6.5	6.3	6.4	6.4
Forestry	225.4	218.2	222.9	222.3	38.3	38.0	37.8	37.7
Dairy farms	99.0	96.0	98.0	97.8	16.8	16.7	16.6	16.6
Ruminant	132.8	128.1	131.2	130.8	22.5	22.3	22.3	22.2
Total	589.2	574.8	589.2	589.2	100.0	100.0	100.0	100.0
Imbalance%	0	-2.4	0	0	-	-	-	-

Numerical Analyses: Production and Price for alternative methods

Table 3. Changes in US agricultural and forestry products and prices under alternative examined experiments for US economy

Sector	%Changes in supplies			%Changes in producer's prices		
	CET1	MCET or ACET	PAMC	CET1	MCET or ACET	PAMC
Paddy rice	-5.2	-1.8	-3.2	3.8	1.1	1.6
Wheat	-6.3	-2.2	-5.9	2.7	0.7	1.6
Coarse Grains	18.3	20.6	26.2	13.8	9.2	1.4
Oilseeds	-4.8	-1.7	-2.5	4.4	1.3	1.6
Sugar crops	-0.3	-0.2	-0.2	6.4	1.9	1.9
Other crops	-3.7	-1.3	-1.9	4.5	1.3	1.7
Forestry	-2.3	-0.9	-1.1	6.9	2.0	2.4
Dairy farms	-0.7	-0.3	-0.3	2.7	1.0	0.7
Ruminant	-1.3	-0.6	-0.6	2.6	0.8	0.7

Numerical Analyses: Welfare impacts for alternative methods

Table 4. Welfare impacts obtained from alternative examined experiments for four representative regions (figures are in million USD)

Region	CET1	MCET or ACET	PAMC
USA	-16,122	-15,727	-16,011
EU27	1,814	2,231	2,285
BRAZIL	197	111	95
Japan	-58	269	409

Table 5. Welfare decomposition for US economy obtained from alternative examined experiments (figures are in million USD)

Description	Allocation effect	Endowment effect	Terms of trade effect	Investment-Saving effect	Total effect (EV)
CET1	-20,189	0	3,708	359	-16,122
MCET	-20,879	1,500	3,082	571	-15,727
PAMC	-20,670	1,405	2,648	606	-16,011

Important related research topics

- Development of a GTAP-based models in percent change to use stochastic productivity distribution functions
- To what extend CET functions impose costs of land transformation and how realistic they are?
- Data on costs of land transformation across uses
- Explicit inclusion of costs of land transformation in CGE model
- A new data base on land use for CGE model is needed
- Productivity of land in transition is not well-examined yet. constraint.

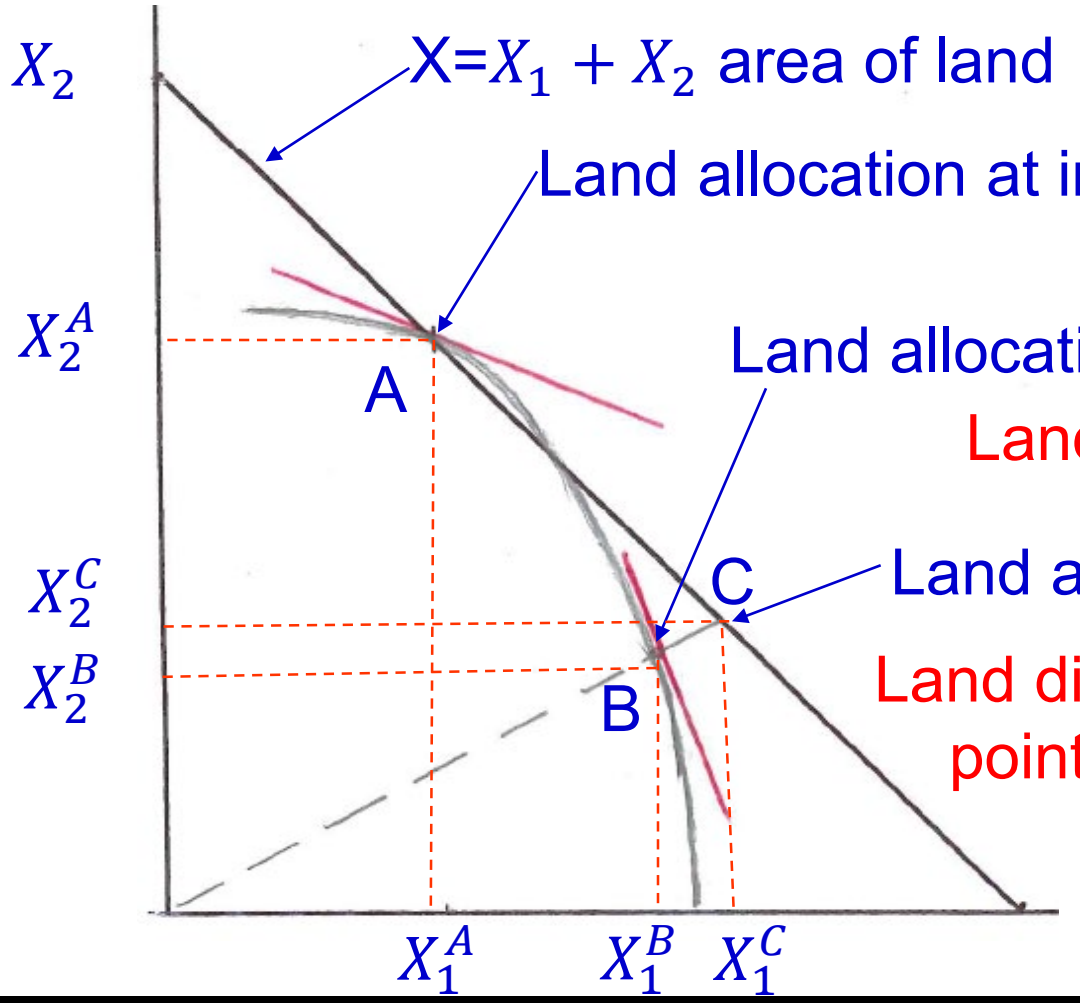
Thanks

Questions and Comments

Land allocation in a CGE model which operates based on physical land and uses the CET land distribution

- Land allocation with CET is defined based on the following optimization problem:
  Max Revenue $\sum_j P_j X_j$ Subject to: $\mathrm{V} = \mathrm{f}(X_1, \ldots, X_j)$, when land prices are given
  f(.) represents a well defined CET function
  P_j shows price of land type *j*, land prices are given
  X_j indicates area of land type *j*
- From the optimization problem we know that:
  $\dot{V} = \sum_j \theta_j \dot{X}_j$ where $\dot{\theta}_j$ represents revenue share of land allocated to sector *j*
- In the model closures, we assume $\dot{V} = 0$ to show that land supply is fixed
- Simulation results provide changes in land allocation, $\dot{X}_j$, given that $\dot{V} = 0$
- From land constraint of $\mathrm{X} = \sum_j X_j$ we know that:
  $\dot{X} = \sum_j \emptyset_j \dot{X}_j$ where $\dot{\emptyset}_j$ represents land share of sector *j* in total physical area of land
- Since $\dot{\theta}_j \neq \dot{\emptyset}_j$ Then $\dot{X} \neq 0$.
- Hence: CET does not preserve area of land in a CGE model which operates based on physical land

Land discrepancy in a CGE model which operates based on physical land: CET and ACET



X=$X_1 + X_2$ area of land

Land allocation at initial point with P_1^A and P_2^A

Land allocation after simulation using CET at P_1^B and P_2^B

Land discrepancy occurs at point B

Land allocation after simulation using ACET and MCET

Land discrepancy does not occur at point C but this point is above the CET land allocation frontier.

Land use: CET with land constraint versus ACET

One nest CET with ETLP5 with land constraint

Land Type	US	EU	Brazil	Russia	Others	Total
1 Paddy_F	-26	2	1	0	-57	-81
2 Wheat	-500	40	2	-2	216	-244
3 CrGrains	6764	40	169	28	502	7503
4 Oilseeds	-657	60	87	9	327	-175
5 Sugar_C	-8	0	-25	-1	-8	-42
6 OthAgri	-586	48	24	-33	297	-251
7 Forestry	-2522	-122	-62	184	-19	-2542
8 Dairy_F	-936	-51	-69	-113	-475	-1645
9 Rumina	-1528	-16	-125	-73	-784	-2526

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P_Rum	-1528	-16	-125	-73	-784	-2526

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Two nest ACET with ETLP5

Land Type	US	EU	Brazil	Russia	Others	Total
PadR	-22	2	0	0	-65	-85
Wheat	-530	42	0	-4	203	-288
CrGrain	6808	36	159	25	452	7481
Oilseeds	-563	55	66	8	273	-162
SugarC	-8	0	-26	-1	-8	-43
OthAgri	-521	51	17	-37	277	-213
Forest	-2743	-119	-47	194	36	-2679
P_Dairy	-919	-51	-63	-112	-447	-1593
P_Rum	-1502	-16	-106	-73	-720	-2418