Efficiency of Forest Carbon Policies at the Intensive Margins and Extensive Margins

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Forest sequestration and Climate Change

• Forests plays a critical role in global carbon cycle

  The terrestrial sink for the decade 1993-2003 at 3,300 MtCO2/yr, ignoring emissions from land-use changes (IPCC, 2007a).
  Carbon sequestration from forest could account for about a quarter of the desired global carbon dioxide (CO2) mitigation.

• An efficiency component of climate change

  By substituting additional carbon storage in forests or wood products for reducing carbon emissions from energy use, countries can meet relatively stringent emission targets at lower costs.
  The emerging regional and voluntary markets and REDD project: Voluntary actors provide 101 MtCO2 offsets in 2012 and is projected to provide 430-1,860 MtCO2 offsets for year 2012-2020).
Different schemes of forest carbon sequestration

- **Carbon subsidy for growth and tax** for net emissions at harvest time (Van kooten et al. (1995))
- **Carbon rental system** with a payment for permanent carbon storage (Sohngen and Mendelsohn (2003))
- **Carbon tax** to deter land use change and GHG emissions due to biofuel production (Searchinger et al. (2009))
- **Subsidy schemes** based on various discounting factors (see Dutschke 2001, 2002; Colombia Ministry of the Environment 2000; Blanco and Forner 2000; Chomitz 2000; and Kim et al 2008)
- **Payment for land use change** and vary the payment based on land opportunity costs (Stavins and Jaffe, 1999; Plantinga et al., 1999)
Research question

- What are the differences in efficiency of different carbon policies recommended by past studies?

- Highlights of the study
  - behavior changes of farmers at intensive margins (i.e., changing carbon stocks on per unit of land) and extensive margins (changing forestland area).
  - policy induced market effects
  - dynamic frameworks
Methods

• An optimal control timber markets model
• Timber prices are endogenously determined
• The full dynamic adjustment to the policy in harvests and replants for every age classes, the optimal control model captures the intertemporal effects both in the near term and long run
• Simulate the effects of five different carbon policies
Model

- $x(a, t)$: forest land hectares at each age $a$
- $h(a, t)$: hectares harvested at each age $a$
- $G(t)$: the replant hectares
- $R(\cdot)$: land rent or the opportunity cost of maintaining land as forest rather than allowing it for alternatives uses.
- $f_c(\cdot)$: the carbon benefit associated with carbon sequestration
- $r$: the interest rate which should reflect the risk with carbon uptake service (e.g., fire risk, slower than expected tree growth, etc)
- $D(\cdot)$: demand function given the stumpage quantity per period.
- $Q(\cdot)$: the total quantity harvested generated by the demand function.
- $V(a)$: is the timber yield function, where $a$ is the age of timber harvested.
\[
\max_{H(t), G(t)} \int_0^\infty e^{-rt} \left\{ \int_0^{Q(t)} D\left(Q(H(t), V(a))\right) dQ - bG(t) - R(t)X(t) \right. \\
\left. + f_c(H(t), X(t)) \right\}
\]

s.t.

\[
\hat{X} = -H(t) + G(t)
\]

\[
H(t) > 0; \ G(t) > 0; \ X(0) \text{ is given}
\]
<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Descriptions</th>
<th>$f_c^{234567}$</th>
</tr>
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<tbody>
<tr>
<td>Scenario 1</td>
<td>Carbon uptakes are subsided at the current carbon price. No tax on emissions.</td>
<td>$p_c \delta [X(a) \cdot \dot{V}(a)]$</td>
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<tr>
<td>Carbon Subsidy</td>
<td></td>
<td></td>
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<tr>
<td>Subsidy</td>
<td></td>
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<tr>
<td>Scenario 2</td>
<td>Per unit tax on carbon emissions released upon harvest but no carbon subsidy.</td>
<td>$-p_c \delta (1 - \sigma) q(H(t), V(a))$</td>
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<tr>
<td>Carbon Tax</td>
<td></td>
<td></td>
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<tr>
<td>(Tax)</td>
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</table>
| Scenario 3        | Carbon emissions are taxed upon harvest and carbon uptakes are subsided at the current carbon price. | $p_c \delta [X(a) \cdot \dot{V}(a)]$  
| Carbon Tax & Subsidy |                                                                              | $-p_c \delta (1 - \sigma) q(H(t), V(a))$ |
| (Tax & Subsidy)   |                                                                              |                |
| Scenario 4        | Annual rents are given for providing annual carbon storage services; also, landowners are paid at the carbon price for carbon stored permanently in wood products. | $r_c \delta [X(t) \cdot V(a)]$  
| Carbon Rental     |                                                                              | $+p_c \delta \sigma q(H(t), V(a))$ |
| (C Rental)        |                                                                              |                |
| Scenario 5        | The carbon payments are given by the total forest area.                     | $l \sum_a x(t, a)$ |
# Key Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Source</th>
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<tbody>
<tr>
<td>Yield function</td>
<td>$\ln(V(a)) = 7.82 - 52.9/a$</td>
<td>Sohngen and Sedjo, 1998</td>
</tr>
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<td>Pickling rate</td>
<td>0.35</td>
<td>Daigneault et al. 2010</td>
</tr>
<tr>
<td>Carbon price</td>
<td>The optimal carbon tax scenario</td>
<td>DICE-2010 Model</td>
</tr>
<tr>
<td>Interest rate</td>
<td>5%</td>
<td></td>
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<td>Carbon conversion rate</td>
<td>0.20 tC/m$^3$</td>
<td>eg. van Kooten et al 1995</td>
</tr>
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<td>Price elasticity for wood products</td>
<td>-0.5</td>
<td>Simangunsong and Buongiorno, 2001</td>
</tr>
<tr>
<td>Land supply elasticity</td>
<td>0.33</td>
<td>Lubowski et al., 2006</td>
</tr>
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Figure 2 Paths of Average Harvest Age
Figure 3 Path of Forest Area
Figure 4 Paths of Timber Prices
Figure 5 Path of Wood Products Outputs
A ‘per hectare’ land subsidy could be 5 to more than 10 times more costly than a ‘per ton’ carbon Tax & Subsidy or carbon subsidy policy depending on carbon prices.
Conclusions

• Government can achieve more carbon sequestration efficiency on both the intensive margin and the extensive margin.

• A ‘per ton’ carbon subsidy policy may be an appropriate choice if taking into consideration of the measurement because it provides the close approximation in efficiency to the optimal policies and it avoids a measurement costs on actual emissions from harvest.

• When designing climate policies, a recommended policy choice is to treat land use sector differently from the other emission sectors.
Global carbon price path