Carbon Sequestration: The Impact of Canadian-Induced Carbon Taxes on Global Timber Markets

by

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INTRODUCTION

Politician leaders in Canada have exhibited an increased interest in a more comprehensive environmental policy over the last years. For example, the Liberal party, Her Majesty's Loyal Opposition, in the "The Green Shift" (2008), suggested implementing a comprehensive carbon tax to help with greenhouse gas (GHG) reductions. Many international treaties and domestic regulations have been developed to tackle greenhouse gases and other pollutants.

The Federal Government issued an action plan in 2007 to reduce greenhouse gases and air pollution. The new regulation sets environmental targets to be reached by 2010, 2020, and 2050. The plan allows for the creation of a technology fund, and firms could obtain credits for compliance with targets. The intention of this fund is to "promote the development, deployment, and diffusion of technologies that reduce emissions of greenhouse gases across industry" (Turning the Corner, 2008). The government also allows for inter-firm trading of credits, credit offsets, and the possibility of banking the credits for future use.

With regard to carbon taxes, there exists currently a federal excise tax on certain motive fuels: diesel (4 cents per litre), jet fuel (10 cents per litre), and gasoline (10 cents per litre). These taxes were introduced in 1975 as a means to raise government revenue and reduce reliance on imported oil. Mintz and Olewiler (2008) note that this fuel tax was "not set on the basis of assessment of environmental damage or to achieve environmental targets".

Some provinces have already introduced carbon taxes and policies to curtail emissions. For example, British Columbia introduced on July 1st 2008 a revenue-neutral carbon tax that applies to virtually all fossil fuels, including diesel, gasoline, natural gas, propane, coal, and home heating fuel. Quebec also introduced a carbon tax in 2007. The rate varies according to the amount of carbon dioxide each fuel produces.

All the industries in Canada will be somewhat affected by the Federal government's initiative to lower greenhouse gases. One particular industry that needs special attention is the forestry industry. It is an $80 billion dollar a year business, representing 3% of the country's GDP. Forestry is central to over 320 communities and nearly 900,000 direct and indirect jobs across the country are related to this industry. Growing trees remove more GHG from the atmosphere than they emits. This process, called carbon sequestration, has been the focus of recent work of Brent Sohngen, Robert Mendelsohn, and Roger Sedjo.

Over the last 20 years, they developed and tuned a dynamic model of carbon sequestration in global forests. They recently employed their model in an evaluation of the global impact of different carbon costing regimes on different regions of the world. They studied the potential impact on reforestation, management intensity, global lumber price, and observed rotational lengths. Their model allows companies to receive credits for storing carbon in forests, and these credits can be drawn down when trees are harvested and moved to markets.

The purpose of this essay is to introduce recent carbon reduction mechanisms into the Mendelsohn, Sedjo, Sohngen model. Of central interest are the proposals of Mintz and Olewiler, of the BC government, and of the Liberal Party of Canada.

The next section presents past literature on carbon sequestration. I will then describe the model used in the analysis. The third part explains the three carbon tax scenarios used, and this is followed by the results, discussion, and conclusion.

LITTERATURE REVIEW

Carbon is stored in forests when trees and other plants convert CO_2 to carbon through photosynthesis. The conversion occurs in the biomass of trees, in understory plants, and builds up in soils and floor litter through leaf and root abscission. Following stand establishment, the total volume of carbon in the forest increases until trees reach maturity. After this time, forest carbon will be roughly in equilibrium as old trees die, creating gaps in the canopy and opportunities for younger trees to grow. Few studies have successfully evaluated the carbon sequestration potential of different mitigation strategies.

Richards and Stokes (2004) evaluated and compared several of these studies and came to the conclusion that a carbon tax ranging between $10 and $150 per tonne would allow carbon sequestration to play a substantial role in global greenhouse gas stabilization plans. The review conducted by the two researchers established that the variation in results came mainly from discrepancies between the definition of a 'tonne of carbon', the difference in carbon accounting and discount rates used, whether the study was conducted with a regional or global scope, and the types of forestry practices incorporated in the models.

Although regional studies work on extensive detailed data with specific cost functions, they often ignore leakages and global substitution. Leakage occurs when efforts to sequester carbon in a region is offset by the release of carbon in another geographical area. This is a serious issue as sequestration costs may be underestimated and governments that spend substantial sums in establishing programs will see no net gain in carbon storage. Global substitution must also be taken into account as some regions of the world may be more suitable for sequestration and others for production. Harvesting activities must therefore be allowed to shift from one region to another, and so must management intensity chosen while replanting. The previous effects were therefore ignored in the otherwise thorough regional studies by Dong et al. (2003), Goodale et al. (2002), Kurz and Apps (1999), Kurz et al. (2008), McKenney et al. (2004), Chen et al. (2000), Stinson and Freedman (2001), and Krcmar et al.(2005) to name a few.

Another issue when evaluating sequestration potential relates to the temporary nature of carbon sequestration. Studies like Feng et al. (2002) fail to recognize that setting aside carbon for a year is different than setting aside carbon permanently. In other words, the cost of carbon, or marginal abatement cost, is the value of permanently setting carbon aside, like keeping an old growth forest in a conservation area permanently that would have otherwise been harvested. Notice that this is different to the rental rate of carbon, which is the value of holding one tonne of carbon for one year.

Models like Kurz and Apps (1999) ignore the dynamic nature of carbon sequestration. Indeed, static models do not allow for changes in technology, carbon prices, and changes in demand. In the most recent literature, this issue has been corrected as the majority of publications are now based on dynamic forestry models with or without some agricultural components (Lee and Lyon, 2004; Feng et al., 2002; Newell and Stavins, 2000; Kurz et al., 2008)

All global models constructed so far, although dynamic, have not been able to capture endogenously the demand for agricultural land resulting from forestry practices (Sathaye et al., 2006; Lee and Lyon, 2004; Sohngen and Mendelsohn, 2003).

In 1999, Sohngen, Mendelsohn, and Sedjo developed a forest management and global timber supply model to simulate harvests, prices, and management decisions. They first used this model to analyze two forest conservation strategies, but soon realized the potential of this model: Sohngen and Mendelsohn expanded the model in 2003 to incorporate it to the Nordhaus-Boyer DICE model (2000). The dynamic model could then capture adjustments in carbon stocks resulting from changes in timber demand and technology across a range of carbon prices. The DICE model is first used to obtain carbon prices and rental rates without sequestration. These rates are then put into the forestry model to calculate the costs and quantities of carbon sequestered, leading to the elaboration of a cost function. The function is then inserted back into the DICE model to obtain new rental rates, and so on. The iterations allow us to compute a set of rental rates, cost functions, and sequestration quantities that are consistent with the two models.

In 2006, Sohngen and Sedjo used the model to evaluate the impact of carbon taxes on the industry. The maximized consumer surplus takes into account the carbon credits received or paid in each year, which are determined by the carbon tax imposed on the model and the level of emissions or sequestration that occurred in the period. A year later, Sohngen and Mendelsohn (2007) expanded the model to include additional regions and timber types, new yield functions and biomass expansion factors for various forests, and examined the sensitivity of estimates of both the baseline carbon in forests and the efficacy of sequestration programs.

Although the agricultural-forestry interface is not modeled endogenously, this last model is state-of-the-art as far as global, dynamic sequestration models go. I have chosen to work with this model as it also discerns Canada from the rest of the countries, making the country-specific analysis more straight-forward. The model is detailed in the next section.

THE MODEL

The presentation of the carbon sequestration model is closely based on Sohngen and Mendelsohn (2007). The model evolved from an earlier Dynamic Timber Supply Model (DTSM) of Sohngen et al. (1999) and used by Sohngen and Mendelsohn (2003) to analyse carbon sequestration potential. It is the most complete and complex optimizing carbon sequestration model presented in the literature, where all forest regions in the world are considered, with new data on age class inventories and yield functions for several major regions, updated yield functions for subtropical regions and updated carbon conversion parameters. The model represents the dynamic behaviour of forest managers and the evolution of forests over 150 years. It is a global model as it considers the interactions among 13 geographical regions[1] having 146 distinct timber types. The decision variables for each period include the amount of acres to harvest and to replant, and the management intensity levels that maximize the net present value of consumer surplus minus the costs of holding and managing each stock of forest.

For the purpose of describing the model, each of the 146 timber types modeled can be allocated into one of three general types of forest stocks:

Stocks S_i: moderately-valued forest managed economically in optimal rotations; located primarily in temperate regions.

Stocks S_j: high valued timber plantations that occur mainly in subtropical regions like the southern United States, South America, the Iberian Peninsula, Indonesia and

[1] "Increasing the area of forests in one region causes supply to expand and lowers the prices. Lower prices can reduce incentives to manage forest elsewhere" (Sohngen, Mendelsohn, and Sedjo, 2003)

Oceania. These stocks have additional establishment costs relative to stocks in i, and are managed in optimal rotation.

Stocks S_k: relatively low-valued forests, managed lightly if at all, located primarily in inaccessible regions of the boreal and tropical forests. Timber types are assumed to be old growth and are not defined in age classes[2].

Global Demand

The global demand for industrial timber harvested from all stocks of all forests is derived from a well-behaved utility function over industrial wood end-products and all other goods and is denoted by

$$P(t) = D\left(Q(\bullet), Z_t\right),$$

where Q (•) is the global timber harvested, and Z_t the consumption of all other goods. Z_t shifts the demand outwards as a function of global economic growth, population growth, and changes in per capita income. Timber demand is therefore programmed to grow by 0.5% per year, with growth falling by 5% per year. The global demand function is assumed to be the additive sum of many different regional demand functions. The model accounts for trade by assuming that each region has a distinct constant marginal cost of transporting timber to its major demand region. Regional price differences exist, but are assumed to follow the law of one price. Industrial timber from each region is quality adjusted to account for the differences in the value of timber from different forest stocks on world markets.

[2] Note that if inaccessible forests are harvested, which occurs if timber prices exceed marginal access costs, they convert to accessible forests and return to stock i and are subsequently managed in age classes.

Total Timber Harvested

The quantity of wood depends on the area of land harvested, the age of trees at time t, and a yield function that depends on the management intensity for a stand planted at time t_0:

$$Q(\bullet) = \sum_{i=1}^{I}\sum_{a=1}^{A} H_{a,t}^{i} V_{a,t}^{i} + \sum_{j=1}^{J}\sum_{a=1}^{A} H_{a,t}^{j} V_{a,t}^{j} + \sum_{k=1}^{K} H_{t}^{k} V_{t}^{k}$$

Over all species harvested in a given year, the quantity of timber harvested at time t is the sum of the area harvested H times the yield per hectare V. For example the term $V_{a,t}^{i}$ is defined by a yield function that depends upon the species, the age of the tree, a, and the management intensity applied to the stand at the time of regeneration t_0:

$$V_{a,t}^{i} = Y^{i}\left(a_t, m_t(t_0)\right)$$

A single yield function exists for the species i in each ecosystem type. This yield function is assumed to be typical for the species in each ecosystem type:

$$\frac{\delta Y^i}{\delta a_t} > 0, \frac{\delta^2 Y^i}{\delta a_t^2} < 0 .$$

The following two conditions hold for trees planted at time t_0 and harvested $(a + t_0) = t_{ai}$ years later:

$$\frac{dV^i(t_{ai} - t_0)}{dm^i(t_0)} \geq 0 \quad and \quad \frac{d^2V^i(t_{ai} - t_0)}{dm^i(t_0)^2} \leq 0$$

Objective Function

The global forestry model maximizes the present value of net welfare in the forestry sector. The benefit of harvest is a Marshallian consumer surplus (area under demand curve) and the objective function is given formally as:

$$Max\sum_{0}^{\infty}\rho^{t}\left\{\{\int_{0}^{Q*(t)}D(Q_t,Z_t)-C_{H^i}(\cdot)-C_{H^j}(\cdot)-C_{H^k}(\cdot)\}\times dQ(t)-\sum_{i,k}C_G^{i,k}(G_t^{i,k},m_t^{i,k})\right.$$

$$\left.-\sum_{j}C_N^i(N_t^j,m_t^j)-\sum_{i,j,k}R^{i,j,k}(L_t^{i,j,k})+CC_t\right\}$$

where $C_H^i, C_H^j, and\ C_H^k$ denote the cost functions for harvesting and transporting logs to mills for each timber type (i, ,j, and k), $C_G^{i,k}(\cdot)$ denote the cost of planting land in temperate and previously inaccessible forests, $C_N^j(\cdot)$ is the cost function for planting forests in subtropical regions. $R^{i,j,k}(\cdot)$ is a rental function for the opportunity costs of maintaining lands in forests, $G_t^{i,k}$ is the area of land planted in types I and k, N_t^j is the area of land planted in plantation forests, $L_t^{i,j,k}$ is the total area of land in forest type i, j, or k, and CC_t represents the payments for carbon sequestration at time t. The financial discount rate used for the simulation is 5%.

Harvest Costs

Marginal harvest costs for temperate and subtropical plantation forests (i and j) are constant, while marginal harvest costs for inaccessible forests rise as additional land is accessed. These costs are expressed as a function of the quantity of timber harvested in each type in time t:

$$C^i(\bullet)=\sum_{i=1}^{I}\sum_{a=1}^{A}\left(ch^i+ct^i+cg^i\right)H_{a,t}^iV_{a,t}^i$$

$$C^j(\bullet)=\sum_{j=1}^{J}\sum_{a=1}^{A}\left(ch^j+ct^j+cg^j\right)H_{a,t}^jV_{a,t}^j$$

$$C^k(\bullet) = \sum_{k=1}^{K}\left(\beta_0 + \beta_1 \sum_{t=1}^{t} H_t^j V_t^j\right) H_t^j V_t^j$$

where:

$ch^{i,j}$ = the marginal harvesting and transportation costs to mills ($ct^{i,j}$) or market regions ($cg^{i,j}$). The marginal costs are considered constant.

C^k = the cost of harvesting k. The marginal cost here is an upward sloping function of the sum of historical harvesting from the initial model period with parameters β_0, β_1. Marginal access costs are assumed to rise as additional land is harvested in this region because the cost of building and maintaining new roads are high in inhospitable regions.

Total Area of Land

The total area of land in each forest type is given by:

$$L_t^i = \sum_{a=1}^{A} X_{a,t}^i, \qquad L_t^j = \sum_{a=1}^{A} X_{a,t}^j, \qquad L_t^k = X_t^k$$

where $X^{i,j}$ is the area of land in each forest stock in age class a and time period t.

Rental Costs

Two forms of the rental cost functions are used:

$R(L_t^{i,j,k}) = \alpha L_t^{i,j,k} + \beta(L_t^{i,j,k})^2$ for temperate and boreal regions, and

$R(L_t^{i,j,k}) = \alpha(L_t^{i,j,k})^2 + \beta(L_t^{i,j,k})^3$ for tropical regions.

These rental cost functions constitute a weakness of the current model as the land supply function is likely to vary across ecosystems and regions. The marginal cost of adding forestland in tropical regions is assumed to be nonlinear to account for relatively high opportunity costs associated with shifting land out of current agricultural areas. The parameters of the rental functions are chosen so that the elasticity of land supply is 0.25 initially, as reported in the United States (Hardie and Parks, 1997, Plantinga et al. 1999). This elasticity means that the area of forest can increase by 0.25% if forests can pay an additional 1% rental payment per year. This estimate is applied globally.

Growth Functions, initial values and non-negativity constraints

The problem is constrained by the stock of land maintained in forests. Land in each age class of each forest stock adjusts over time according to:

$$X_{a,t}^{i} = X_{a-1,t-1}^{i} - H_{a-1,t-1}^{i} + G_{a=1,t-1}^{i} + H_{a=1,t-1}^{K=I} \quad \forall i$$
$$X_{a,t}^{j} = X_{a-1,t-1}^{j} - H_{a-1,t-1}^{j} + N_{a=1,t-1}^{j} \quad \forall j$$
$$X_{t}^{k} = X_{t-1}^{k} - H_{t-1}^{k} \quad \forall k$$

where: G_t^i, N_t^j are the area planted in i and j in year t respectively. These equations express the change in size of the total population of each stock type in each period. They represent the difference between area harvested and area regenerated. Initial stocks must be given:

$$X_i(0) = X_{i,0} \quad \forall i.$$

Finally, all choice variables are constrained to be non negative:

$$X_i(t), H_i(t), G_i(t), N_i(t), m_i(t) \geq 0 \quad \forall i.$$

Carbon Sequestration Rental Payments

The term CC_t in the objective function represents carbon sequestration rental payments at time t. Rental payments are made on the total stock of carbon in forests estimated by:

$$CC_t = CR_t \sum_{i,j,k} \gamma_{i,j,k} \sum_a \{V_{a,t}^{i,j,k}(m^{i,j,k}(t_0))\} X_{a,t}^{i,j,k}$$
$$+ P_t^c \sum_{i,j,k} \theta_{i,j,k} \sum_a \{V_{a,t}^{i,j,k}(m^{i,j,k}(t_0))\} H_{a,t}^{i,j,k} - E_t^b,$$

where CR_t is the annual rental value of a tonne of carbon[3], P_t^c is the price of a tonne of carbon, $\gamma_{i,j,k}$ is a conversion factor to convert forest biomass into carbon, $\theta_{i,j,k}$ is a conversion factor to convert harvested biomass into carbon stored in products, and E_t^b is baseline carbon sequestration. In this model it is assumed that product storage in long-lived wood products is 30% of total carbon harvested (Winjum et al. 1998).

Terminal conditions

The model was programmed into GAMS and solved with MINOS in 10-year increments. Terminal conditions were imposed on the system after 150 years to allow stocks to regenerate and to better evaluate the first 100 years of the simulation. These conditions are set far enough in the future not to affect the study results over the period of interest. They also calculate the value for each age class of timber in each stock assuming that steady state conditions have evolved and then apply this value to the stock in the terminal period. The authors warn that there is debate as to whether steady state rotations will ever be achieved. The model is a non convex, nonlinear maximization problem with 91,517 variables

[3] Annual carbon rental rates CR_t depend on current and future carbon prices. If the carbon prices are constant, then the rental rate can be calculated as: $CR_t = r \bullet P_t^c$ where r is the interest rate.

and 82,510 equations. The data and full description of its development can be found on http://aede.osu.edu/people/sohngen.1/forests/GTM/index.htm. Table 1 summarizes the 2005 data used as initial values.

Table 1: 2005 Data

	Total Forest Area (million ha)	Inaccessible Hectares (millions)	Harvest Accessible (million cubic meters)	Total Harvest (million cubic meters)	Subtropical Plantations (million ha)	Aboveground carbon (PgC stored)	Market carbon (PgC stored)	Soil Carbon (PgC stored)	Total Carbon (PgC stored)
US	201.72	59.84	3665.45	4082.64	11.98	12.22	0.93	38.01	51.16
Canada	412.82	305.69	1764.13	2407.61	0.00	12.95	0.50	119.44	132.89
S. America	868.68	0.00	1541.85	1541.85	11.05	103.72	0.47	106.37	210.55
C. America	56.42	0.00	167.77	167.77	1.30	5.25	0.05	7.10	12.40
Europe	186.65	3.47	3110.89	3306.92	2.76	6.04	0.71	21.91	28.66
Russia	838.12	724.34	920.39	1672.25	0.00	35.94	0.39	219.68	256.02
China	154.04	27.45	739.40	1002.92	9.71	7.44	0.22	19.93	27.59
India	49.92	0.00	174.24	174.24	3.82	3.29	0.04	6.59	9.92
Oceania	199.17	0.00	406.69	406.69	5.17	5.19	0.09	19.99	25.27
SE Asia	209.05	0.00	837.26	837.26	11.03	27.56	0.26	27.18	55.00
C. Asia	38.02	0.00	121.28	121.28	1.83	1.36	0.03	4.94	6.33
Japan	23.68	0.00	602.26	602.26	10.30	0.92	0.14	3.08	4.14
Africa	356.06	0.00	658.22	658.22	4.00	35.59	0.22	45.38	81.18
Total	**3594.35**	**1120.79**	**14709.83**	**16981.91**	**72.95**	**257.45**	**4.06**	**639.60**	**901.12**

Limitations of the approach

It is important to remember that the model does not formally include agricultural markets and that supply of land in forestry is only sensitive to timber prices. The reader should also note that natural disturbances were not accounted for in the model. Unlike the model presented in Sohngen and Mendelsohn's paper (2007), I have not modeled in carbon discounting due to the already high non-convexity of the objective function. Indeed, if we only discount financial costs and revenues, "there will be an obvious bias towards carbon sequestration in later periods." (Krcmar et al., 2005)

THE CARBON TAX SCENARIOS

The Baseline Scenario

The baseline scenario is intended to represent 'business as usual' as a benchmark to analyze the proposed carbon taxes. Here, P_t^c is set to zero so that the CC_t term has no impact on the objective function. In the Canadian context, this scenario corresponds somewhat to the current situation.

As global environment policies go, Canada has committed to reduce its greenhouse gas emissions by six percent from 1990 levels in Kyoto, Japan. In 2004, Canada's emissions were 27% above that of 1990, which demonstrates the failure of previous efforts put towards emission reduction. Recently, the Harper government announced that it did not intend to reach the 2008-2012 targets and instead, set its own target for 2020 and 2050.

One of the reasons why Canada has decided not to go forward with the Kyoto Protocol is that the international agreement did not take into account carbon sequestered by forests. As van Kooten and Hauer (2001) explain, "Countries with a large forest sector are interested in C credits related to reforestation, and those with large tracts of (marginal) agricultural land are interested in afforestation as a means for achieving some of their agreed upon CO2-emissions reduction." Indeed, Canada wanted carbon credits for replanting a forest that had been logged.

Harper's environmental plan introduces mandatory and enforceable actions across various industries and sectors. Concretely, the government is imposing a regulation to existing facilities, such as pulp and paper, in which firms have to reduce their emissions by 18%, starting in 2010, and 2% thereafter for a total of 33% reduction from the 2006 levels in

2020. Companies will be able to comply with the new regulation and obtain tradable credits that can be banked for future use, or sold to other parties, by contributing to a technology fund given that their emissions are below the imposed target. So far, "industry has indicated it will have difficulty in meeting the targets through in-house reductions alone" (Government of Canada, 2008)

The Mintz and Olewiler Proposition

In 2008, Mintz and Olewiler suggested to convert the existing Canadian excise tax on gasoline into a true environmental tax. That is, they deemed that the current tax on gasoline is not efficient in targeting true environmental damage since other fuels are not being taxed. Indeed, the tax is only applied to motive fuels, which is unfair as only some industries bear the cost (e.g. transportation), which in turn reflects uneven effects on the final prices of goods and services sold to consumers. The authors argue that the tax structure could be made more efficient by applying an environmental tax to all polluting sources equal to the current carbon-equivalent tax of $42 per tonne of CO_2.

Currently, gasoline is taxed by the federal government 10 cents per litre, while diesel and airplane fuel are taxed 4 cents per litre. Some of the provinces have additional taxes on motive fuel in order to build and maintain their roads. As van Kooten and Hauer (2001) noted, "the different positions that Canada has taken over time reflect the consequences of politics rather than careful assessment of the economic costs and benefits, and full analysis of the scientific aspects of the choice."

Historically, the federal government has mainly relied on voluntary action and regulations to tackle pollution. Again, van Kooten and Hauer (2001) warn that "voluntary action is clearly untenable and stronger measures such as taxes or regulation will likely be required if more substantial results are to be achieved."

In their latest environmental policy publication, Turning the Corner (2008), the federal government announced various new regulations to tackle greenhouse gas emissions. As mentioned above, their main device for achieving this target is through industry regulation. Economic theory shows that regulations can reduce harmful activities and are effective in application. On the other hand, if this regulation prescribes a technology, the polluter may find himself locked into using the specified technology instead of continuously improving his productivity and emission abatement efforts. Indeed, market-based incentives have proved to be more cost-effective to reach a specified environmental target with fewer distortions to the economy. Mintz and Olewiler (2008) argue that by restructuring the current excise tax on gasoline, the government could "correct market distortions rather than introducing new ones."

They therefore propose to introduce an environmental tax based on an index of the relative damage of environmental pollutants and GHG emissions that would focus mainly on energy-related emissions. They also stress the importance of revenue-neutrality where the revenue from tax should be used to reduce taxes that undermine economic growth and fairness, thereby reducing distortions.

The current tax on gas would remain unchanged at 10c/litre, which is equivalent to a $42 per tonne of CO_2 emitted. This tax would then be applied to other fuels and energy production. By applying the tax to all other sectors, the federal government could initially raise an additional $15 billion to the current excise tax revenue which could be used to reduce taxes or fund climate-related government tax credits. Such credits could be given to industries that adopt environmentally-friendly technologies. They even stress that "some tax credits such as for carbon storage and recapture technologies could serve a dual function in assisting businesses with these costs as well as ensuring the overall tax change is neutral among regions." Indeed, a critical issue as emissions tax go is that the tax would be borne more heavily by some areas compared to others. Redistribution of the revenue generated should bear in mind the significant regional effects of the programme.

For this scenario, I will then set the tax rate at $42 per tonne of carbon-equivalent emissions.

The British Columbia Carbon Tax

On July 1st 2008, the government of British Columbia introduced its first revenue-neutral carbon tax. The tax is based on five principles: broad-based, phased in, protection for low-income households, revenue neutrality, and integrated approach.

The tax spans all fossil fuels in order to be comprehensive and will be phased in to give industries and individuals time to adapt. It started at $10 per tonne of carbon-equivalent emissions and will rise by $5 per year for four years, reaching $30 per tonne in 2012. Lower-income households will receive an offset of $100 per adult and $30 per child, paid quarterly. The government guaranteed that all the revenue generated by the tax will not be used for expenditure programs and will be given back to businesses and individuals as tax cuts. The government also allowed for other measures such as the cap-and-trade system to be integrated with the tax to avoid double taxation and unfairness. In addition to the tax reductions, the government will issue a one-time $100 dividend to every resident to help in the transition.

The third and fourth scenarios will account for the British Columbia carbon tax scheme by setting the tax rate at $10 initially, rising at $5 per year until $30 per tonne of carbon.

The Liberal Party Proposition

The Liberal Party of Canada published a document entitled "The Green Shift" (2008) in which they propose a federal carbon tax which is closely structured like the British Columbia carbon tax. The Party proposes a revenue-neutral carbon tax of initially $10 per tonne of carbon-equivalent emissions in year one, rising by $10 per year, up to $40 per tonne in year four. Here, the tax will initially be set at $10 per tonne of carbon, rising by $10 annually until $40 per tonne.

In summary the scenarios will be as follows:

1- Baseline: $0 carbon tax

2- Mintz and Olewiler: $42 per tonne

3- British Columbia: $10 per tonne initially, rising by $5 for four years to $30

4- Liberal proposition: $10 per tonne initially, rising by $10 for four years until $40

RESULTS

The Baseline

For the baseline, the model was run setting the carbon tax to zero so that the CC_t term would have no effect on the objective function. The model predicts that in the century to come, global forests will shrink by about 12.5% from the 2005 level, averaging a 0.13% decrease per year, or 4.5 million hectares (ha) each year (see table 2 in the appendix).

In the first five decades, most regions seem to remain stable. Deforestation mainly occurs in South and Central America, South East Asia, and Africa, while Europe, China and central Asia experience significant afforestation. As a matter of fact, China is the region in which most inaccessible forests are harvested relative to the other regions, followed closely by Europe. The rate of harvesting of accessible forests is significantly higher in China, Oceania, and India, where increases in subtropical plantations are also the highest. South and Central America also experience a significant increase in their subtropical plantations. Interestingly, China is the leader in carbon sequestration for these years, storing 1Pg C (1 Pg C=$1x10^{15}$g C; C=Carbon equivalents) more in 2055 than in 2005 (see table 3 in appendix). Oceania and Europe only manage to sequester half as much with Japan further behind. The largest losses in carbon occur in Africa and South East Asia, each emitting 18 and 15 Pg C respectively. In relative terms though, Japan and China experience the highest increase in carbon sequestration, while Central America and South East Asia's forests emit the most carbon.

Canada's forest area seems to remain stable at about 420 million of hectares, with afforestation mainly occurring in the first decade. Looking at the predictions more closely, its inaccessible forests shrink by close to 15% during this period, while accessible regions experience a decrease in harvesting of about 500 million hectares. Even if the total harvesting decreases by about 48%, the Canadian forests are a small source of carbon when compared with their 2005 sequestration levels. The carbon stored in market products seems to be the main reason for this drop, while carbon stored in soil increases by a small amount. Aboveground carbon also experienced a decrease in storage of about 10%.

In the second half of the century, Russia experiences the highest increase in hectares in forests, followed by China and Canada. In relative terms, India sees the highest percentage increase in total forest area. South America, on the other hand, loses close to 34 million hectares throughout the 5 decades. Africa, Oceania and South East Asia also lose substantial amounts of forests, the latter forgoing 15% of its stocks. When looking at inaccessible forests, all regions harvest these old growth stands during the half century, with the exception of Canada. Europe, for example, loses 65 percent of its inaccessible forests.

The largest increases in harvesting occur in Canada and Oceania. It is clear that most of the wood harvested came from accessible forests. During the same period, the US and China cut drastically their harvesting by 12 and 45 percent respectively. Regions that can support tropical plantations increase the number of hectares assigned to this form of silviculture. The most notable efforts are observed in Oceania where plantations increase by more than 14%, and South America where the increase if of 2.53 million of hectares.

When comparing total carbon sequestered in 2105 to the 2055 levels, the net gainers are Central America and Japan in relative terms, while South East Asia, China, and India have emitted more carbon. The carbon sequestered in soil appears to be increasing in all countries, while the aboveground carbon has been decreasing in the majority of the regions.

The market carbon storage proved to be positive in all regions but the US, China, India, Japan, and Africa.

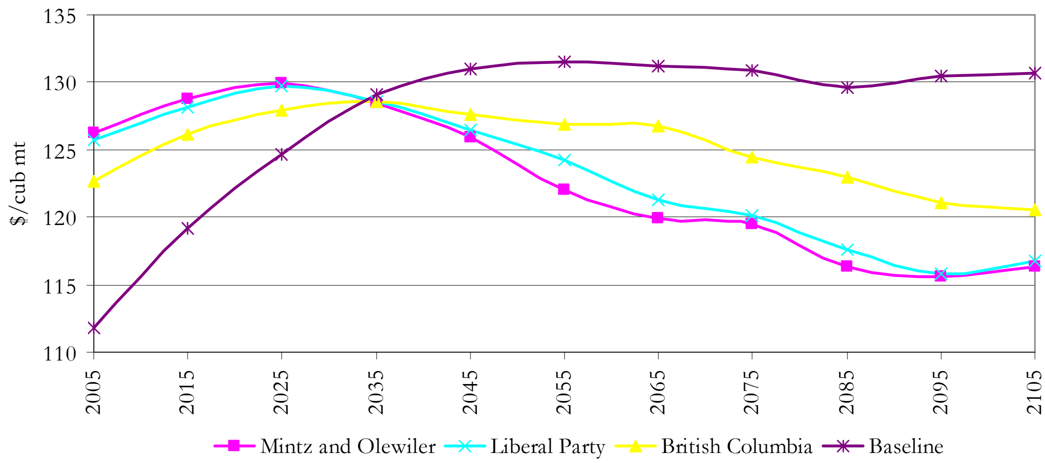
In Canada, an increase of 4.11 million ha of forests occurs in the five decades. The inaccessible forest area remained unchanged as the increase in harvesting mainly occurred in the accessible forests. The second half of the century allowed Canadian forests to sequester 0.66 Pg C above the 2055 level. The aboveground carbon, regional market storage, and soil carbon increased by 2%, 65%, 0.2% respectively.

Overall, the model shows that the deforestation rate will decrease in the second half of the 22nd century, subtropical plantations will increase by about 80% from the 2005 level, and that the harvesting of inaccessible forest stocks will mainly occur in Canada and Russia. As Sohngen and Mendelsohn explain, "continued harvests in inaccessible regions of the boreal forest offset many of the gains in carbon that occur with afforestation."(2007). One must keep in mind that the simulations assumed that the forest stock in inaccessible regions was of old growth and therefore did not sequester additional carbon.

The Mintz and Olewiler Proposition

Under this scenario, the global price of timber initially increases by 9% above the baseline, to eventually fall short of 7% in 2055 and 10% in 2105 (figure 1).

Figure 1: Global Timber Real Prices



When comparing the Mintz and Olewiler proposition with the baseline results, we can see that in 2015, the world's forest area already increases by about 5%, with the largest relative increases occurring in India, Africa, and Central America (see table 4 in appendix). By 2055, Africa now has close to 50% more forested hectares than in the baseline and the world already has 10% more woodland than without the tax. South America experiences an increase of about 75 million hectares which represents an 11% increase from baseline. The results are even more dramatic in 2105 with 350 millions of hectares more over the globe. Africa, South America and South East Asia are the regions that experience the highest increase. The only country that sees its stock decrease is Russia by a negligible 0.4%. The inaccessible forests also increase in most global regions during the whole century. China actually sees its stock increase by more than 530% in 2055 and even 766% in 2105 compared to baseline. Europe starts by losing 7% of their forests but quickly catches up after 50 years with an increase of 35% above baseline, and in 2105, the 0.7 extra million hectares represents an 500% increase above the no tax scenario.

The global timber production falls short of the baseline initially, with the biggest drops occurring in South East Asia where harvesting decreases by 51%. Central America decreases initially its production by 35% and Africa by 40%. These three regions experience subsequent falls in production for the main duration of century. The total production of Russia also falls by 20%, although their accessible harvest increases by 25% initially, meaning that their inaccessible stocks of forest were not as exploited as under the baseline. In 2105, China and the US increase their production by 93% and 73% respectively. Notice that the US fell short of the baseline production in the previous years. The number of hectares of tropical plantations increases in every region, with the largest differences observed in China and Central Asia.

The increase of forest area, the decrease in harvests in early periods, and the increase in subtropical plantations, allowed for an additional 73 Pg C sequestered in forests by 2105 (see table 5 in appendix). This is 8% more than under the baseline. The regions sequestering the most carbon are South America, Russia, South East Asia, and Africa.

Looking at the impact of the $42 tax on Canada specifically, one can see that the total number of hectares in forests greatly increases in the first part of the century, slowly approaching the baseline level by 2105. In the fifth decade, the hectares in inaccessible lands are 8% higher than under the baseline. The proportion of timber harvested from the inaccessible stocks decreases sharply in the first half of the century, falling to 0% in 2055, and slowly increases afterwards to account for 4% of the total timber harvested in year 2105. The model also predicts that an additional 1.47 Pg C could be sequestered with this policy than under the baseline. This result is smaller than the 1.6 Pg C obtained by Sohngen and Mendelsohn for Canada under their low-damage carbon tax scenario. Nevertheless, the

Mintz and Olewiler proposition could increase carbon sequestration by 1.1% in Canada mainly through a significant increase in aboveground carbon storage.

The British Columbia Carbon Tax

The British Columbia carbon tax, starting at $10 per tonne of carbon and reaching $30 per tonne in 2012, initially raises the price of logs by about 6%, pushing global production down by 10% from the baseline predictions (figure 1). Fifty years later, the price is below baseline by $4.60 and total production therefore increases, and by 2105, there is a $10 differential with the baseline as there is 14% more worldwide timber production.

The number of total hectares in forests increases substantially in Central America, India, South East Asia, and Africa (see table 6 in appendix). China sees its stock of inaccessible forests rise by up to 500% from baseline in 2105. Few countries actually see their stocks decrease in this simulation. The fall in total harvests in 2015 is mainly caused by the decrease in harvesting in Africa, the US, and South America. China is the only country that decides to substantially increase harvesting mainly in accessible stocks. In 2055, the US is still downsizing production as South East Asia increase theirs by a staggering 231%. At the end of the century, North American countries, China, and European countries take advantage of the high market price for timber and increase their harvesting activities mainly in accessible forests. Plantations of high value timber are mostly increasing during the exercise with China, Central Asia, and Africa leading the group.

Under this tax scheme, the global forests would be able to sequester close to 54 Pg C more than without a sequestration program in the year 2105 (see table 7 in appendix). The regions that are the most effective at sequestering are Africa, South America and South East Asia.

The results for Canada show an increase above baseline in total acres in forests, with inaccessible stocks rising by 6.25 percent from the business as usual in 2105. The decrease in harvesting in initial years is offset by harvesting increases in accessible areas in later decades. The carbon sequestered aboveground, in soil, and in market products all contribute to increase the total Pg C stored by a yearly average of 3% above baseline. Notice that the total carbon sequestered above the baseline is, once again, smaller than Sohngen and Mendelsohn's results for the low damage scenario by the year 2105.

The Liberal Party Proposition

Under the Liberal Party's Proposition, the total production of timber declines initially by 13% as the price for logs increases by $9 compared to the baseline (figure 1). After five decades, the production bounces back by nearly 11%, to reach 19% on top of the baseline at the end of the century. By that time, the model predicts that global timber prices will have fallen by 11% relative to the business as usual results.

The timber inventory increases in all regions of the world during the whole simulation period, with Africa and South East Asia experiencing increases above baseline of 63% and 56% respectively in 2105 (see table 8 in appendix). The Chinese and European inaccessible forests also increase drastically by 700% and 320% at the end of the century under observation. In fact, very few inaccessible stocks are depleted in periods following the initial change. In 2015, Central America, South East Asia, and Africa reduce their total harvesting to increase it in later periods. Not surprisingly, the plantations of subtropical timber increase in nearly all regions for the whole century, with China and Africa leading the group.

By 2105, the Liberal's proposition is predicted to sequester about 70 Pg C above the baseline (see table 9 in appendix). The highest increases in sequestration occur in South East Asia, Africa and Central America. The proposition being very close to that of Mintz and Olewiler, the results do not differ much from the $42 tax scheme as they situate themselves in between the low-damage and the high-damage scenarios evaluated by Sohngen and Mendelsohn.

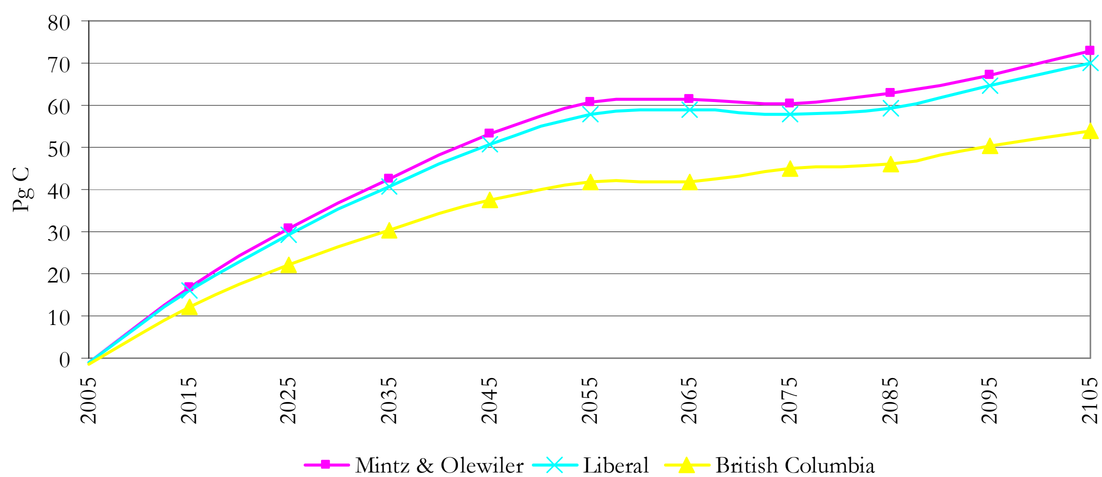
Under this tax scheme, the total area of Canadian forests is consistently superior to that under the baseline and inaccessible forests are 7.8% larger by 2105. Production initially falls by nearly 7% in the first decade to increase by 44% in 2050 above baseline. In later years, the harvesting falls once again short of the baseline levels. Under this scheme, Canada could sequester an additional 2.1 Pg C above baseline by the midcentury, with notable increases in carbon stored in living aboveground biomass.

DISCUSSION

In this section, I will compare the effectiveness of the three tax schemes and their impacts on the Canadian production of timber for the upcoming century.

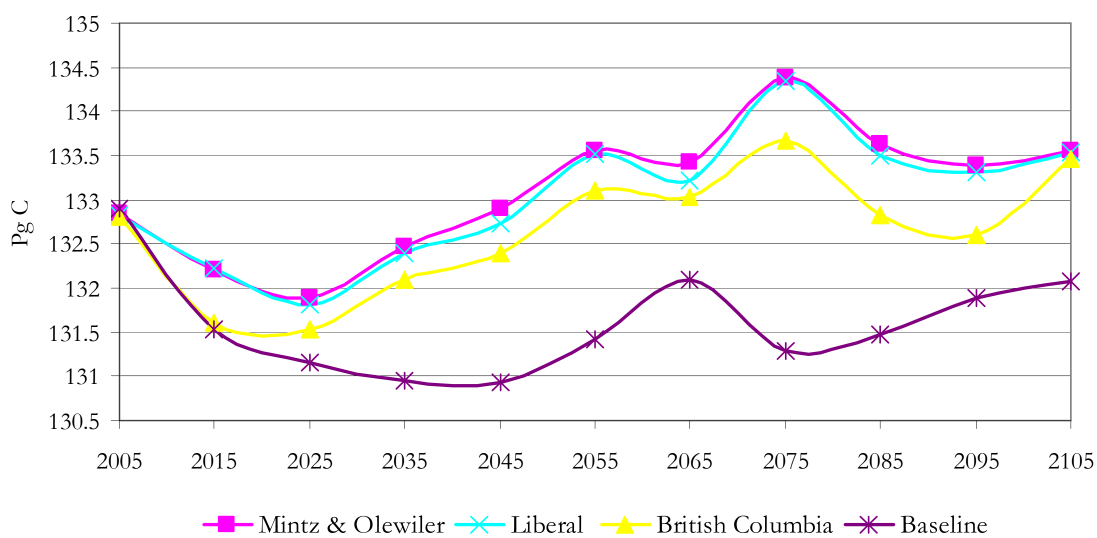
Looking at the global carbon sequestration above the baseline (figure 2), we can see that the Mintz and Olewiler proposition is the most effective, nearly reaching 73 Pg C stored worldwide above baseline at the end of the century. Since the Liberal Party's proposition is closely related to this scheme, it is therefore not surprising to see its sequestration path follow that of Mintz and Olewiler. The British Columbia carbon tax also follows the same path, ending with 54 Pg C sequestered above baseline in 2105.

Figure 2: Global Carbon Sequestration above baseline



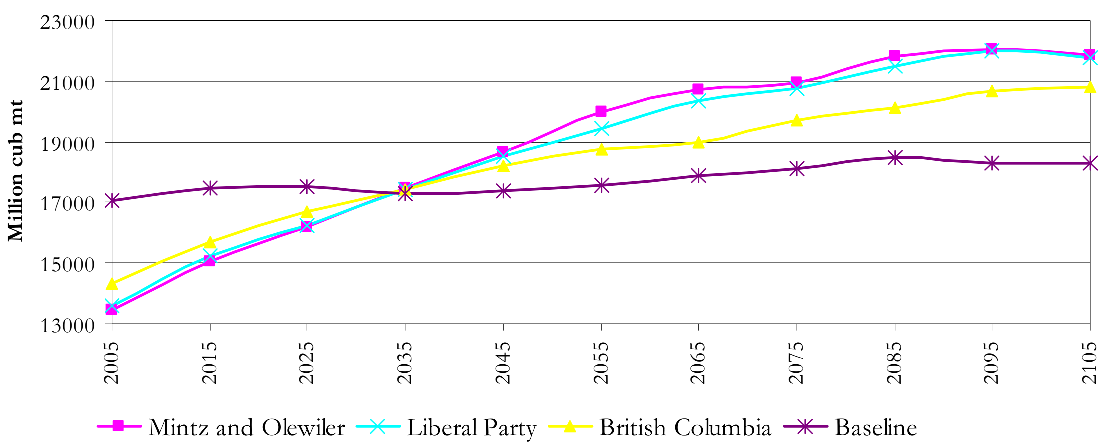
The Canadian sequestration paths offer a different conclusion (figure 3). Although the Mintz and Olewiler proposition and the Liberal tax paths follow each other closely and the B.C. tax is lower throughout the century, all three scenarios end up sequestering the same amount of carbon at the end of the period. Imposing a worldwide carbon tax would therefore allow Canada increase sequestration by more than 1% from the baseline. Notice that all three scenarios peak in the year 2075, where additional carbon sequestered reaches up to 3 Pg C in the Mintz and Olewiler proposition.

Figure 3: Canadian Carbon Sequestration Paths



It is evident that by imposing a carbon tax, the global production of timber would initially fall (figure 4). Indeed, the higher the tax rate, the larger the reduction in harvesting. As the years go by and firms accumulate credits for carbon stored, it can become economically efficient to start harvesting when the price for timber is high enough to cover the costs. By 2035, all tax scenarios have increased the production levels by more than the baseline prediction. Indeed, timber harvest increase smoothly throughout the century, with the higher carbon tax scheme producing the highest level of wood. Sohngen and Mendelsohn (2007) explain that "[al]though global wood harvests have been relatively constant for the past 20–30 years[…], it is possible that rising population and income in Asia, India, and other developing countries could substantially expand the demand for wood products.” The authors have also obtained robust increases in plantations in China, South America, and Oceania.

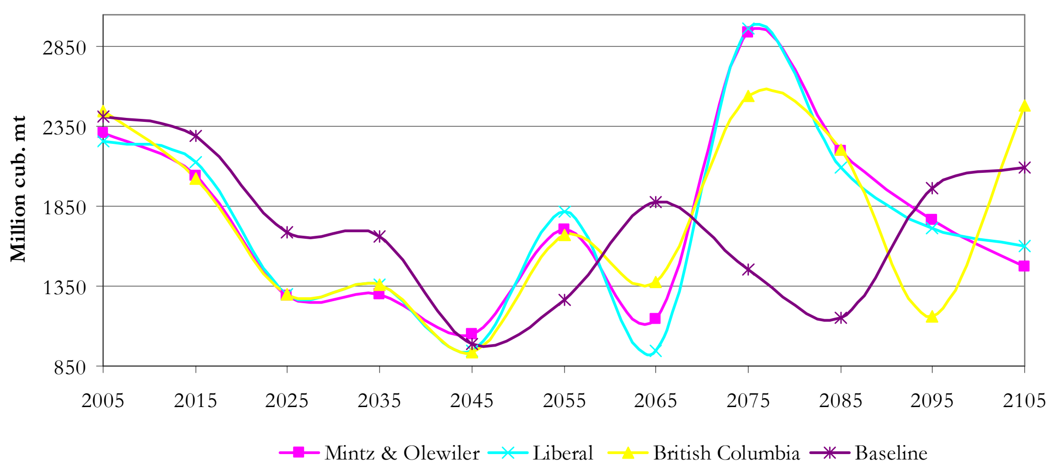
Figure 4: Global Timber Production



In Canada, the timber production increase is not as smooth as the global predictions (figure 5). The total harvesting decreases significantly in the first half of the century where the lowest levels of production occurring under the B.C carbon tax scheme. In 2045, production bounces back up for a decade, before plunging down again two decades later. Inaccessible stocks were left untouched until this date, and it has now become economically efficient to harvest them. The increase in harvesting of these stocks and of the accessible forests in the later part of the century reaches a new peak in 2075, the very year in which carbon sequestration is at its highest level. The highest tax scenarios push the levels of production down to about 1500 million tonnes by the end of the century, while the B.C.

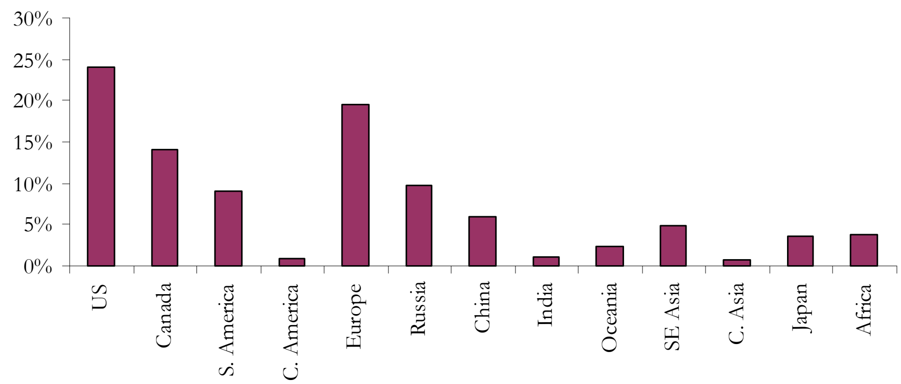
carbon tax allows for a significant increase to nearly 1000 million tonnes above the other scenarios.

Figure 5: Total Canadian Harvest



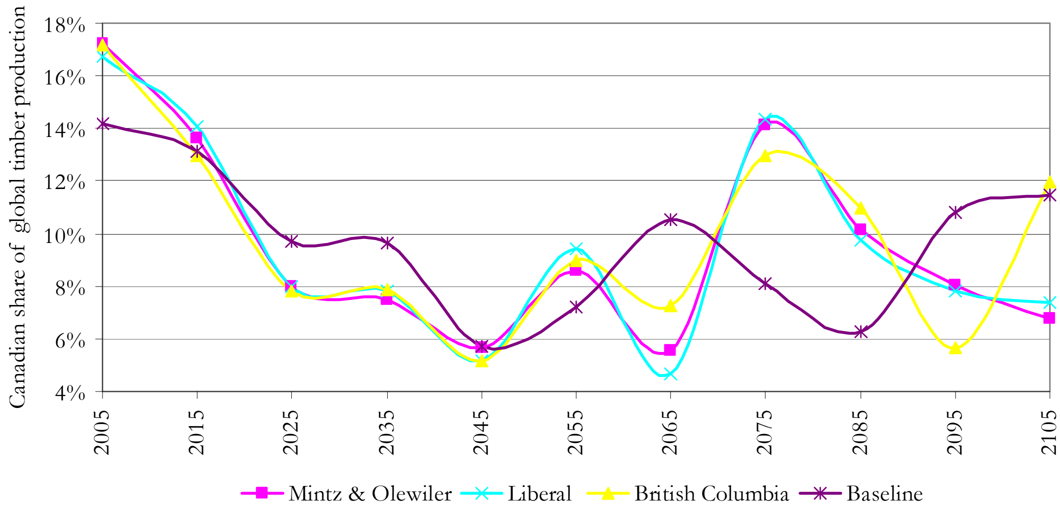
In 2005, Canada was the third largest producer of timber behind the U.S. and Europe, with a market share of 14% (figure 6). Forest industries in Europe and the United States have adopted new and improved methods for extracting timber from forests, which has potentially improved productivity in the forestry sector (Sedjo, 1999). The baseline simulation anticipates Asian countries to increase aggressively their wood production in the next century. Indeed, China, South East Asia and Oceania are expected to gain substantially in market share. The US, Canada, and Russia would therefore lose a considerable amount of their production, while South America and Europe remain stable. In recent years, there has been an important expansion of subtropical plantations in regions such as Chile, Argentina, Brazil, South Africa, Indonesia, Australia, and New Zealand. These expansions usually involve conversion of agricultural land or existing natural forests to intensive plantation management, raising the production levels (Sohngen and Mendelsohn, 2007).

Figure 6: 2005 Total Timber Harvests



The Canadian timber production market is expected to lose substantial market share under any of the three tax schemes presented here (figure 7). The fifth and eighth upcoming decades should help gain momentarily some shares back but the country is not expected to regain its initial levels. By 2105, the Mintz and Olewiler tax predicts a fall of 7% in global share, closely followed by the Liberal proposition. The $30 B.C. carbon scheme, on the other hand, forecasts a less negative conclusion, in which Canada would own the same share in 2105 as without a tax.

Figure 7: Canadian Timber Market Share



A sequestration program can help preserving the inaccessible forests from being harvested, no matter the carbon tax rate employed. For countries with these stocks, it may be a relatively inexpensive option to reduce CO_2 emissions as inaccessible forests tend to have high carbon content. As Sohngen and Mendelsohn (2007) explain, "[…] carbon sequestration in forests is a low-cost way to slow greenhouse gas concentrations from rising over time." The authors also warn that tax schemes that are too aggressive too soon will be unnecessarily expensive, thereby making the Mintz and Olewiler proposition less attractive.

CONCLUSION

This essay reviews the impact of Canadian-induced global carbon sequestration programs on timber markets, carbon stored and forestland. The model relies on paying forest owners a price for each unit of carbon stored in their stocks.

All sequestration programs under study proved beneficial to the conservation of inaccessible forests. Higher tax rates would lead to higher levels of timber production, lower market prices, and more carbon sequestered in a century time. In Canada, all taxes evaluated lead to the same levels of carbon sequestered by 2105, though the market share differs substantially during this period. The British Columbia tax scheme offers the most consistency in market share above baseline, while the Liberal Party proposition has the largest amplitude. All tax scenarios have a mean market share lower than the baseline prediction.

An important conclusion is that forest carbon sequestration should be included in an efficient program to control global greenhouse gases, yet creating an efficient sequestration program is admittedly a big challenge. The analysis suggests that it is critical to design dynamic policies that increase the incentives to sequester over time in concert with the benefit of sequestration, or price of carbon. Programs that are too aggressive too soon, like the Mintz and Olewiler proposition, will be unnecessarily expensive. Also, targeting only a specific region will have problems with leakage. For efficiency purposes, a sequestration program should equate the marginal cost of sequestration across all regions of the world.

The model does not examine the impact of sequestration programs on habitat, water resources, or forest recreation, and does not incorporate endogenous changes agricultural demands. It would be interesting to include these non-timber impacts in future research. Another venue that could be explored would be to analyze the impact of a sequestration program in a sole region, and evaluate the amplitude of leakage that would occur.

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Table 2 Baseline scenario PC=0 : Forest areas

	Total Forest Area (million ha)			Inaccessible Hectares (millions)			Harvest Accessible (million cubic meters)			Total Harvest (million cubic meters)			Subtropical Plantations (million ha)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	204.5	204.0	203.0	53.4	37.7	35.5	4369.8	2993.9	2657.8	4714.5	3198.6	2805.3	13.3	14.1	14.8
Canada	419.8	420.9	425.0	287.7	261.3	261.3	2086.6	1264.2	1914.4	2288.8	1264.2	2094.6	0.0	0.0	0.0
S. America	833.8	732.3	698.7	0.0	0.0	0.0	1745.2	2028.0	2279.5	1745.2	2028.0	2279.5	15.6	24.1	26.6
C. America	49.5	38.0	36.5	0.0	0.0	0.0	175.4	134.4	161.6	175.4	134.4	161.6	2.9	3.9	3.9
Europe	188.1	192.3	199.4	2.6	0.7	0.2	3048.2	3339.5	3532.1	3207.1	3438.3	3588.2	4.4	7.6	8.3
Russia	840.0	839.4	855.7	693.7	649.4	647.4	704.0	1114.7	779.7	1097.9	1162.2	1451.5	0.0	0.0	0.0
China	159.2	166.4	172.1	18.5	3.1	2.2	860.5	2300.8	1224.1	1049.1	2318.8	1287.9	13.3	20.1	21.1
India	48.3	44.9	48.0	0.0	0.0	0.0	224.8	475.0	442.8	224.8	475.0	442.8	4.6	5.5	5.7
Oceania	195.9	180.1	161.4	0.0	0.0	0.0	614.0	1324.9	2022.7	614.0	1324.9	2022.7	7.3	11.3	12.9
SE Asia	184.3	128.3	108.5	0.0	0.0	0.0	861.3	660.1	689.6	861.3	660.1	689.6	12.3	14.8	15.2
C. Asia	38.3	39.5	39.8	0.0	0.0	0.0	131.0	190.1	202.8	131.0	190.1	202.8	2.5	3.7	3.7
Japan	23.3	23.7	23.9	0.0	0.0	0.0	648.2	794.1	753.3	648.2	794.1	753.3	10.4	10.6	10.7
Africa	305.3	196.0	173.8	0.0	0.0	0.0	647.4	515.9	445.6	647.4	515.9	445.6	5.3	8.0	8.5
Total	**3490.2**	**3205.7**	**3145.8**	**1055.9**	**952.2**	**946.6**	**16116.3**	**17135.4**	**17105.9**	**17404.7**	**17504.5**	**18225.5**	**92.0**	**123.6**	**131.3**

Table 3 Baseline scenario PC=0: carbon storage in forests

	Aboveground carbon (PgC stored)			Market carbon (PgC stored)			Soil Carbon (PgC stored)			Total Carbon (PgC stored)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	11.32	10.87	10.44	1.06	0.75	0.65	38.01	38.05	38.19	50.39	49.67	49.28
Canada	11.62	11.59	11.83	0.47	0.26	0.44	119.44	119.56	119.81	131.53	131.41	132.08
S. America	99.78	87.83	82.60	0.51	0.53	0.57	106.24	105.95	106.14	206.53	194.31	189.31
C. America	4.13	2.07	2.27	0.05	0.03	0.04	7.06	7.06	7.34	11.24	9.17	9.66
Europe	6.29	6.36	5.84	0.69	0.77	0.78	21.91	21.96	22.11	28.89	29.09	28.72
Russia	33.03	29.80	30.11	0.26	0.28	0.34	219.68	219.72	219.94	252.97	249.80	250.39
China	7.92	8.07	6.53	0.24	0.52	0.30	19.93	20.01	20.16	28.09	28.60	26.99
India	3.35	2.65	1.94	0.06	0.13	0.11	6.58	6.59	6.67	9.98	9.37	8.72
Oceania	5.38	5.59	5.14	0.14	0.30	0.45	19.97	19.95	19.96	25.49	25.84	25.55
SE Asia	24.07	12.09	7.84	0.26	0.18	0.19	27.10	26.96	27.08	51.43	39.23	35.12
C. Asia	1.37	1.26	1.24	0.03	0.04	0.05	4.94	4.94	5.00	6.34	6.25	6.28
Japan	0.91	1.05	1.18	0.15	0.19	0.17	3.08	3.09	3.15	4.14	4.32	4.50
Africa	30.53	18.09	14.83	0.20	0.14	0.11	45.23	44.90	45.20	75.96	63.14	60.14
Total	**239.71**	**197.33**	**181.78**	**4.12**	**4.14**	**4.19**	**639.16**	**638.75**	**640.76**	**882.99**	**840.22**	**826.73**

Table 4 Projected Effect of Mintz and Olewiler Scenario PC=42 relative to Baseline: Forest Areas

	Total Forest Area (million ha)			Inaccessible Hectares (millions)			Harvest Accessible (million cubic meters)			Total Harvest (million cubic meters)			Subtropical Plantations (million ha)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	16.81	17.0	17.9	-0.2	6.1	8.3	-924.2	-378.5	2042.9	-941.3	-503.6	2036.0	1.4	0.9	0.5
Canada	12.43	11.5	8.1	1.1	21.6	21.6	-219.9	439.8	-499.6	-251.9	439.8	-624.9	0.0	0.0	0.0
S. America	25.36	74.8	84.0	0.0	0.0	0.0	-368.8	-198.2	-61.1	-368.8	-198.2	-61.1	1.4	1.4	1.0
C. America	6	7.2	8.4	0.0	0.0	0.0	-62.9	-61.8	7.0	-62.9	-61.8	7.0	0.8	0.0	0.0
Europe	17.31	17.3	13.1	-0.2	0.2	0.7	233.7	492.7	1718.4	241.9	393.9	1672.6	0.5	0.5	0.0
Russia	11.99	12.4	-3.7	30.6	74.9	77.0	174.2	-153.5	-230.6	-219.7	-201.1	-902.5	0.0	0.0	0.0
China	16.42	18.7	15.6	5.5	16.3	17.2	-2.7	549.5	1152.0	-104.8	531.5	1203.5	3.1	6.1	8.1
India	8.07	8.7	5.9	0.0	0.0	0.0	-20.8	-58.6	27.1	-20.8	-58.6	27.1	0.2	0.5	0.3
Oceania	1.45	6.5	15.6	0.0	0.0	0.0	23.3	-76.5	-111.3	23.3	-76.5	-111.3	0.5	0.3	-0.4
SE Asia	17.69	47.6	64.0	0.0	0.0	0.0	-438.9	2273.2	245.6	-438.9	2273.2	245.6	0.7	1.0	1.6
C. Asia	3.04	3.5	2.9	0.0	0.0	0.0	-16.3	-21.5	-17.4	-16.3	-21.5	-17.4	0.6	0.8	0.8
Japan	2.61	2.6	2.8	0.0	0.0	0.0	-3.0	-50.2	47.8	-3.0	-50.2	47.8	0.1	0.1	0.2
Africa	37.69	99.9	115.7	0.0	0.0	0.0	-265.4	-93.1	19.8	-265.4	-93.1	19.8	1.0	1.4	1.8
Total	**176.87**	**327.7**	**350.4**	**36.8**	**119.1**	**124.7**	**-1891.6**	**2663.3**	**4340.4**	**-2428.5**	**2373.9**	**3542.2**	**10.3**	**13.1**	**13.7**

Table 5 Projected Effect of Mintz and Olewiler Scenario PC=42 relative to Baseline: carbon storage in forests

	Aboveground carbon (PgC stored)			Market carbon (PgC stored)			Soil Carbon (PgC stored)			Total Carbon (PgC stored)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	0.01	1.11	1.80	-0.21	-0.13	0.45	0.00	0.22	0.37	-0.19	1.20	2.62
Canada	0.73	1.88	1.34	-0.05	0.09	-0.12	0.00	0.18	0.25	0.68	2.15	1.47
S. America	2.86	9.70	12.70	-0.13	-0.07	-0.03	0.08	0.27	0.19	2.80	9.90	12.87
C. America	1.02	2.46	2.51	-0.02	-0.02	0.00	0.03	0.01	-0.24	1.03	2.46	2.27
Europe	0.30	1.13	2.46	0.06	0.07	0.41	0.00	0.12	0.21	0.35	1.33	3.08
Russia	3.01	6.66	6.42	-0.05	-0.05	-0.22	0.00	0.14	0.13	2.97	6.75	6.33
China	1.20	4.08	5.06	-0.02	0.12	0.27	0.00	0.16	0.32	1.18	4.35	5.65
India	0.30	1.35	1.45	-0.01	-0.02	0.00	0.01	0.06	0.11	0.30	1.39	1.57
Oceania	0.04	0.21	0.55	0.00	-0.02	-0.02	0.00	0.02	0.05	0.04	0.21	0.58
SE Asia	3.74	17.32	20.45	-0.15	0.79	0.08	0.04	0.07	0.19	3.63	18.17	20.72
C. Asia	0.08	0.45	0.71	0.00	-0.01	0.00	0.00	0.03	0.03	0.08	0.47	0.74
Japan	0.01	-0.03	0.10	0.00	-0.01	0.01	0.00	0.02	0.07	0.01	-0.02	0.18
Africa	3.82	11.97	14.78	-0.09	-0.04	0.00	0.09	0.30	0.02	3.82	12.23	14.80
Total	**17.13**	**58.29**	**70.34**	**-0.68**	**0.71**	**0.85**	**0.25**	**1.59**	**1.70**	**16.70**	**60.59**	**72.89**

Table 6 Projected effect of British Columbia scenario PC=30 relative to baseline: Forest areas

	Total Forest Area (million ha)			Inaccessible Hectares (millions)			Harvest Accessible (million cubic meters)			Total Harvest (million cubic meters)			Subtropical Plantations (million ha)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	12.15	13.68	15.79	-0.3	4.2	5.8	-878.3	-497.8	1465.9	-888.6	-601.7	1467.0	1.1	0.6	1.3
Canada	9	7.7	3.8	-2.3	16.3	16.3	-176.1	407.4	462.1	-266.7	407.4	383.2	0.0	0.0	0.0
S. America	18.14	53.7	54.5	0.0	0.0	0.0	-274.2	-145.0	-45.1	-274.2	-145.0	-45.1	1.0	1.4	1.1
C. America	4.33	4.6	5.2	0.0	0.0	0.0	-56.2	-55.0	6.8	-56.2	-55.0	6.8	0.7	0.0	0.0
Europe	13.13	12.1	9.5	-0.2	0.2	0.5	21.8	369.2	803.9	28.0	292.2	763.7	0.4	0.5	0.0
Russia	8.77	8.9	-4.0	28.5	62.9	65.0	93.0	-198.0	-272.5	-177.8	-245.5	-843.7	0.0	0.0	0.0
China	12	9.6	12.1	3.8	10.7	11.2	274.0	105.3	1036.1	201.8	98.6	1193.8	2.3	4.7	8.1
India	5.72	6.1	6.0	0.0	0.0	0.0	-21.4	-29.3	-20.1	-21.4	-29.3	-20.1	0.2	0.5	0.3
Oceania	1.03	4.8	10.3	0.0	0.0	0.0	14.4	-25.2	-131.3	14.4	-25.2	-131.3	0.4	0.4	-0.2
SE Asia	12.97	35.6	47.1	0.0	0.0	0.0	-113.0	1525.8	-270.5	-113.0	1525.8	-270.5	0.5	0.9	1.1
C. Asia	2.15	2.6	1.1	0.0	0.0	0.0	-12.4	-12.7	-13.4	-12.4	-12.7	-13.4	0.4	0.7	0.7
Japan	1.84	2.1	3.1	0.0	0.0	0.0	-8.0	-39.8	3.4	-8.0	-39.8	3.4	0.1	0.1	0.1
Africa	27.63	74.1	82.7	0.0	0.0	0.0	-206.5	-29.1	17.4	-206.5	-29.1	17.4	0.7	1.2	1.5
Total	**128.86**	**235.6**	**247.2**	**29.5**	**94.3**	**98.8**	**-1343.1**	**1375.9**	**3043.0**	**-1780.7**	**1140.8**	**2511.4**	**7.7**	**10.9**	**13.8**

Table 7 Projected effect of British Columbia scenario PC=30 relative to baseline: carbon storage in forests

	Aboveground Carbon (PgC stored)			Market Carbon (PgC stored)			Soil Carbon (PgC stored)			Total Carbon (PgC stored)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	-0.13	0.74	1.66	-0.20	-0.15	0.30	0.00	0.16	0.30	-0.33	0.75	2.25
Canada	0.13	1.48	1.07	-0.05	0.09	0.10	0.00	0.13	0.22	0.08	1.69	1.38
S. America	2.03	7.11	8.92	-0.10	-0.05	-0.02	0.06	0.20	0.10	1.99	7.25	9.00
C. America	0.83	2.05	2.06	-0.02	-0.01	0.00	0.02	0.00	-0.24	0.83	2.03	1.82
Europe	0.08	0.93	0.49	0.01	0.05	0.23	0.00	0.10	0.19	0.09	1.08	0.91
Russia	2.60	5.48	5.39	-0.04	-0.06	-0.20	0.00	0.10	0.11	2.56	5.52	5.30
China	0.98	1.90	4.79	0.04	0.02	0.27	0.00	0.12	0.32	1.03	2.04	5.38
India	0.24	0.92	0.88	-0.01	-0.01	0.00	0.01	0.05	0.09	0.24	0.95	0.97
Oceania	0.02	0.15	0.35	0.00	-0.01	-0.03	0.00	0.02	0.04	0.03	0.16	0.36
SE Asia	2.91	10.15	15.43	-0.04	0.53	-0.10	0.03	0.02	0.15	2.90	10.71	15.48
C. Asia	0.05	0.31	0.45	0.00	0.00	0.00	0.00	0.02	0.02	0.05	0.33	0.46
Japan	0.00	-0.03	0.05	0.00	-0.01	0.00	0.00	0.02	0.05	0.00	-0.02	0.10
Africa	2.79	9.03	10.58	-0.07	-0.02	0.00	0.07	0.24	-0.06	2.78	9.24	10.53
Total	**12.54**	**40.21**	**52.11**	**-0.47**	**0.37**	**0.54**	**0.18**	**1.15**	**1.29**	**12.25**	**41.74**	**53.94**

Table 8 Projected effect of Liberal Party scenario PC=40 relative to baseline: Forest areas

	Total Forest Area (million ha)			Inaccessible Hectares (millions)			Harvest Accessible (million cubic meters)			Total Harvest (million cubic meters)			Subtropical Plantations (million ha)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	16.13	17.21	17.47	-0.2	5.5	7.7	-932.6	-389.1	1770.6	-953.6	-511.8	1769.1	1.3	0.8	0.9
Canada	12.03	10.8	8.5	1.0	20.5	20.5	-151.1	556.3	-385.8	-158.5	556.3	-491.7	0.0	0.0	0.0
S. America	24.16	71.4	78.5	0.0	0.0	0.0	-354.9	-168.8	-48.2	-354.9	-168.8	-48.2	1.4	1.5	0.9
C. America	5.71	6.7	7.9	0.0	0.0	0.0	-62.3	-60.0	6.9	-62.3	-60.0	6.9	0.8	0.0	0.0
Europe	16.8	17.3	9.9	-0.2	0.2	0.6	236.2	539.2	1766.9	241.9	445.3	1722.5	0.5	0.5	0.0
Russia	11.36	11.9	1.1	30.6	74.9	77.0	227.1	-154.0	-238.9	-166.8	-201.5	-910.7	0.0	0.0	0.0
China	15.63	17.7	15.8	5.2	15.1	15.9	-3.7	-357.6	1132.8	-103.8	-375.6	1217.4	3.0	5.9	8.1
India	7.69	8.6	5.7	0.0	0.0	0.0	-21.0	-27.9	30.3	-21.0	-27.9	30.3	0.2	0.4	0.2
Oceania	1.38	6.2	13.9	0.0	0.0	0.0	21.5	-38.7	-161.9	21.5	-38.7	-161.9	0.5	0.3	-0.4
SE Asia	16.94	45.9	60.3	0.0	0.0	0.0	-431.4	2276.0	228.8	-431.4	2276.0	228.8	0.7	1.0	1.2
C. Asia	2.89	3.3	2.6	0.0	0.0	0.0	-15.7	-18.0	-17.9	-15.7	-18.0	-17.9	0.6	0.8	0.8
Japan	2.43	2.6	2.1	0.0	0.0	0.0	-3.9	-36.2	77.9	-3.9	-36.2	77.9	0.1	0.1	0.1
Africa	36.01	95.6	110.1	0.0	0.0	0.0	-256.6	-15.7	20.5	-256.6	-15.7	20.5	0.9	1.4	1.8
Total	**169.16**	**315.2**	**333.7**	**36.5**	**116.3**	**121.9**	**-1748.3**	**2105.5**	**4182.0**	**-2264.9**	**1823.4**	**3442.9**	**9.9**	**12.8**	**13.5**

Table 9 Projected effect of Liberal Party scenario PC=40 relative to baseline: carbon storage in forests

	Aboveground carbon (PgC stored)			Market carbon (PgC stored)			Soil Carbon (PgC stored)			Total Carbon (PgC stored)		
	2015	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**	**2015**	**2055**	**2105**
US	-0.01	0.96	1.44	-0.21	-0.12	0.38	0.00	0.21	0.37	-0.22	1.05	2.19
Canada	0.72	1.81	1.31	-0.03	0.12	-0.10	0.00	0.17	0.25	0.69	2.10	1.46
S. America	2.72	9.27	12.03	-0.13	-0.06	-0.02	0.08	0.26	0.17	2.67	9.46	12.17
C. America	0.99	2.41	2.43	-0.02	-0.02	0.00	0.03	0.01	-0.24	0.99	2.40	2.19
Europe	0.25	1.14	2.42	0.06	0.08	0.42	0.00	0.12	0.21	0.32	1.34	3.05
Russia	2.91	6.67	6.43	-0.03	-0.05	-0.22	0.00	0.13	0.16	2.88	6.75	6.37
China	1.17	3.05	5.11	-0.02	-0.08	0.27	0.00	0.15	0.32	1.14	3.12	5.70
India	0.29	1.27	1.39	-0.01	-0.01	0.01	0.01	0.06	0.11	0.29	1.31	1.50
Oceania	0.03	0.20	0.47	0.00	-0.01	-0.04	0.00	0.02	0.04	0.04	0.21	0.48
SE Asia	3.61	16.96	19.77	-0.15	0.79	0.07	0.04	0.06	0.17	3.50	17.82	20.02
C. Asia	0.08	0.43	0.68	0.00	0.00	0.00	0.00	0.02	0.03	0.08	0.45	0.70
Japan	0.01	-0.02	0.10	0.00	-0.01	0.02	0.00	0.02	0.07	0.01	-0.01	0.19
Africa	3.65	11.52	14.02	-0.09	-0.02	0.00	0.09	0.29	0.01	3.64	11.79	14.03
Total	**16.42**	**55.66**	**67.61**	**-0.63**	**0.61**	**0.80**	**0.24**	**1.51**	**1.65**	**16.03**	**57.79**	**70.07**