APPENDIX C: MONTE CARLO SIMULATION RESULTS AROUND GTM BASELINE

This appendix describes the results of a Monte Carlo analysis of parametric uncertainty focusing the parameters of the forest biomass yield functions and the land supply elasticity parameter used for each land class. These methods were developed and described by Kim (2015). The reason we have focused on these sets of parameters is that based on the sensitivity analysis and the work of Kim (2015), carbon sequestration is most sensitive to these parameters.

The forest biomass yield functions used in the numerical model have the following form:

$$V_{a,t}^{i}\left(\mathrm{Z}_{a,t}^{i}\right) = h(\mathrm{Z}_{a,t}^{i}) * \left[\exp\left(\delta^{i} - \frac{\pi^{i}}{a}\right)\right], \qquad \text{[C1]}$$

where $V_{a,t}^{i}$ is forest yields (volume per hectare) in each age a and type i at time *t*; $h(\mathrm{Z}_{a,t}^{i})$ is the stocking density, controlled by management inputs; and $\mathrm{Z}_{a,t}^{i}$ is the management intensity.

For this analysis, we apply Monte Carlo techniques on parameters δ^{i} and π^{i}. Assuming δ^{i} and π^{i} are uncertain, we draw random values from the following triangular distributions to avoid draw negative number:

$$\delta^{i} \sim randTriangle(low,\ mid,\ high),$$

$$\pi^{i} \sim randTriangle(low, mid,\ high).$$

- Low: Taken at the bottom of the standard normal distribution (2%)
- High: Taken at the top of the standard normal distribution (98%)
- Mid: Sample mean

The triangular distribution functions used in this analysis are drawn from Kim (2015). Importantly, we do not have information on the distributions of the yield function parameters for regions outside the United States, so for other regions, we assume that the standard errors are the same size relative to the mean in those other countries as in the United States, and we apply the standard errors from the United States to the yield function parameters in other regions.

Monte Carlo analysis is also applied to the land supply elasticity in the land rental functions. These functions represent the marginal costs of a new hectare of land in forest type *i*:

$$\mathrm{A}^{i} \frac{1}{\eta^{i}} \left\{\sum_{a} X_{a,t}^{i}\right\}^{\frac{1}{\eta^{i}}-1}, \qquad \text{[C2]}$$

whereA^i is constant, $X^i_{a,t}$ is the total timber area, and $\frac{\eta^i}{1-\eta^i}$ is the rent elasticity of land supply.

As forest rents increase, one will add land to forests, with an elasticity of η^i, which is the random parameter used in the Monte Carlo analysis. Apply Monte Carlo techniques on η^i. Once again we assume a triangular distribution, using the same assumptions for the low, high, and midpoint values as for the yield functions:

$$\eta^i \sim randTriangle(low, mid, high).$$

The elasticity parameter is obtained from Lubowski, Plantinga, and Stavins (2006). Given this estimate, we are able to recover a standard error for the land supply elasticity. Unlike for forest yield functions, where we can determine average yield parameters for each region from the literature or existing data, but we cannot recover standard errors, in the case of land supply elasticity, we have found no estimates in the literature for other regions. We thus apply the standard error assumptions for the United States to the rest of the world.

The results of the Monte Carlo analysis for 200 independent draws for each of the yield function and other parameters is shown in Figure C1 below. The average of the 95% confidence interval is about 18% of the mean. This result reflects uncertainty only in the yield functions. We have not made distributional assumptions about the biomass expansion factors and other components of the carbon calculations, which would increase our estimated bounds. Incorporating this type of uncertainty would not require additional scenario runs because those parameters are not part of the economic analysis, but it would require additional calculations.

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FIGURE C1

Uncertainty Bound in the U.S. Carbon Flux for All Pools, Showing the 95% Confidence Interval and the Minimum and Maximum for 200 Draws