Exploring the Impact of Land Conversion Costs on Modeling Land Use in CGE Models: Case Study of Non-CO2 Emissions

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1. Introduction

CGE models are increasingly utilized in climate change and emission modeling, necessitating enhanced representation of land due to the importance of land use change emissions. The widely employed CET approach tackles the slow-paced nature of land conversion in short and medium run but disregards the explicit costs associated with converting land from one use to another. This oversight hampers the accuracy of the models, as land conversion costs influence landowners' decisions and play a crucial role in the long-term dynamics of land use change. By integrating land conversion costs into existing methods, we can enhance modeling accuracy and more effectively capture real-world dynamics of land use changes.

2. Objectives

We explicitly introduced the land conversion costs to the demand side of the factor market of the standard GTAP model in GAMS, then modified the model to allow for the modeling of the marginal cost of abating process-based greenhouse gas emissions by introducing a new bundle of process-based GHG emissions as an input to the top of the model's CES production function. The objectives of the poster are:

- Extending models factor market to enable it of handling Agro Ecological Zones (AEZs) in a three-level nested structure.
- Introduce land conversion costs to the CES based demand side of land market
- Adding a new nest to the top of the production CES nests combines the model's original output, with the GHG bundle, XGHG, resulting in the new emissions-inclusive output bundle
- Using the new model to estimate the marginal cost of abating process-based greenhouse gas (GHG) emissions and construct MAC curves based on the result

3. Method

3.1. Introducing land conversion costs to the GTAP Model in GAMS

- To incorporate land conversion costs into the CGE model, we modified the GTAP Model in GAMS by van der Mensbrugghe (2018). Our focus was on the factor demand market, specifically addressing the representation of land. In the original model, land was indexed only by regions, but we introduced Agro Ecological Zones (AEZs) to better represent land characteristics.

- Within the production module, we modified the model to distinguish land over different AEZs and incorporated land-specific demand equations. The increased costs from accounting for land conversion were added to the average price equation. For area changes, we employed mixed complementary formulations to handle both increases and decreases in land areas.

- In the land supply side, we expanded the nesting structure to a three-level nested framework, providing flexibility to allocate land across uses. The option to choose between CET and ACET formulations was also introduced. Land conversion costs were incorporated into this structure, allowing for explicit inclusion in either the demand or supply side of the land market, depending on the chosen model specification.

- Our findings indicate that neglecting land conversion costs could lead to an overestimation of land conversion levels. The distinction of which side of the market bears the land conversion costs is not expected to significantly impact the levels of land conversion.

- Overall, our modifications enhance the model's representation of land and provide insights into the implications of explicitly accounting for land conversion costs.

3. Method (Continued)

3.2. Modifying the model to accommodate emission taxes

- To allow for the modeling of the marginal cost of abating process-based greenhouse gas (GHG) emissions a new nest added to the top of the production CES nests combines the model's original output, XPX, with the GHG bundle, XGHG, resulting in the new emissions-inclusive output bundle, XP. The GHG bundle, with a price of PXGHG, represents the marginal cost of abating process emissions and enables the model to capture the substitution between different inputs as the price of the process-based GHG bundle increases due to policy interventions such as an emissions tax.

- Equations (1), (2), and (3) represent the new nest that combines the original model's production and GHG emissions bundle. PXP and PX represent the emissions-exclusive and emissions-inclusive output prices for each activity a in region r respectively, while α^{xp} and α^{ghg} represent the CES share parameters for production and GHG emissions, respectively. Finally, σ^{xp} is the elasticity of substitution between the production and emissions bundle.

$$XPX_{r,a} = \alpha_{r,a}^{xp}\left(\frac{PX_{r,a}}{PXP_{r,a}}\right)^{\sigma_{r,a}^{xp}} XP_{r,a} \qquad (1)$$

$$XGHG_{r,a} = \alpha_{r,a}^{ghg}\left(\frac{PX_{r,a}}{PXGHG_{r,a}}\right)^{\sigma_{r,a}^{xp}} XP_{r,a} \qquad (2)$$

$$PX_{r,a}.XP_{r,a} = PXP_{r,a}.XPX_{r,a} + PXGHG_{r,a}.XGHG_{r,a} \quad (3)$$

- To overcome the calibration issues caused by the lack of revenue from process emissions in the GTAP 10 database (Aguiar et al., 2019) used in this study, we adopted the approach of the ENVISAGE model (Van der Mensbrugghe, 2008). In this process, the elasticity of substitution between the production and emissions bundles, which indicates how much flexibility producers have in substituting between the two inputs, was the last piece of information we needed. To estimate these elasticities, we utilized the EPA's emission projections and mitigation potential data (USEPA, 2019). This data provides the absolute and relative levels of potential reduction in emissions for different greenhouse gases at different price points ranging from -\$20 to \$1000 for 195 countries and 20 sectors from 2020 through 2050 at 5-year intervals. While we estimated the elasticity for individual GHG emissions independently, the data does not show any heterogeneity across GHG emissions in relative abatement potentials, so the results do not vary by the emission type.

- To estimate the substitution elasticity between emissions and production, we utilized a log-log least square model based on the emission reduction potential and corresponding cost data described above. Equation (4) shows the estimation model, where E_P represents the relative emissions at price point P, and P_0 represents the carbon tax in the base scenario. To avoid calculation complications, we assumed a small value for P_0 in our model. By minimizing the sum of squares of the residual terms, ε_P, the model provides the σ^{xp} estimations for each country and sector.

$$\ln(E_P) = \sigma^{xp}.\ln\left(\frac{P_0}{(P/P_0)}\right) + \frac{\sigma^{xp}}{1-\sigma^{xp}}\ln\left(\alpha^{ghg}\left(\frac{P}{P_0}\right)^{1-\sigma^{xp}} + \alpha^{xp}\right) + \varepsilon_P \qquad (4)$$

- To address negative P values, we considered two linear transformation and truncation approaches. In the linear transformation approach, we transformed all P values using the equation $P^T = P + (1 + \min(P))$, while in the truncation approach, we omitted any data with a negative price point $P < 0$. Our results showed no significant sensitivity to this choice in modeling approach, and the reported results are based on the linear transformation approach.

3. Method (Continued)

- We estimated results for different regions and sector aggregations and employed a pre-estimation aggregation approach. To simplify the aggregation of elasticities across regions and sectors, we aggregated the base emission volumes and each price point emission reduction volumes for each target region-sector aggregation. We then estimated the elasticities using the estimation model described in Equation (4) using the aggregated data.

- The aggregation procedure involves a simple summation over mappings from the disaggregated regions r to aggregated regions R, and disaggregated sectors a to aggregated sectors A for emission reductions with respect to the baseline emissions. We calculated the baseline emissions $Emi0$ in $(MtCO_2e)$ and aggregate emissions in the baseline $EmiR$ for each region-sector aggregation. Aggregated emission reduction values obtained from Equation (5) and disaggregated percent emission reductions with respect to the baseline will be used to calculate the aggregated percent emission reduction using Equation (7).

$$EmiR_{R,A,p} = \sum_{r\in R}\sum_{a\in A} EmiR_{r,a,p} \quad (5)$$

$$Emi0_{R,A} = \sum_{r\in R}\sum_{a\in A} Emi0_{r,a} \quad (6)$$

$$PEmiR_{R,A,p} = \frac{\sum_{r\in R}\sum_{a\in A} EmiR_{r,a,p}}{\sum_{r\in R}\sum_{a\in A}\left(\frac{EmiR_{r,a,p}}{PEmiR_{r,a,p}}\right)} \quad (7)$$

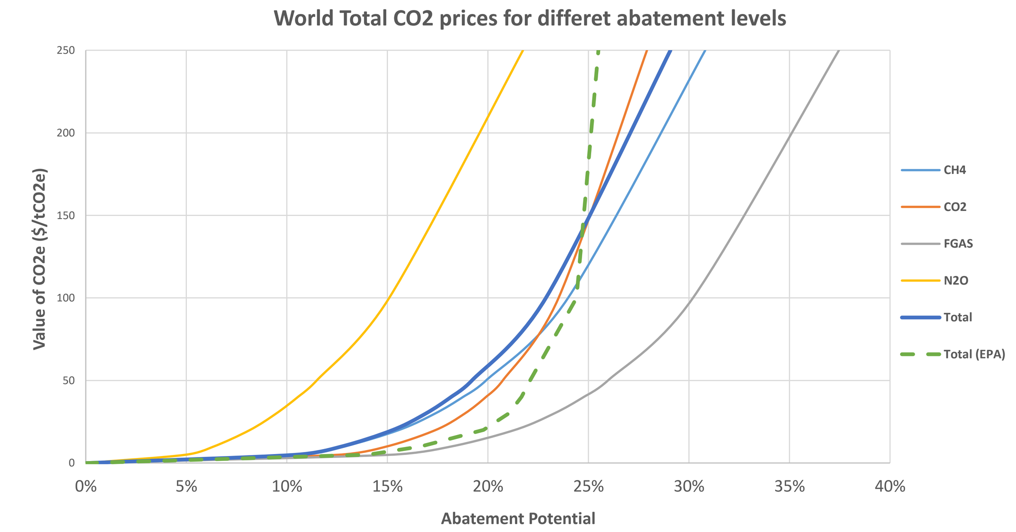
5. Results and discussion

- We used the above described approach and estimate the elasticity of substitution between process emission and production using EPA data on mitigation potentials (USEPA, 2019). Table 1 shows the heterogeneity of the distributions across different sectors

Table 1. Summary statistics of estimated elasticities (Year 2030)

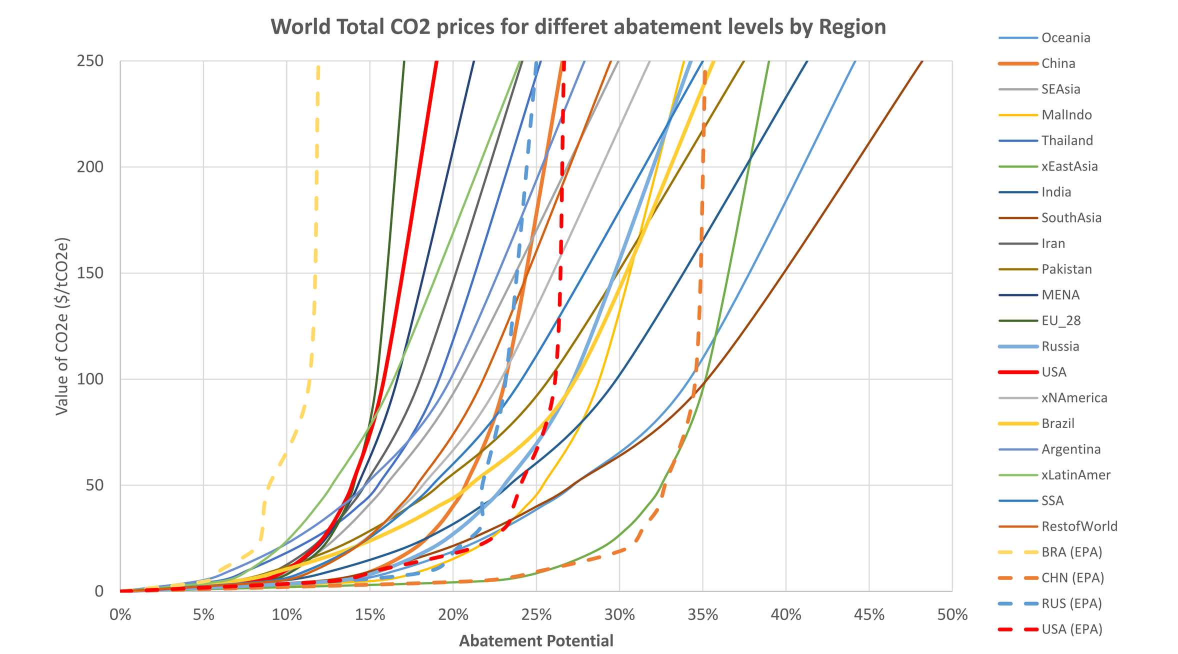
Sector	Description	Min	Max	Mean	Std. Dev.
PDR	Rice	0.0089	0.3228	0.0747	0.0844
WHT	Wheat	0.0007	0.0116	0.0040	0.0030
GRO	Oth. grains	0.0007	0.1212	0.0094	0.0257
V_F	Veg., fruit, nuts	0.0003	0.0115	0.0039	0.0030
OSD	Oil seeds	0.0002	0.0082	0.0036	0.0024
C_B	Sugar crops	0.0002	0.0082	0.0035	0.0024
PFB	Fiber crops	0.0002	0.0082	0.0032	0.0022
OCR	Oth. cops	0.0002	0.0099	0.0036	0.0029
CTL	Livestock	0.0014	0.0235	0.0080	0.0048
OAP	Animal prod.	0.0014	0.0235	0.0081	0.0049
RMK	Raw milk	0.0014	0.0234	0.0080	0.0048
COA	Coal	0.0358	0.1287	0.1093	0.0196
OIL	Oil	0.0224	0.0731	0.0375	0.0137
GAS	Gas	0.0224	0.0731	0.0401	0.0133
CHM	Chemical	0.0396	0.1209	0.0595	0.0176
BPH	Pharmaceutical	0.0615	0.0664	0.0629	0.0020
NFM	Metals	0.0192	0.2445	0.0444	0.0529
ELE	Electronics	0.0185	0.0323	0.0252	0.0039
EEQ	Electrical	0.0454	0.0590	0.0505	0.0033
OME	Oth. Machinery	0.0015	0.0523	0.0197	0.0143
WTR	Water	0.0071	0.0793	0.0504	0.0186
ELY	Electricity	0.0683	0.1354	0.0873	0.0186

- We use these estimated elasticities to calculate the abatement potential and construct MACC curves using the GTAP in GAMS model, describe above. Below graph shows the aggregated MAC curves for the whole world by GHG type. The green line represent the EPA estimates.

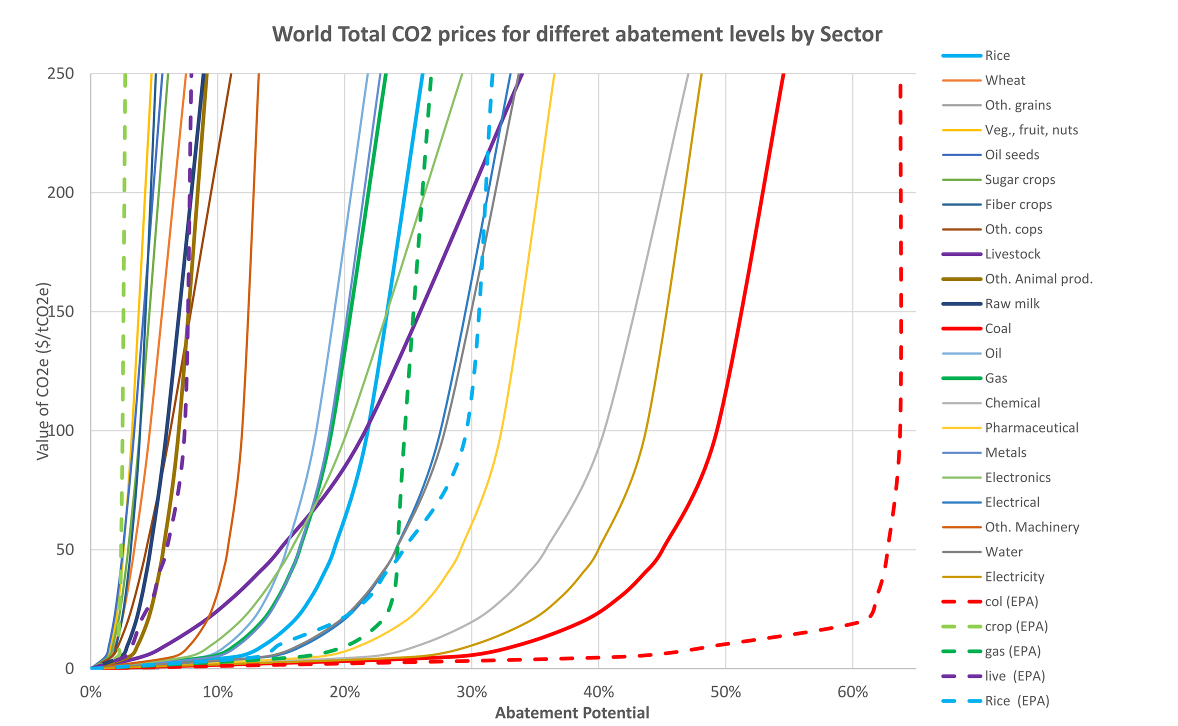


5. Results and discussion (Continued)

- The graph below illustrates the region-specific MAC curve, with accompanying EPA estimates for select regions. When interpreting the results, it is important to consider that the model's outcomes reflect the overall general equilibrium effects.



- Finally, sector specific MAC curves are shown belwo. Similar to the above results, it is important to consider that the model's outcomes reflect the overall general equilibrium effects.



6. References

- Aguiar, A., Chepeliev, M., Corong, E. L., McDougall, R., & Van Der Mensbrugghe, D. (2019). The GTAP data base: Version 10. Journal of Global Economic Analysis, 4(1), 1–27.
- USEPA. (2019). Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential 2015–2050. US Environmental Protection Agency Washington, DC.
- Van der Mensbrugghe, D. (2008). The environmental impact and sustainability applied general equilibrium (ENVISAGE) model. The World Bank, January, 334934–1193838209522.
- Van der Mensbrugghe, D. (2018). The standard GTAP model in GAMS, version 7. Journal of Global Economic Analysis, 3(1), 1–83.