How big is leakage from forestry carbon credits?

Estimates from a global model

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Introduction

Currently, there is substantial concern over global warming, greenhouse gas emissions and their potential effects on society. According to the IPCC (2001), about 43% of total carbon emissions from 1850 to 1998 have remained in the atmosphere, instead of being absorbed by oceans, biomass, organic matter and soils. Deforestation alone has contributed to about one quarter of all these emissions (Schoene, 2007). To deal with this problem, much research has delved into forestry's potential for carbon sequestration. For example, Nabuurs et al. (2007) and Richards and Stokes (2004) assert that about 7 billion tons of carbon dioxide per year could be sequestered for US$60 per ton of CO_2. This amount of CO_2 storage could provide up to one-third of total global abatement during this century (Sohngen and Mendelsohn, 2003 and Tavoni et al., 2007).

To encourage forestry carbon sequestration, researchers have supported the implementation of forestry carbon credits. For example, since 2006, the UNFCC's Clean Development Mechanism (CDM) has awarded credits to projects in developing countries for certified emission reductions (CERs). These have focused on waste management, methane capture and renewable electricity generation. Currently there is one CDM-certified soil conservation project in Moldova and one reforestation project in the Guangxi Watershed in China. CERs are equivalent to one ton of CO_2 if the project developers can prove that additional CO_2 reductions have occurred as a result of the project (UNFCCC). Since these can be traded (at a market price), industrialized countries have more flexibility in achieving their Kyoto Protocol emissions standards. They also provide developing nations an innovative way to obtain funds for growth and reduce CO_2 emissions. Presently, the UNFCC has discussed providing economic incentives for the reduction of emissions through deforestation and degradation (REDD) by pricing the carbon stored in forests (Bellassen and Gitz, 2008).

The potential for reductions in deforestation to contribute to climate mitigation are possibly quite large, given the scale of overall emissions (e.g., Kindermann et al., 2008). However, a number of important concerns have been raised about the potential for REDD to become an acceptable climate mitigation tool, including leakage. Leakage can be defined at many scales, but it reflects the idea that if carbon policies have incomplete geographical coverage, the carbon gains in regions where policies induce carbon storage may partially be offset by losses elsewhere that are induced by these policies (see discussion in Murray et al., 2007). Leakage in forest carbon projects has been examined thus far within countries by Murray et al. (2004) for the United States, and Sohngen and Brown (2004) for Bolivia, but international leakage in carbon has not yet been examined. This paper begins to address the potential for leakage if policies to address REDD are widely implemented, but only some countries are involved.

Leakage across countries can result from price adjustments along several different dimensions. First, incentives to increase carbon in forests could cause landowners to alter management practices to increase carbon sequestration. For example, landowners may increase rotation ages (e.g., Daigneault et al., 2009; Sohngen and Brown, 2008), which would cause landowners to withhold timber from markets, and which in turn would cause timber prices to rise. Second, carbon incentives likely will cause some landowners to hold forests that they would otherwise liquidate and convert to other uses (e.g., in the tropics) and they likely will cause other landowners to plant forests on land currently used in some lower value activities. Both of these actions would have effects on timber prices by shifting supply across regions and time. The second set of actions, however, would be expected to influence land rental values in the agricultural sector as well, by shifting land between uses.

When considering leakage, adjustments in both timber and agricultural markets are important to measure. For this analysis, though, we are only able address the adjustments likely to occur in timber markets. Specifically, in this paper, we utilize a forestry and land use model to focus on the implications of different types of carbon policies on global leakage caused by timber price adjustments. We begin by specifying the model, the baseline, and the optimal global policy. We then introduce a policy that focuses effort only on regions where deforestation is occurring, e.g., developing tropical countries. We compare and contrast the efficiency of the global optimal policy and the alternative policy.

Literature Review

Much research has endeavored into the determinants of leakage and definite ways of indentifying it. Aukland et al. (2003) categorize leakage into primary (when greenhouse gas benefits of a project are counteracted by increased emissions elsewhere) and secondary (when the project's output creates incentives to increase GHG emissions elsewhere). These, in turn, are further classified into: activity shifting and market effects (Schwarze et al., 2002). It is important to note, however, that these two types may be conversely related because the displacement of activity allows the market to clear and vice versa. Distinguishing between each type of leakage and the main factors contributing to it is essential in being able to minimize a project's off-site effects. For this reason, Aukland et al. (2003) suggest that in order to measure and quantify leakage it is important to establish a baseline and find who are causing it (baseline agents), what is happening (baseline drivers), causes and motivations and indicators.

To estimate leakage, most authors have focused on project-level analyses. For example, the Noel Kempff Climate Action Project in Bolivia (Brown et al., 2000) consisted in setting aside natural forests that could potentially be used for logging and agricultural practices. Sohngen and Brown (2004) used a dynamic optimization Bolivian timber model to estimate market leakage (project price effects) within the country's boundaries under different baseline scenarios. Leakage is calculated as the percentage of (non-discounted) cumulative carbon emissions minus net carbon savings. Their estimates of leakage range from less than 10% to 42% depending on the baseline assumptions related to the time period, amount of carbon sequestered globally, capital adjustment constraints and demand elasticities.

Relating leakage with deforestation, Chomitz (2002) posits that leakage might be high when a project affects the people subsisting from the land, while it may be lower when deforestation is related to markets because the latter can react by a change in prices. In addition, both conservation and energy projects can incur in significant leakage that could be more than 100%. This depends on the price elasticities of supply and demand for fuel and agricultural products and the scope of the project.

Wear and Murray (2004) built and econometric model that integrated the supply, demand, and market of US softwood lumber and timber to assess the effects of different policies imposed in these markets that could reduce harvests or affect prices. Using this general equilibrium approach, their results show that the policies generated significant market effects due to an increase in prices. The targeted areas reduced production while other areas with fewer restrictions increased their market share and gained significant benefits. The amount of leakage varied depending on the scope of analysis: regional leakage was 43%, national leakage was 58%, while continental leakage (U.S. and Canada) was 84%.

Similarly, Murray et al. (2004) used a general equilibrium analysis of the timber market to measure leakage of different carbon sequestration activities in the forestry sector and apply it to econometric and optimization models. Creating a specific expression for leakage estimation that allows for comparative statics, their results suggest that smaller projects tend to have less leakage in absolute terms, but more leakage relative to its benefits. Leakage estimates range less than 10% to more than 90% depending on the activity and region where carbon is being sequestered. Focusing on agricultural soil carbon sequestration, Murray et al. (2007) found that changes in tillage and harvest practices have the potential to store additional carbon. However, these projects can incur in significant leakage if they affect the yields or costs of production and prices. In comparison to land set-asides, changing tillage practices reduces leakage because the former reduces land supply, resulting in leakage estimates of 20% - 100%.

Evaluating forest conservation, Gan and McCarl (2007), calculated potential leakage in the timber market due to both activity displacement and market (price) effects between countries. They developed an analytical framework for measuring leakage using the supply and price elasticities of demand for forestry products and a country cooperation coefficient and found that cooperation reduces leakage if many countries are involved. Leakage estimates range from 42% - 95% where activity displacement will move from 21% - 75% of production to developing nations, especially those in the tropics.

Using a global approach, Lee et al. (2007) evaluated the global effects of carbon emissions reductions in the agricultural sector using an optimization model that included agricultural production, consumption and trade, as well as variables that affect greenhouse gas emissions mitigation. They found that those countries directly implementing mitigation efforts bear its costs, while un-regulated countries not involved in emissions reductions will increase production and disseminate GHG emission mitigation benefits. As the price of carbon increases in the country implementing the mitigation policies, production and exports decrease and the prices for agricultural commodities increase, moving production to cheaper areas, leading to activity displacement leakage. They found that consumers are the net losers of agriculture mitigation policies due to the price increase in agricultural commodities. In addition, they concluded that to reduce leakage, more countries should work together in mitigation practices.

The implementation of the REDD mechanism by the UNFCCC has brought much of the carbon storage attention to areas with plenty of forest availability since these areas would then be able to obtain economic benefits from their carbon stock. Through the CDM, reforestation and afforestation projects that can prove to sequester additional amounts of carbon are given monetary incentives equal to the value of the carbon stored. Silver et al. (2000) and others argue that reforestation in tropical areas has the potential to be a significant source of carbon offsets for approximately 40 – 80 years. Deforestation may contribute to around 25% of global carbon dioxide emissions (Schoene, 2007). For these reasons, it is important to evaluate the effects of reductions of deforestation and afforestation and the potential leakage implications of each.

Evaluating land eligible for CDM afforestation and reforestation projects, Zomer et al. (2008) found that about 749 Mha are appropriate for these kinds of project, of which 46% of the land is found in South America and 27% in Sub-Saharan Africa. The Asian countries, however, have less land availability of which almost 25% is degraded. Some authors have analyzed leakage in specific projects in the aforementioned areas. For example, Lasco et al. (2007) evaluated the implementation of different land-use activities that can sequester additional amounts of carbon in the upper magat watershed in the Philippines and found that the leakage amount depends on the technology adoption rate; from 3.7 M Tg C to 8.1 M Tg C under a baseline and project scenario. In Sub-Saharan Africa, Vagen et al. (2005) found that soil carbon sequestration, through agroforestry or natural fallow systems can sequester from 0.1 Mg C to 5.3 Mg C per hectare per year. In India, Ravindranath and Somashekhar (1995) established that implementing a scenario offsetting about 50% of carbon emissions can sequester up to 78 Mt C per year, mainly through agroforestry.

The largest tropical forest, the Brazilian Amazon, has undergone continuous degradation and deforestation since the construction of the Transamazon Highway, especially along the "arc of deforestation" or the southern and eastern edges (Fearnside, 2005). Laurance et al. (2002) suggest that deforestation in this area is not only affected by highways, but also by the amount of people that settle in the areas surrounding it and the increasingly severe dry seasons that have recently affected the region. Thus, by reducing the rate at which the Amazon is degraded and deforested, less carbon is emitted to the atmosphere.

Other research on the Brazilian Amazon has focused on the causes of deforestation and degradation and/or the amount of land that has been affected (Skole and Tucker, 1993 and Morton et al., 2005). These studies suggest that there is great potential for carbon storage in Asia, Sub-Saharan Africa and the Brazilian Amazon. Because of the CDM and REDD mechanisms, it is important to consider afforestation and reforestation activities, as well as degradation and reducing deforestation. Leakage, however, has not been as investigated and discussed in the literature. Some estimates of leakage are available for specific markets and projects, but global and regional-level analyses have yet to be fully developed.

Model and Description of Analysis

The present paper uses a global forestry and land use model that optimizes the distribution of timber age classes and the area of land in forests. The model is built upon the global timber model described in (Sohngen and Mendelsohn, 2007). Several important updates have been included in this version of the model. First, the model has been expanded from 13 regions to 16 regions (Table 1). Second, the model adopts constant elasticity of transformation functions to specify the land supply side (see Hertel et al., 2008). These constant elasticity of transformation functions are used to develop constant elasticity land supply functions for forestry that are dependent on rents in other land using sectors (e.g., agriculture and livestock). In principle, these rents can be modeled endogenously, but for this analysis, we assume they are fixed between the baseline and the carbon price scenarios. Third, the forest inventory data has been updated for many regions and we have allocated all forests into agro-ecological zones (AEZs), as described in Sohngen et al. (2009). There are up to 18 AEZs within each of the 16 global regions.

The model is solved in decadal time steps for 15 decades using GAMS. It solves for the optimal age class distribution in forests, the optimal intensity to manage forests (e.g., US$ per hectare investment in timber quantity and quality, as well as carbon quantity), and the area of forests in each of the AEZs. Land supply functions are specified for each AEZ, such that each forest type in each AEZ is assumed to compete directly with other forest types and other land uses within the AEZ. Competition across AEZs does occur indirectly through timber price adjustments.

The baseline scenario assumes a path of crop and livestock rents for each AEZ in each of the 16 regions and consequently a set of land rental functions for timber in each AEZ. Demand for forestry products shifts outward over time as income rises (income elasticity is set at 0.87 and price elasticity is set at 1.0). Two sets of scenarios are then simulated across a range of carbon prices. The first set of scenarios assumes that policy is global, and any gain in carbon in any part of the world will be credited. Such a global set of credits is the same as Sohngen and Mendelsohn (2003) although they solved carbon prices endogenously with an integrated assessment model. The second set of scenarios assumes that carbon credits are gained only through actions undertaken in tropical developing countries. The regions where carbon payments are made in this second set of scenarios are: Brazil and the Rest of South America, Southeast Asia and Sub-Saharan Africa.

Under the baseline scenario, carbon prices are US\$0 t CO_2, thus it represents a policy where no regions are awarded carbon payments. As carbon prices increase, it is expected that aboveground carbon storage also rises as the regions obtaining the payments become more motivated to sequester additional carbon. Constant carbon prices assume that climate change damages are also constant, which is unrealistic. However, to calculate the present value of aboveground carbon sequestration under each scenario it necessary to make this conjecture because it is the only way to theoretically discount carbon.

To determine the marginal costs of carbon storage, it is first necessary to run the model for constant payment levels ranging from US\$10 t CO_2 to US\$900 t CO_2. Each region of the world is subject to the same constant carbon prices under each scenario. Using these results, cumulative carbon gains are calculated between the baseline and the scenario for each decade. Then, the present value of carbon for the world and the developing regions is evaluated for the first 100 years at a 5% discount rate.

Leakage occurs if the gains of implementing a carbon sequestration project in one region are offset by increased emissions somewhere else. Under the first set of scenarios all regions are awarded the same payment, so leakage is not present. The second set of scenarios, however, awards carbon credits only to tropical developing countries. This policy opens up the possibility of incurring in leakage in the regions not obtaining carbon credits. Therefore, to measure leakage I calculate the difference between the global marginal costs of sequestration and those of the developing regions obtaining carbon credits. If leakage is present, then policymakers are essentially paying for negative sequestration.

Results

The model is solved without carbon payments to all regions for 15 decades to obtain a baseline scenario. From figure 1 (see section after references for all figures and tables), it is clear that Brazil and the rest of the South American nations have the highest amount of carbon sequestered due to forest carbon stored in the Amazon rainforest as well as other tropical forest regions in Ecuador, Bolivia, among others. In 2050, for example, Brazil has the potential of sequestering about 43,387 Tg of carbon, while the other South American nations can sequester up to 19,655 Tg of carbon. These regions are followed by Sub-Saharan Africa and Southeast Asia with sequestration amounts ranging from 10,852 - 9,690 Tg of carbon during 2050.

The aforementioned results are expected since most of the world's leading rainforests, the lungs of the Earth, are located in Brazil, South America and Southeast Asia. With the current rate of deforestation, aboveground carbon decreases at a rate of approximately 2% to 4% per year for

Brazil, the rest of South America, and Southeast Asia. Although this decline is consistently negative for the first two regions, it is variable between years for Southeast Asia.

Although aboveground carbon storage in the tropical forest regions decreases through time, figure 2 shows that timber output in these regions increase. Since these regions do not have climate mitigation programs put in place under the baseline scenario, their governments do not have incentives to implement policies that protect their carbon stocks. Thus, tropical forest dwellers and timber concessionaires are not prohibited from exploiting the land or supervised to guarantee its adequate management. The negative trend in carbon stocks and positive timber output is also consistent with added pressure by the world's rising population to forests, agricultural, and pasture lands.

After obtaining the results of the baseline scenario, the dynamic optimization model is re-solved by awarding carbon credits to all regions of the world in one scenario, and only to tropical forest regions in another scenario (Brazil, rest of South America, Sub-Saharan Africa and Southeast Asia). Carbon credits are constant for each of the 15 decades and range from US$10 dls per Tg C to US$900 dls per Tg. It is expected that these credits have interesting effects on the timber market which merit some scrutiny.

Figure 3 and plots the decadal timber prices assuming a carbon payment of US$100 per Tg carbon for each of the scenarios and the baseline; the dashed line represents global timber prices under a policy where carbon credits are awarded to all the regions while the dotted line represents global timber prices when only tropical developing regions are awarded carbon credits. The first observation that warrants some attention is that prices in the business-as-usual scenario and that of the carbon credits only to the developing world scenario follow a similar path. This implies that the effect on timber prices of carbon credits to the developing world

(Brazil, rest of South America, Southeast Asia and Sub-Saharan Africa) is minor. This result makes sense since the largest timber suppliers (US and Europe) are not directly affected by the carbon policy.

On the other hand, if policy-makers award global carbon credits, the effect on timber prices are quite different. Initially, global timber prices are approximately 16% higher than the baseline, but within two decades they become lower than the business-as-usual scenario. Remember that global carbon payments are awarded to conserve existing forests and sequester additional amounts of carbon. Since these are now affecting the leading timber producers, a possible explanation for the disparity between the baseline and the world is that timber suppliers take some time to adapt to the new carbon policies. These initially reduce the amount of timber supplied so that timber prices increase. Nevertheless, within two decades, timber suppliers adapt to the new climate policy and are able to increase timber production, leading to a timber price decrease compared to the baseline.

Figure 4 reveals the marginal costs curves of the US and the tropical developing regions chosen for the present analysis when awarding global carbon credits. The regions with the highest marginal costs are also those that have the highest aboveground carbon storage as shown in figure 1 (Brazil and the rest of South America). The marginal costs of storing an additional teragram of carbon increase rapidly in these regions until they reach 4.61 Tg C/yr and 4.49 Tg C/yr. The US and Sub-Saharan Africa have the lowest marginal costs of carbon storage ranging from 0.19 Tg C/yr to 2.55 Tg C/yr. Southeast Asia is the intermediate region in this group, with marginal costs ranging from 0.75 to 4.07 teragrams of carbon per year.

Considering that all countries are awarded carbon payments to protect their stocks, this scenario can be thought of as the optimal conservationist policy. This does not mean, however, that it is the most efficient policy because it is the most expensive plan. The present policy does not take into consideration whether some regions have a comparative advantage in sequestering additional amounts of carbon. For example, certain timbers can sequester more carbon than others depending on their type and their age, so that some forests can store more carbon than others. Also, the reader has to keep in mind that the short-term effect on prices and quantity varies greatly from the business-as-usual scenario which the world will have to adapt to.

Instead of awarding carbon credits to all regions, governments might choose to provide payments to only certain nations that they believe are more at risk of affecting climate change, such as those with high levels of deforestation. Thus, the analysis will now focus on the effects of implementing carbon payment policies to the tropical developing nations of Brazil, the rest of South America, Southeast Asia and Sub-Saharan Africa. The first result to consider is that from figures 3 and 4 in the appendix timber prices and quantities are not very different from those of the business-as-usual scenario under the new carbon credit policy. This is a plausible result since the world's largest timber producers are not affected by the policy.

Then, figure 5 displays the marginal cost curves of aboveground carbon storage for the regions obtaining the credits. Analogous to the analysis above, Brazil and the rest of South America have the largest marginal costs in comparison with Southeast Asia and Sub-Saharan Africa. In general, the marginal costs when these regions are obtaining payments are higher than when policy-makers implement a global carbon payment scheme.

The focus of this paper is to demonstrate that leakage is an important phenomenon to take into consideration when implementing carbon sequestration projects with credits for timber carbon storage and to obtain estimates of the magnitude of leakage under different policy scenarios. Table 2 (see pg. 28) shows leakage calculations under scenario 2; that is when Brazil, the rest of South America, Southeast Asia and Sub-Saharan Africa are obtaining carbon credits. The second column is related to the global marginal costs occurring under the second scenario averaged over 100 years; that is, the marginal costs of carbon storage of the globe under a policy where the developing tropical regions are awarded carbon credits. The third column represents the marginal costs of carbon storage only of the developing regions over 10 decades; the marginal cost of Brazil, Southeast Asia, Sub-Saharan Africa and the rest of South America. That is, it represents the marginal costs of carbon storage that the world is paying for. If the global marginal costs of carbon under a specific carbon price are less than those of the regions obtaining the credits, then there is leakage. This implies that there are increased carbon emissions in regions not awarded carbon credits due to market or subsistence effects after greenhouse gas reducing policies are implemented.

The fourth column of table 2 displays the results for leakage calculations when developing tropical regions are obtaining carbon credits. As carbon prices increase, leakage decreases. Though there could be many reasons for this behavior, one potential explanation is that as carbon prices increases, governments awarded credits have more incentives to enforce and supervise carbon sequestration policies. Timber producers and forest dwellers that depend on the land are awarded more compensation for foregoing their previous activities and incurring in newer non-greenhouse gas emitting activities. Thus, carbon storage increases as prices increase at a faster rate than leakage increases in regions not provided with carbon credits.

Conclusion

As the world's climate becomes more and more unpredictable, many countries have started implementing climate change mitigation policies involving the use of renewable resources. To reduce global warming, scientists have shown that carbon sequestration is effective in decreasing greenhouse gases. Thus, some international organizations have started motivating projects that can store carbon in different sources, such as the ocean, biomass, organic matter and soils. One of these institutions is the UNFCC's Clean Development Mechanism (CDM), which has awarded credits to projects in developing countries for certified emissions reductions (CERs).

Nowadays, most of the world's carbon emissions are coming from developing nations that lack the institutions necessary to regulate forest deforestation and degradation. For this reason, the UNFCC has also initiated actions to provide credits for projects that can effectively reduce carbon emissions caused by deforestation and degradation (REDD). These projects can reduce global warming significantly, but the effects that these can have on the worldwide markets has caused some trepidation in their quick implementation. One of the main concerns is the potential of these projects to incur in leakage, or when the gains of implementing a carbon mitigation policy in one region are offset by increased carbon emissions somewhere else.

Therefore, the present paper focuses on the potential effects of implementing two carbon mitigation policies: global carbon credits vs. carbon credits to developing tropical regions represented by Brazil, the rest of South America, Southeast Asia and Sub-Saharan Africa. To estimate aboveground carbon storage, we use a forestry and land use model based on the global timber model described in Sohngen and Mendelsohn (2007) which optimizes the distribution of timber age classes and the area of land in forests for 16 regions. The model is solved for 150 years in 15 decade steps using GAMS for each of the policy scenarios under constant carbon prices that range from US$0 tC to US$900 tC.

The baseline scenario (when no carbon credits are awarded) indicates that Brazil and the rest of South America have the highest carbon storage potential. After running the models for both scenarios and all payment levels, the results on the timber market differ depending on the regions that obtain the carbon credits. When only the developing regions are awarded payments, timber prices through time are similar to those of the baseline scenario, so we can conclude that these regions have minor effects on the timber market. When the world, however, is awarded carbon credits, results indicate that short term timber prices are high while in the long term, prices decrease, consistent with improvements in carbon storage technology and added pressure of the world's population on the timber market.

Using the results provided by the model, the marginal costs of carbon sequestration are calculated by estimating the annual present value of aboveground carbon storage using a 5% discount rate. The marginal cost curves indicate that the regions with the greatest storage potential under the baseline also have the highest marginal costs. These are also higher when only developing regions are provided carbon credits than when global carbon payments are implemented. Finally, leakage, derived as the difference between the marginal costs of the world and those of the developing tropical regions awarded credits, ranges from 14% to 2%, decreasing as carbon prices increase. This could imply that if policymakers choose to implement higher prices, carbon storage increases at a faster rate than carbon emissions in regions not awarded payments.

The current paper only presents leakage analysis for the timber market under two different carbon scenarios. A more interesting case involves adjustments in both the timber and agricultural markets. Therefore, future research should focus on improving the global timber model to include the agricultural sector and provide marginal cost and leakage estimates under different carbon prices.

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Fig. 1: Baseline Scenario of Aboveground Carbon Storage (in Tg C) from 2010 - 2100

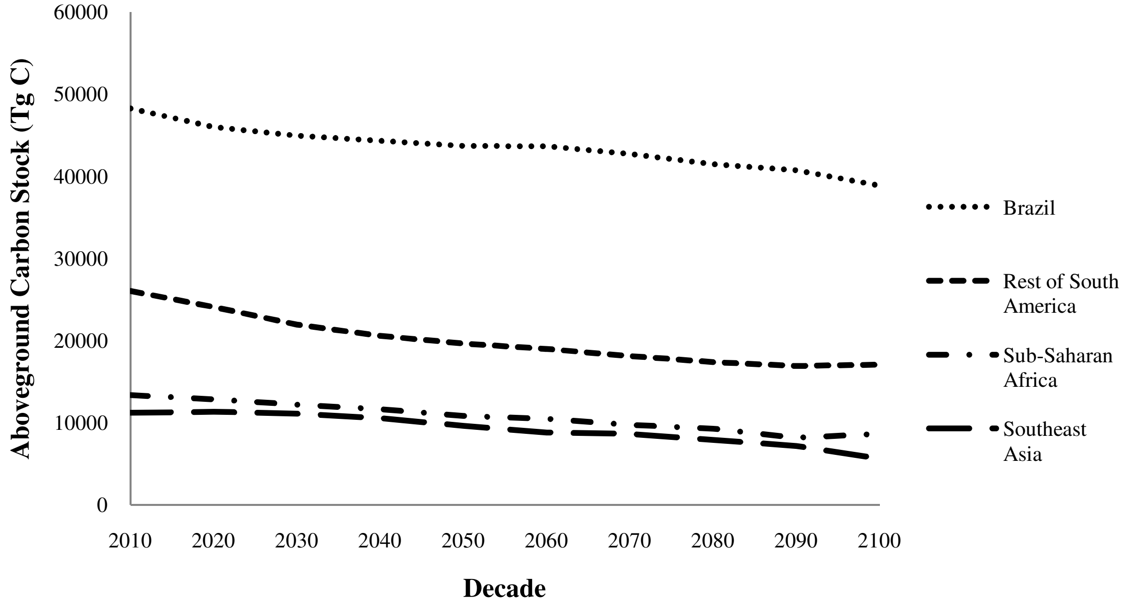

Fig. 2: Timber Output (in Tg C) for Tropical Forest Regions under the Baseline Scenario

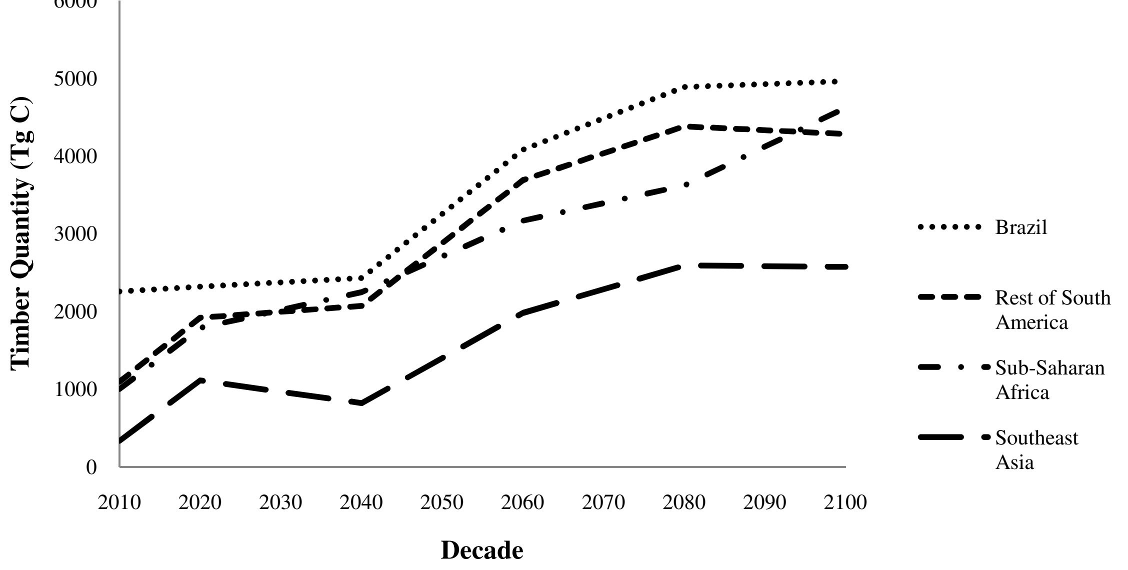

Fig. 3: Decadal Timber Prices at Carbon Payment of $100 dls per Tg C /yr to all Regions

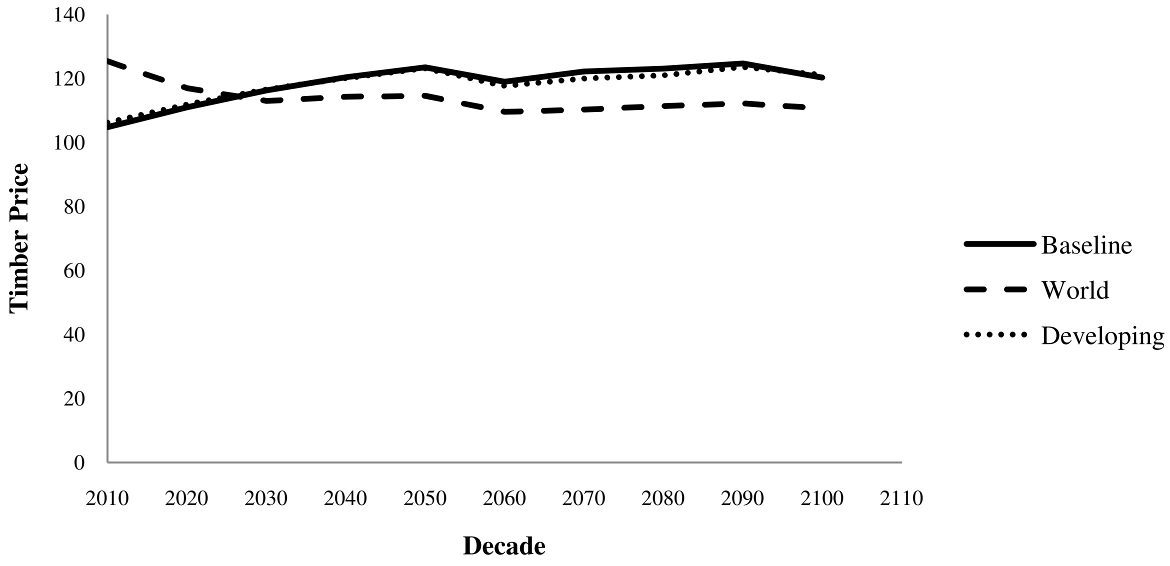

Fig. 4: Marginal Cost Curves for US and Developing Regions when all Regions Obtain Carbon Payments

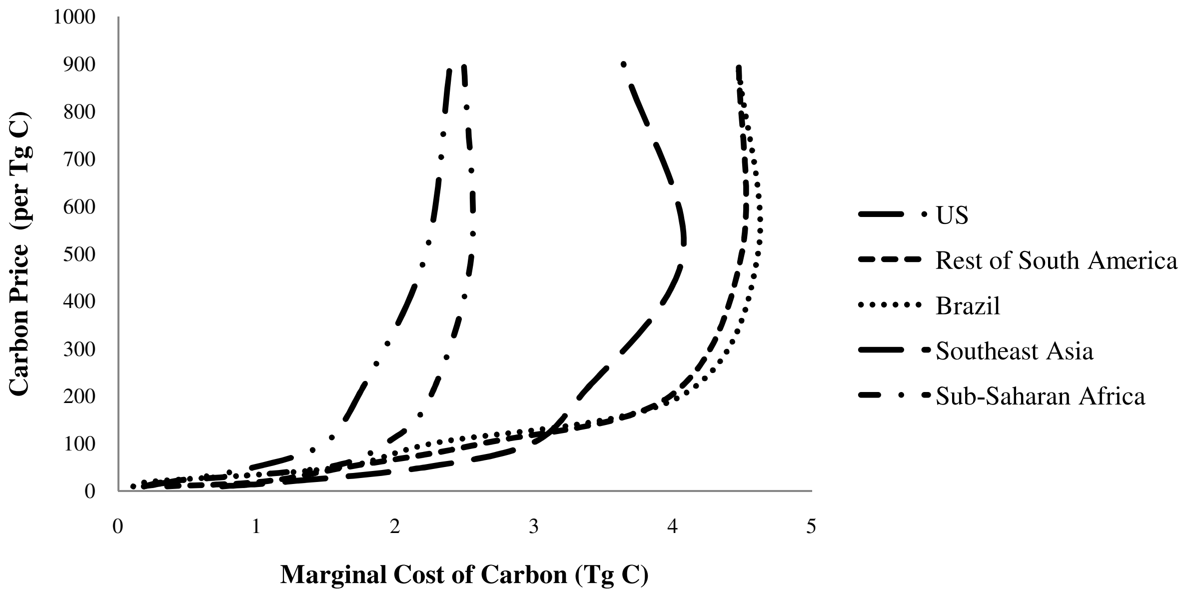

Fig. 5: Marginal Cost Curves for Developing Regions Obtaining Carbon Payments

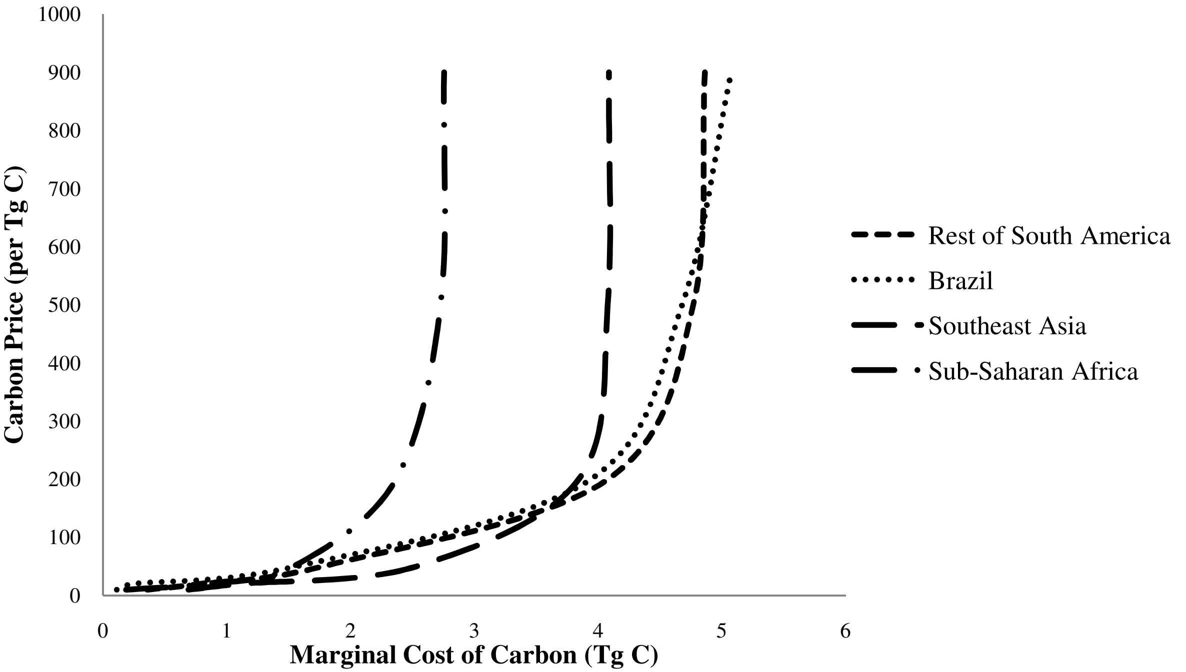

Table 1: 16 regions of Global Timber Model

	Region	Countries
1	US	United States
2	CHINA	China, Hong Kong
3	BRAZIL	Brazil
4	CANADA	Canada
5	RUSSIA	Russia
6	EU ANNEX I	Austria, Belgium, Denmark, Finland, France, Germany, U.K. Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, Switzerland, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Estonia, Latvia, Lithuania, Turkey, Rest of EFTA
7	EU NON ANNEX I	Rest of Europe except EU ANNEX I
8	SOUTH ASIA	Bangladesh, India, Sri Lanka, Rest of South Asia
9	CENTRAL AMERICA	Mexico, Rest of Caribbean
10	REST OF SOUTH AMERICA	Colombia, Peru, Venezuela, Argentina, Chile, Uruguay, Rest of South America
11	SUB SAHARAN AFRICA	Botswana, South Africa, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Madagascar, Uganda, Rest of South Africa
12	SOUTH EAST ASIA	Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, rest of Southeast Asia
13	OCEANIA	Australia, New Zealand, Rest of Oceania
14	JAPAN	Japan
15	AFRICA MIDDLE EAST	Morocco, Tunisia, Rest of Middle East, Rest of North Africa
16	EAST ASIA	Korea, Taiwan, Rest of East Asia

Table 2: Leakage when Developing Regions Obtain Carbon Credits

Carbon Price	Global Marginal Cost	Marginal Cost Developing Regions	Leakage
US$10	1.18	1.35	14.30%
US$20	2.72	2.94	7.81%
US$50	7.02	7.40	5.40%
US$200	13.72	14.23	3.74%
US$500	15.86	16.25	2.45%
US$900	16.42	16.78	2.19%