Implications of the CET Supply Function Approach of GTAP

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The way that GTAP allocates land between crops, pasture, and forest is to use a function called the constant elasticity of transformation (CET) supply function. This is a function that allocates land based on a function that depends on the share of revenue from each type of land cover and the transformation elasticity σ. This function is used because it is parsimonious and because it gives necessary convexity so that a solution to the maximization problem can be obtained. However, the convenience of this function imposes some restrictions that are quite important in predicting how much pasture land relative to forest land is converted in response crop price increases related to biofuels expansion.

Following the notation on page 4 of Ahmed, Hertel, and Lubowski, the cross price elasticity of the supply of forest land in response to a crop price increase equals $\varepsilon_{forest,\,crop} = \theta_{crop}\sigma$ where θ_{crop} is the share of revenue from crops. The cross price elasticity of pasture land in response to a crop price increase is $\varepsilon_{pasture,\,crop} = \theta_{crop}\sigma = \varepsilon_{forest,\,crop}$. This means that a 10% increase in crop prices will result in the same percent change in pasture and forest land.[1]

Homogeneity of supply means that the own price elasticity equals (in absolute value) the sum of the cross price elasticities so that the own price elasticity of pasture, forest and crop in GTAP differ only by the share of revenue:

$$\varepsilon_{pasture,\,pasture} = -\sigma(1-\theta_{pasture})$$

$$\varepsilon_{forest,forest} = -\sigma(1-\theta_{forest})$$

$$\varepsilon_{crop,crop} = -\sigma(1-\theta_{crop}) .$$

The central value of σ in CARB's biodiesel analysis is -0.2, which is equal to the revenue-share-weighted average of the estimated individual land cover CET parameters (discussed below) after five years. Page 5 of Ahmed, Hertel, and Lubowski reports revenue share values of 0.7489 for crops, 0.0975 for pasture, and 0.1023 for forest. This means that the GTAP own return elasticities of supply are 0.05, 0.18 and 0.18 for crops, pasture, and forest respectively. One cost of using the CET function to allocate land is that the own return elasticities for pasture and forest are significantly different than what Ahmed, Hertel, and Lubowski estimate them to be. Their estimates are derived from analysis of plot-level National Resources Inventory data from 1982 to

[1] The equilibrium solution will not typically be exactly the same percent change because the own supply elasticities of forest and pasture may differ and the demand elasticities for forest products may differ from pasture products.

1996 conducted by Lubowski and Lubowski, Plantinga, and Stavins. Their own estimates of the own price elasticities at five years are approximately 0.045, 0.22, and 0.005 for crops, pasture, and forest respectively[2]. Thus the GTAP own price elasticities for crops and pasture are roughly equal to the empirically based own price elasticities. But the forest elasticity in GTAP is 36 times higher than the estimated value.

The estimated values for this elasticity of land transformation for the each type of land cover can be found in Figure 3 of Ahmed, Hertel, and Lubowski. These values are approximately -0.006 for forest, -0.26 for pasture, and -.25 for crops. The difference between the CARB central value of -0.2 and the elasticity of land transformation for forest that is consistent with the empirical data is particularly important when considering the response of forest land to higher crop prices.

As stated above, GTAP imposes the homogeneity condition that the own price elasticity equals the absolute value of the sum of the cross price elasticities. Because both cross price elasticities are negative (a higher price of crops leads to less forest land) we know that their value must be between zero and the value of the own price elasticity. Using a forest own price elasticity of 0.18 allows the cross price elasticities to be between 0 and -0.18. For example, if the cross price elasticity of forest with respect to pasture equals -0.08, then the cross price elasticity of forest with respect to crops equals -0.1.[3] If GTAP had instead used 0.005 as the own price elasticity of forests, then this implies that the cross price elasticity of forest land with respect to crop prices would be limited to between 0 and -0.005.

The most important factor affecting the magnitude of the change in greenhouse gas emissions from land use changes is the response of forest land to an increase in crop prices. Thus use of the GTAP own price elasticity of 0.18 instead of the empirically-estimated own price elasticity of forests of 0.005 results in dramatically higher greenhouse gas emissions. The GTAP cross price elasticity of forest with respect to crop price equals

$$\varepsilon_{forest,\,crop} = \theta_{crop}\sigma = -0.7489 * 0.2 = -0.15$$

This elasticity is 30 times higher than the maximum cross price elasticity that would be possible if the empirically-estimated forest own price elasticity was used in the analysis.

[2] These estimates were obtained from Figure 2 of Ahmed, Hertel, and Lubowski. The approximation of the forest elasticity was difficult because the five year value was so close to zero.

[3] The share of revenue in Ahmed, Hertel, and Lubowski do not sum to one, which implies that "other" land use must be equal to one minus the sum of share to forest, crops, and pasture. The other land use is ignored in this explanation.

The GTAP cross price elasticity of pasture with respect to crops is also equal to -0.15, which may be close to the value that is consistent with the empirical estimates. This suggests that a model that used empirically based own and cross price elasticities for forest, pasture, and crops would have pasture land being at least 30 times more responsive to crop prices than forest land in a five year horizon. The ratio of responsiveness would be similar for longer time periods, given the very low own return elasticities for forest shown in Figure 2 of Ahmed, Hertel, and Lubowski.

Because the CET supply function is seemingly so fundamental to GTAP, it is not clear how empirically estimated own and cross price elasticities of land transformation could be accommodated. An ad hoc approach could take the total amount of pasture and forest land converted in GTAP and reallocate it between pasture and forest such that the percentage change in pasture is some multiple of the percentage change in forest land. For example, suppose GTAP predicts that U.S. crop acreage expands by 100,000 ha with 45,000 ha coming from forest and 55,000 ha coming from pasture. These estimates would be consistent with the -0.15 cross price elasticities in GTAP. An allocation of pasture and forest land that is more consistent with the empirically consistent cross price elasticities would be 95,000 ha of pasture and 5,000 ha of forest. This would be an ad hoc approach because these ratios would not account for the likely increase in the price of pasture because of the greater loss of pasture, which would limit the amount of pasture that would be converted. So, instead, perhaps lowering the ratio of responsiveness from 30 to 1 to 10 to 1 would be more consistent with a model that used the empirically-estimated cross price elasticities. This might result in 90,000 ha of pasture and 10,000 ha of forest. The magnitude of these changes suggests that making forest land less responsive to crop prices than pasture would result in major reductions in the amount of forest land converted to cropland. This would dramatically reduce estimated greenhouse gas emissions from land use changes in response to expansion of biodiesel.

References

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