C I N T R A F O R

Working Paper

104

The Potential Trade and Competitive Implications of Alternative Approaches for Harvested Wood Products

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December 2006

CINTRAFOR Working Paper 104

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Acknowledgements: We wish to acknowledge the valuable contributions of Reid Miner, Vice President, Sustainable Manufacturing, National Council for Air and Stream Improvement, Inc. for his review of an earlier draft and providing us with current IPCC recommended calculation guidelines and worksheets which we include in this work. We also appreciate the instructive review comments by Ken Skog, USDA Forest Service on terminology and economics. We also acknowledge the financial support from ICFPA. ICFPA is pleased to have supported this work as a contribution to our collective understanding of this issue. The research was also aided by the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture, and the State of Washington Department of Community, Trade, and Economic Development through their support of CINTRAFOR. However, all conclusions and opinions put forth within it are those of the author(s) and do not necessarily reflect those of the ICFPA or its member associations or other funding agencies.

Technical Editor: Clara Burnett

EXECUTIVE SUMMARY

Forests play three central roles in the carbon cycle. Forests act as sinks and sources of carbon. Second, harvested wood products (HWP) from forests store carbon over their life cycle. Third, wood products conserve fossil fuels through energy substitution and by their lower fossil-fuel usage during their manufacture. International governmental bodies have recognized these roles in their discussions. The current United Nations Framework Convention on Climate Change (UNFCCC) methodology used to prepare national greenhouse gas (GHG) inventories provides the suggested default assumption that all forest biomass harvested be recorded as an immediate source. Additionally, the convention also recognizes that the wood product sink can be included if it can be documented that existing stocks are increasing. Our study focuses on the second role -- HWP and their function in forest carbon accounting.

Past studies estimated carbon additions and emissions under alternate accounting approaches and analyzed their impacts using case studies. We calculated the emissions associated with three alternative approaches for 30 regions comprising the global forest sector and reported results for the globe and regions. We briefly investigated alternative methods to calculate the additions and emissions under alternate approaches by examining the sensitivity of alternative assumptions on landfill pools. We also investigated economic implications associated with the alternative approaches by imposing costs on the global forest products industry for national emissions of the forest carbon account.

Three approaches to calculate stock changes and estimated emissions associated with HWP proposed by IPCC are the stock change approach, the production approach and the atmospheric flow approach. The stock change approach estimates the net annual change in carbon stocks in the forest and wood products pool within national boundaries. Briefly stated, stock changes in the forest pool are accounted for in the producing country. Stock changes in HWP pool are accounted for in the consuming country. The production approach also estimates net annual changes in the forest and HWP carbon stocks. Producing nations account for forest stock changes and the changes in carbon from HWP that came from domestic harvests including exported wood products. The atmospheric flow approach estimates carbon flows between the atmosphere and the forest and HWP pools within the national boundary. Producing nations account for forest growth carbon and consuming countries count emissions from wood and wood products.

We examined the overall effect of the approaches on national emissions to compare the results to those obtained using the IPCC default. For sake of clarity, we divided the national account into the forest account and the HWP account. All that we were interested in the forest account was that portion of emissions calculated by measuring stock changes affected by the HWP accounting approaches.

Within each accounting approach there may be more than one estimation method that can be applied with different levels of complexity, depending on data availability. Two examples are alternative assumptions on the fraction of wood product leaving the in-use pool every year and degrading half lives. We examined the sensitivity of IPCC good practice guidelines default assumptions changing the default parameters associated with half-lives of discarded products. Other sensitivities are possible given the data base created but not pursued for this study.

We used an economic model of global forest sector to extend the calculations of carbon emissions under the different approaches to 2016. Economic equilibria to production, consumption, traded volumes and prices were calculated for coniferous and non-coniferous sawn wood and plywood. We maintained industrial roundwood material balances in the production of these products using estimated input/output coefficients such that equilibrium amounts produced, consumed and traded for saw logs were also calculated for the years 2004 to 2016. Projections of other panels and paper and paperboard products and their use of industrial roundwood were required as input by the economic model so as to maintain material balances at the roundwood level. Paper and paperboard projections were made using estimated income elasticities and gross domestic product (GDP) projections differentiated regionally.

Scenario assessment was employed to examine the trade and competitiveness implications associated with alternative approaches. We imposed a cost in the country in the form of an emission tax. The tax level was determined by using the calculated forest sector removals/emissions for the default and three alternative approaches.

The impact of the emission tax for each approach was then compared with the IPCC default approach. We chose to limit the analysis of economic impacts to the softwood lumber sector since other wood product sectors accounted for in the model do not use equilibrium methods to determine stock inflows in response to a cost increase. We investigated a carbon price of $10 and $35 per tonne of CO_2.

We summarize our conclusions as follows.

- Using available forestry data and IPCC accounting methods that consider carbon in HWP, it is demonstrated that HWP pools are increasing globally. By 2002, global carbon stocks in products in use had accumulated to approximately 4,508 Tg C, and were increasing at a rate of 1.2% per year. Global carbon stocks in landfills were estimated to be 3,447 Tg C and were increasing at 2.4% per year.
- Different accounting approaches (i.e. the current IPCC default, stock change, production, and atmospheric flow) led to different national accounts of emissions. Compared to alternative approaches, the IPCC default approach resulted in higher national emissions for all nations, with the possible exception of a few regions where much of the harvest is used for fuel wood. The stock change approach produced lower emissions for large net importers of HWP. The production and atmospheric flow approaches led to lower emissions for large net exporters of HWP.
- If the forest products industry became financially responsible for HWP carbon emissions, the selection of an accounting approach could significantly affect the industry. In particular, the current IPCC default approach could result in lower global industry output and higher lumber prices than the three alternatives (i.e. stock change, production, and atmospheric flow). The differences between the three alternative approaches, do not appear to be significant at the global level (differences in wood costs of $0.25 per m^3 or less). In some countries, however, the differences between the three alternatives can be more than $10 per m^3 of wood.
- The stock change approach can give rise to the elimination of accounted HWP emissions when import levels lead to increasing HWP pools that are greater than domestic harvest emissions.
- Calculating the land-filled pool using alternative values of half-lives led to relatively small changes in emission accounts. These changes were relatively constant across accounting approaches.
- The economic impact of emission changes depended on the level of these charges
- High carbon prices led to persistent change in coniferous sawlog harvest levels and higher prices in softwood lumber markets. We expect similar responses in other forest product markets including pulp and paper. Their raw material costs would increase since the emission tax increases harvesting costs, and lower output by the softwood lumber sector reduces residual supply to pulp mills.
- Low carbon prices led to higher price in these markets as consumption levels recovered.
- Higher prices under both low and high carbon values could signal product substitution.

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INTRODUCTION

Forests play three central roles in the carbon cycle. Forests act as sinks and sources of carbon (Cooper 1983). Second, harvested wood products (HWP) from forests store carbon over their life cycle (Skog and Nicholson 1998, Borjesson and Gustafson 2000, Glover et al. 2002). Third, wood products conserve fossil fuels through energy substitution and by their lower fossil-fuel usage during their manufacture (Schlamadinger and Marland 1996, Lippke et al. 2004). International governmental bodies have recognized these roles in their discussions. The current United Nations Framework Convention on Climate Change (UNFCCC) methodology used to prepare national greenhouse gas (GHG) inventories provides the suggested default assumption that all forest biomass harvested be recorded as an immediate source (IPCC 1997). Additionally, the convention also recognizes that the wood product sink can be included if it can be documented that existing stocks are increasing (IPCC 2003). Our study focuses on the second role -- HWP and their function in forest carbon accounting.

Once it has been documented that HWP pools are increasing, a country can elect one of three approaches to account for additions to and emissions from harvested wood products. The approaches differ in the way emissions from traded wood and wood products are allocated to consuming and producing countries. These differences may have important trade and competitiveness implications as global trade in forest products continues to grow (Nabuurs and Sikkema 2001).

The approaches carry with them terminology specific to GHG inventory accounting. The annual carbon change estimated under each particular accounting approach is the contribution of HWP to total annual CO2 emissions/removals. In our discussions below we use the term emission estimates as an explanatory device since emissions associated with the stock change and production approaches are based on estimates of carbon pool changes and not emissions in their true sense. The measured change in stocks was considered an emission estimate and is reported in CO2 units.

Past studies estimated carbon additions and emissions under alternate accounting approaches and analyzed their impacts using case studies (Winjum et al. 1997, Nabuurs and Sikkema 2001, Dias et al. 2005). We calculated the emissions associated with three alternative approaches for 30 regions comprising the global forest sector and reported results for the globe and regions. We briefly investigated alternative methods to calculate the additions and emissions under alternate approaches by examining the sensitivity of alternative assumptions on landfill pools. We also investigated economic implications associated with the alternative approaches by imposing costs on the global forest products industry for national emissions of the forest carbon account.

Our next section describes the alternative approaches and their relation to the IPCC default approach. It is followed by the description of the projections of national stock and emission estimates to 2016 and economic impact measures.

THE THREE ALTERNATIVE APPROACHES

Three approaches to calculate stock changes and estimated emissions associated with HWP proposed by IPCC are the stock change approach, the production approach and the atmospheric flow approach. The stock change approach estimates the net annual change in carbon stocks in the forest and wood products pool within national boundaries. Briefly stated, stock changes in the forest pool are accounted for in the producing country. Stock changes in HWP pool are accounted for in the consuming country. The production approach also estimates net annual changes in the forest and HWP carbon stocks. Producing nations account for forest stock changes and the changes in carbon from HWP that came from domestic harvests including exported wood products. The atmospheric flow approach estimates carbon flows between the atmosphere and the forest and HWP pools within the national boundary. Producing nations account for forest growth carbon and consuming countries count emissions from wood and wood products.

THE STOCK CHANGE APPROACH

To simplify our explanation of the approaches, let us first consider an existing HWP stock. What we wish to measure is how this stock changes: What are the additions to and emissions from this stock each year. Calculations for the stock change approach require that the year-to-year changes in national carbon stocks in HWP pools produced by domestic consumption be estimated.

We considered two components of the HWP stock: a product in-use pool and a landfill pool. We first addressed the product in-use component. We began by considering inflows to an existing stock. Initially the amounts of different types of final products consumed in a country in the year were determined. This was done by taking the categories of products listed in Table 1 that are tracked by FAO and calculating consumption as production plus imports minus exports. Estimation of the product in-use component of the HWP stock under the stock change approach in existence in year t begins as:

$$\textit{Stock Change inflows to in-use stock}_t = (\textit{production} + \textit{imports} - \textit{exports})_t$$

Then, the consumption values were converted to Mg product and then Mg carbon. The conversion to Mg was held constant across regions but allowed to vary across products (Table 1). The conversion to Mg carbon was held constant using the default value of 0.5 for products and regions. Imports and exports of recovered paper were treated in the same manner as imports and exports of market pulp, assuming that the pulp yield from recovered paper was 80%. There were other minor data manipulations required in some of the FAO data to get complete data series for each of the products since some product categories were combined or disaggregated over the 32 year period for which data exists.

Table 1: FAO products, conversion factors and fractions assumed under the IPCC default (IPCC 2003).

Product	m3 to Mg	"r" values[1]	Half-life (years)
Sawn wood Coniferous (C)	0.45	0.0198	35
Sawn wood NonConiferous (NC)	0.56	0.0198	35
Veneer sheets	0.59	0.0231	30
Plywood	0.48	0.0231	30
Particle board	0.26	0.0347	20
Fiberboard, compressed	1.02	0.0347	20
Insulating board	0.5	0.0347	20
Hardboard	1.02	0.0347	20
MDF	0.5	0.0347	20
Paper and paperboard	0.9	0.3466	2

[1] Fraction of wood product leaving the in-use pool every year

Carbon was accumulated in the product in-use pool by adding this year's inflow to last year's pool and correcting for the fraction of wood leaving the in-use pool each year. The fraction “r“ in Table 1 was based on half lives for products in use provided by IPCC (IPCC 2006).

$$\textit{Product in-use stock}_t = (\textit{Product in-use stock}_{t-1} + \textit{Stock Change inflow to in-use stock}_t) * (1/(1+r))$$

Data required to calculate stock inflows started in 1961. For years between 1900 and 1960, the product in-use pools were calculated from backcasting algorithms provided by IPCC (IPCC 2003). Pre 1961 growth assumptions varied for each region (Table 2).

Table 2: Growth assumptions by regions to calculate pre 1961 carbon stocks (IPCC 2003)

	"k" values [1]
World	0.0148
Europe	0.0151
USSR	0.0160
North America.	0.0143
Latin America	0.0220
Africa	0.0287
Asia	0.0217
Oceania	0.0231

[1]from LULUCF Guidance

We next turned to the calculation of the carbon stock in landfill for each year. This required utilizing the amount removed from use every year and calculating how much of this was landfilled. The amounts discarded were calculated directly from the product in-use information – i.e. discards equal new production plus last year’s stocks in use minus this year’s stocks in use.

$$\textit{Discards}_t = \textit{Stock Change inflow to in-use stock}_t + \textit{Product in-use stock}_{t-1} - \textit{Product in-use stock}_t$$

The fraction of discards that were landfilled is set by the user. IPCC defaults for fraction of solid waste landfilled (m) in various parts of the world were used (Table 3) (IPCC 2006).

$$\textit{Discards to landfill}_t = \textit{Discards}_t * m$$

Table 3: IPCC 2006 revised guidelines, Table 1.1 Chapter 5 (IPCC 2006)

Region	“m” values [1]
Eastern Asia	0.55
South-Central Asia	0.74
South-eastern Asia	0.59
Northern Africa	0.76
Southern Africa	0.57
Western Africa	0.40
Eastern Europe	0.89
Northern Europe	0.62
Southern Europe/Caribbean	0.83
Western Europe	0.44
Central America	0.50
South America	0.54
North America	0.60
Oceania (whole region)	0.85

[1]Fraction of MSW disposed in solid waste disposal sites

A fraction of the carbon in the landfilled material was assumed to be non-degradable and to be permanently stored. This fraction is based on IPCC defaults and was set at 0.5 for paper and wood products (IPCC 2006).

$$\textit{Discards permanently sequestered}_t = \textit{Discards to landfill}_t * q$$

and

$$\textit{Accumulated discards from permanently sequestered}_t = \textit{Accumulated stock from permanently sequestered}_{t-1} + \textit{Discards permanently sequestered}_t$$

The annual loss of the degradable fraction of the carbon from the landfill was calculated as a percent of the degradable carbon in the landfill in a given year. This fraction degraded per year was also taken from an IPCC default half-life values (i) for dry boreal and temperate climates of 0.055 (12.6 years half life) and 0.0275 (25.2 years half life) for paper and wood products respectively (IPCC 2006).

$$\textit{Discards temporarily sequestered}_t = \textit{Discards to landfill}_t - \textit{Discards permanently sequestered}_t$$

and

$$\textit{Accumulated Discards from temporarily sequestered}_t = (\textit{Accumulated Stock from temporarily sequestered}_{t-1} + \textit{Discards temporarily sequestered}_t) * (1/(1+i))$$

From this information, the annual stocks and stock changes in the landfill were calculated.

$$\textit{Stock in landfill}_t = \textit{Accumulated discards from permanently sequestered}_{t-1} + \textit{Accumulated discards from temporarily sequestered}_t$$

We now have measures of the stocks in use and the stocks in landfills for each year. The two stocks are summed and the differences in the summed carbon stock from year-to-year equal the stock changes.

$$\textit{Stock Change Approach Stock}_t = \textit{Product in-use stock}_t + \textit{Stock in landfill}_t$$

$$\textit{Estimated Emissions}_t = \textit{Stock Change Approach Stock}_t - \textit{Stock Change Approach Stock}_{t-1}$$

A negative stock change is considered an emission of equivalent CO_2. A positive stock change represents a reduction in reported emissions of CO_2 from the atmosphere under the IPCC reporting guidelines.

THE PRODUCTION APPROACH

The production approach employs data on the way domestically grown timber and wood product are processed, used and consumed in the countries where they are utilized. This is the same as stock change accounting approach except that the calculations are not based on consumption but on production attributable to the reporting country. Also, and very importantly, the production is based on the origin of the wood. This means that a country's production of sawnwood, for instance, must be corrected to remove that fraction that was produced from imported logs. Likewise, paper and paper production must be corrected for imported wood and pulp. These adjustments require assumptions about how imported sawlogs and pulpwood are used.

Several calculations were necessary in order to determine the inflow to the production in-use pool. The calculations included determining the fraction of domestic used wood that is of domestic origin, the production from domestically produced wood used domestically, and the production from exported wood products. We allocated exports of logs and chips to final products using the fraction 0.5 for wood products or 0.25 for pulp production and the relative quantities of each wood product produced from exported sawlogs and veneers. The default values were based on the relative quantities of different forest products produced globally (Table 4). Exports were assumed to be used and disposed in the same manner as those used and disposed domestically.

$$\textit{Fraction of domestically used wood of domestic origin} = (\textit{domestic production of roundwood} - \textit{exports}) / (\textit{domestic} - \textit{production} + \textit{imports} - \textit{exports})$$

Production from domestically produced wood used domestically

= fraction of domestically used wood of domestic origin

** production volume*

Production from exported sawlogs and veneer logs

= fraction of domestically used wood of domestic origin

** fraction of log that ends up in final product*

** fraction of product produced globally in 2003*

Once the data are changed to be on a production basis instead of a consumption basis, the calculations to measure carbon pools and their changes are the same as those for the stock change approach. All of the calculations yield estimates of stocks of carbon in products in use and in landfills that are attributed to domestic production. The stock changes under the production approach were determined as the differences from one year to the next. Emissions are equal to negative stock changes and positive stock changes represent a reduction in reported CO2 emissions.

Table 4: Default fraction of wood products produced globally in 2003 (FAO 2005)

Relative quantities of each wood product	Default
Sawn wood C	0.49
Sawn wood NC	0.17
veneer sheets	0.02
plywood	0.11
particle board	0.15
Insulting board	0.01
hardboard	0.01
MDF	0.05

THE ATMOSPHERE FLOW APPROACH

It can be shown that atmospheric flow emissions are easily calculated from emissions calculated by the stock change approach. The equation is as follows.

atmospheric flow emissions = stock change emissions + all carbon in imports – all carbon in exports

Or alternatively since stock change emissions are negative stock changes:

atmospheric flow emissions = all carbon in imports – all carbon in exports – stock change from previous year

Since the stock changes were already calculated, all that was needed was a calculation of the carbon in all imports and exports. This includes wood fuel, recovered paper and all other imports and exports.

RELATING THE DIFFERENT APPROACHES TO IPCC DEFAULT

We examined the overall effect of the approaches on national emissions to compare the results to those obtained using the IPCC default. For sake of clarity, we divided the national account into the forest account and the HWP account. All that we were interested in the forest account was that portion of emissions calculated by measuring stock changes affected by the HWP accounting approaches.

In the IPCC default, all of the carbon removed from the forest during harvest results in a reduction in the forest carbon stocks, showing up in the calculations as an emission from the forest account. There are no emissions from the HWP pool under this approach since HWP stocks are considered to be constant. In the stock change approach, the carbon associated with the harvest is considered an emission from the forest account. In countries where the HWP stocks are growing, there are negative emissions from the HWP pool -- a reduction in emissions reported from the forest account. The production approach is similar to the stock change approach with respects to its relationship with the default approach.

The atmospheric flow approach tracks transfers of carbon to and from the atmosphere instead of changes in stocks of carbon. The removal of carbon from the forest during harvesting is not considered an emission since there is no transfer of carbon to the atmosphere. The removals/emissions are assigned to the HWP account and are equal to the carbon in domestically harvested wood plus the carbon in imports minus the carbon in exports plus the change in the stocks of carbon in the domestic product pool.

CALCULATING METHODS

Within each accounting approach there may be more than one estimation method that can be applied with different levels of complexity, depending on data availability. Two examples are alternative assumptions on the fraction of wood product leaving the in-use pool every year and degrading half lives. We examined the sensitivity of IPCC good practice guidelines default assumptions changing the default parameters associated with half-lives of discarded products. Other sensitivities are possible given the data base created but not pursued for this study.

IPCC default parameter values were used throughout the analysis but national governments are free to use other parameter values. As a result, the estimates herein will not necessarily match those developed by national governments. For purposes of comparing the different approaches, however, it was necessary to use a consistent approach across all regions, so the IPCC default parameter values were used.

PROJECTING EMISSIONS TO 2016

We used an economic model of global forest sector to extend the calculations of carbon emissions under the different approaches to 2016. The CGTM is primarily a structural wood products model and is incomplete in its coverage of all forest products used to calculate emissions related to HWP pools. As such, supplementary calculations, in addition to the equilibria that the model produced, were made in order to cover the product listings under consideration in Table 1. The calculations are explained below.

Economic equilibria to production, consumption, traded volumes and prices were calculated for coniferous and non-coniferous sawn wood and plywood. We maintained industrial roundwood material balances in the production of these products using estimated input/output coefficients such that equilibrium amounts produced, consumed and traded for saw logs were also calculated for the years 2004 to 2016.

Projections of other panels and paper and paperboard products and their use of industrial roundwood were required as input by the economic model so as to maintain material balances at the roundwood level. Unlike sawn wood and plywood however, production and consumption of these other wood and paper products were not allocated across markets using market equilibrium methods. Instead, projections for their use and production were calculated using alternative approaches described below.

Paper and paperboard projections were made using estimated income elasticities and gross domestic product (GDP) projections differentiated regionally. Alternative assumptions on GDP and elasticities were assessed using sensitivity analysis. We first projected global consumption using regional income elasticity estimates. Then, regional production of paper and paperboard was determined using market share data on capacity and capacity utilization. Net trade projections, the difference between production and consumption, were assumed to follow historical trends. These calculations led to regional estimates of production, consumption and net trade for paper and paper board.

The above calculations were adequate for the stock change approach but not for other approaches when import and export volumes are required. The production approach required projections of exports. The atmospheric approach required projections of exports and imports for recovered paper, fuel wood and others. We analyzed the historical trends and the projections were either held constant, increased or decreased accordingly.

Wood pulp was calculated using region specific input/output coefficients. Trend analysis was employed to project changes in yearly input/output coefficients in the future. The change in the coefficient is an important consideration since recovered paper use has been increasing steadily overtime. Trends were also evaluated for recovered paper and its use in paper and paperboard production. Trade projections for wood pulp were made using trend analysis of input/output coefficients of pulp consumption and paper and paperboard production. Wood pulp and recovered paper analyses for each region in the model were completed.

As with wood pulp production projections, the economic model also required non-structural panel projections for each market. These panel projections were calculated using historical trend analyses and market share information for 2003.

The wood pulp, recovered paper and non-structural panel projections and the model-determined production, trade and consumption projections of sawn wood and plywood were used to calculate carbon stocks and their changes using the three alternative accounting approaches described above. Since annual projections from 2000 to 2016 were made and equilibria produced by the economic model differ from historical data, we used the 2016 projection and information about the trend from 2000 to 2016 to calibrate the model projections with the 2003 FAO historical data. This was necessary to assure carbon stocks in 2004 did not substantially increase or decrease due to equilibrium conditions imposed by the economic model.

MEASURING ECONOMIC IMPACTS

Scenario assessment was employed to examine the trade and competitiveness implications associated with alternative approaches. We imposed a cost in the country in the form of an emission tax. The tax level was determined by using the calculated forest sector removals/emissions for the default and three alternative approaches. The impact of the emission tax for each approach was then compared with the IPCC default approach.

We chose to limit the analysis of economic impacts to the softwood lumber sector since other wood product sectors accounted for in the model do not use equilibrium methods to determine stock inflows in response to a cost increase. Other wood products are related to the softwood lumber sector through their demands on industrial roundwood. However, price information is lacking in these other sectors since market equilibrium conditions via supply and demand functions are not used in the projection of production, consumption and trade volumes.

The following modifications of the economic model were imposed for studying the effects of the accounting approaches. First, we calibrated the model to 2000 conditions using historical data. Then we recoded the timber supply equations to account for changing costs when the emission tax was included. Differences in emissions estimates for each alternative approach led to each approach impacting the forest sector differently through the shifting of the supply function. Changes in production, consumption, trade and prices were then recorded over a 17 year projection period from 2000 to 2016. Adjustments were made to calibrate the projection to historical data to maintain consistency when calculating carbon stock changes/emissions from 2003 to 2004.

To recode timber supply equations we first calculated the value of emissions and then translated this value into a cost to timber producers. We considered that the forest sector assumed the liability and that the government utilized a tax scheme to assign the burden to timber producers. We supposed that timber producers were assigned the cost of emissions under the default approach since (i) they undertake the harvest activity, and (ii) this approach considers the harvest as an immediate emission. We did not attempt to assign burdens to different segments in the value-added chain. Under the alternative approaches, the cost to timber harvesters associated with the emission tax was lowered when HWP product pools were increasing.

The impact of the tax policy on each nation was expected to be different since each region is likely to see their HWP pools increasing differently under each approach, dependent on their trading activity. We investigated a carbon price of $10 and $35 per tonne of CO_2. We did not differentiate between countries participating in the Kyoto Protocol and those who are not for this stage of analysis.

RESULTS

We organized our results into three sections below. Our first section describes the accounting approach impacts on emission calculations. We follow it with a limited sensitivity analysis on alternative calculations. The third section describes the economic impacts on the forest sector.

HARVESTED WOOD PRODUCT POOLS CONTINUE TO INCREASE

The stock of HWP increased from 6.3 billion tonnes in 1990 to 8.1 billion tonnes of carbon in 2003. Global stocks of harvested wood products increased at an annual rate of nearly 1.8 percent per year during the projection period reaching 10.2 billion tonnes of carbon in 2016. Figure 1 illustrates the carbon in two calculated HWP pools using the stock change and production approaches. The two calculated estimates are similar since the approaches will produce identical values at the global level. The chart includes the back-casted pools calculated under default parameters, historical pools using FAOSTAT data (FAO 2005), and projected pools using CGTM to 2016. Each global pool is the sum of calculated national stocks.

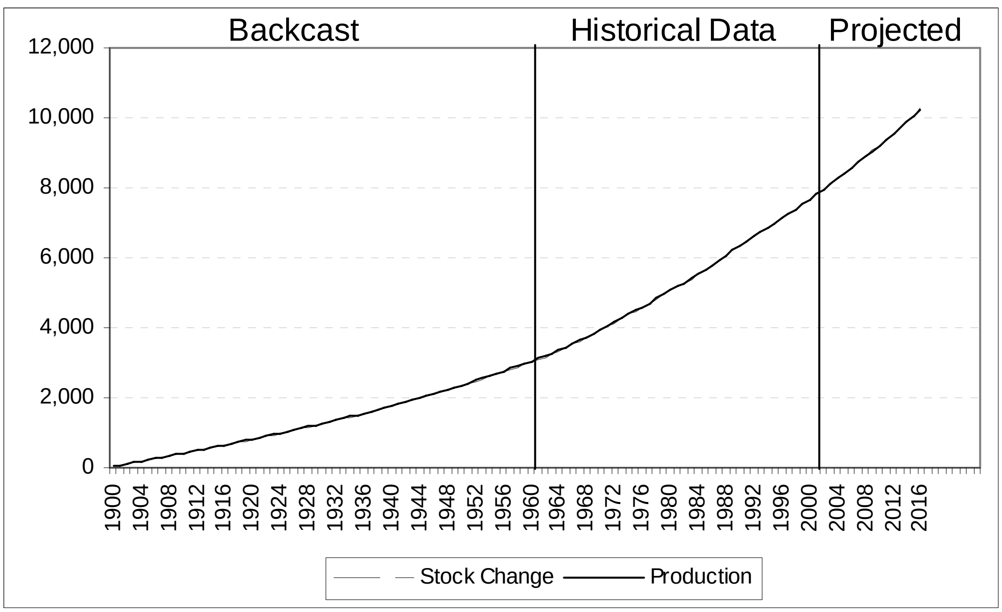

Figure 1: Global HWP pools measured in Tg C

The land-filled portion of the HWP stock is increasing most rapidly about 2.4 percent per year, while the in-use pool is growing at 1.2 percent per year (Figure 2). This growth behavior is due in part to the adopted default IPCC values on discards and half lives. We explore the sensitivity to alternative values in the section the follows.

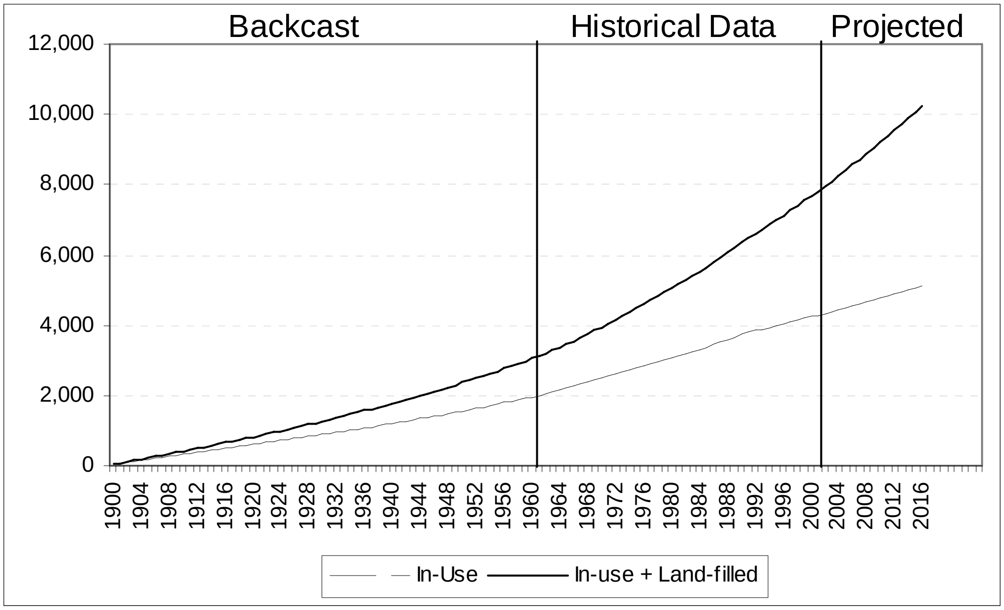

Figure 2: Global in-use and in-use plus land-filled HWP pool calculated using the stock change approach in Tg C

Table 5 presents the IPCC default approach calculated emissions and the effect on these emissions for 2016 using the three alternative approaches. Emissions are reported in CO_2 units. The values reported under the columns for each alternative approach represent changes from the IPCC default approach. All three approaches reduce calculated emissions under the IPCC default using the default parameters for regions (Tables 1 through 4). The small, but higher emission calculated using the atmospheric flow approach was unexpected. We speculate that our assumptions on fuel wood may be impacting these calculated emissions since they occur in regions where much of the harvest might be for fuel wood.

Table 5: Emission in 2016 under the IPCC default and reduction for three alternative approaches (Tg CO2)

Region	IPCC Default Approach	Change from IPCC Default Approach using		
		Stock change	Production	Atmospheric flow
Eastern Africa	149.57	-1.18	-0.98	-0.68
Northern Africa	137.43	-4.05	-1.06	1.50
Southern Africa	28.76	-2.09	-3.21	-3.10
Western Africa	242.21	-2.48	-3.64	-6.85
Australia	32.27	-8.08	-8.42	-9.07
Brazil	242.36	-19.36	-24.79	-25.73
Central America and Mexico	89.33	-11.53	-6.31	0.72
Canada	218.48	-23.06	-69.55	-85.04
Chile	56.37	-5.69	-10.34	-10.22
China	248.33	-113.15	-87.37	-80.58
Eastern Europe	94.06	-34.21	-40.42	-45.57
Western Europe	191.39	-99.84	-79.01	-48.54
Finland	56.62	-17.50	-15.90	-20.65
Indochina	109.89	-8.49	-8.82	-6.43
Indonesia	107.32	-7.99	-16.39	-15.18
India	380.69	-16.25	-13.44	-8.92
Japan	16.61	-26.42	-10.91	-4.24
Korea	3.61	-15.09	-2.75	-8.37
Malaysia	27.34	-5.44	-8.84	-12.63
Middle East	6.92	-9.90	-1.20	3.49
New Zealand	28.96	-3.89	-11.09	-16.73
Oceania	1.11	-0.31	-0.25	-0.54
Philippines	15.61	-2.14	-0.79	0.20
Papua New Guinea	6.64	-0.07	-0.70	-2.38
Northern South America	46.00	-3.15	-2.86	-1.94
Southern South America	19.56	-3.85	-3.98	-4.36
Soviet Union West	218.84	-18.24	-35.46	-79.44
Sweden	69.37	-6.24	-18.35	-22.96
Taiwan Hong Kong[1]	--	-0.59	--	0.17
USA	582.16	-186.11	-151.51	-145.30
World	3427.77	-656.40	-638.32	-659.37

[1] does not report production of industrial roundwood

Calculated emissions for selected countries/regions in Tg CO_2 from 1901 to 2016 are charted below. Figure 3a graphs the calculated emissions while Figure 3b contains the calculated emission reductions for 1990, 2002 and 2016 for the U.S. In the charts that follow, the emissions plotted in the "a" series (i.e. Figures 3a through 9a) reflect the total effect of the HWP accounting approach on the combined forest and HWP carbon pools. Changes in stocks of forest carbon would have to be added to these numbers to obtain the total national emissions from the forest and HWP pools. The emissions shown in the bar graphs in the "b" series (i.e. Figures 3b through 9b) are reductions in emissions compared to the IPCC default approach considering the net effects of the accounting approach on the combined forest and HWP carbon pools.

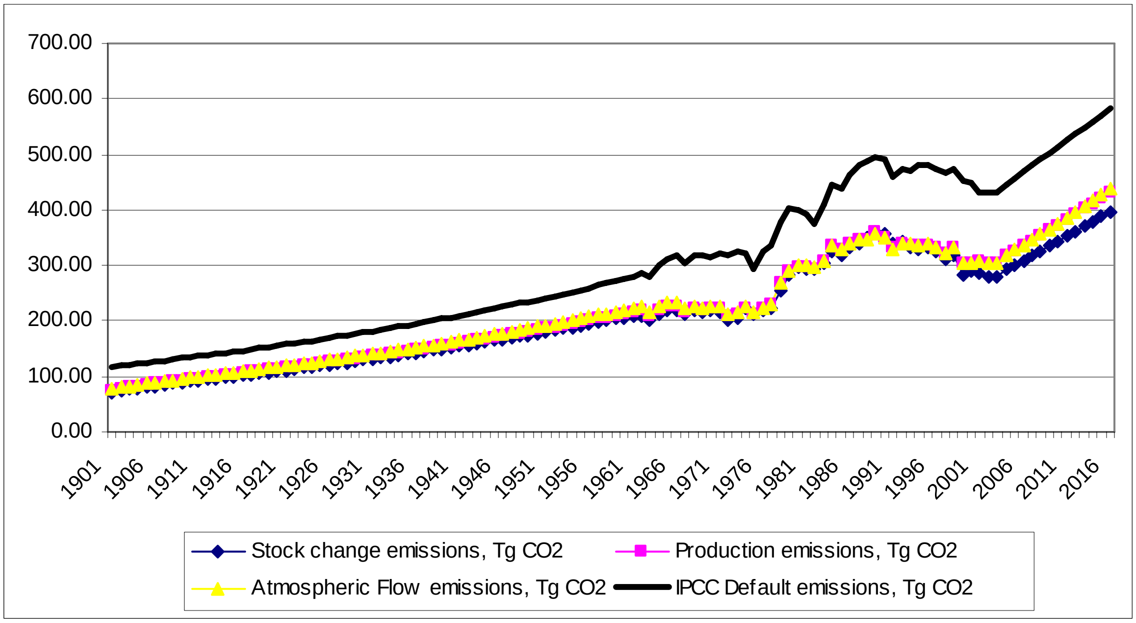

Figure 3a: Estimated emissions for USA under the default approach and alternative accounting approaches.

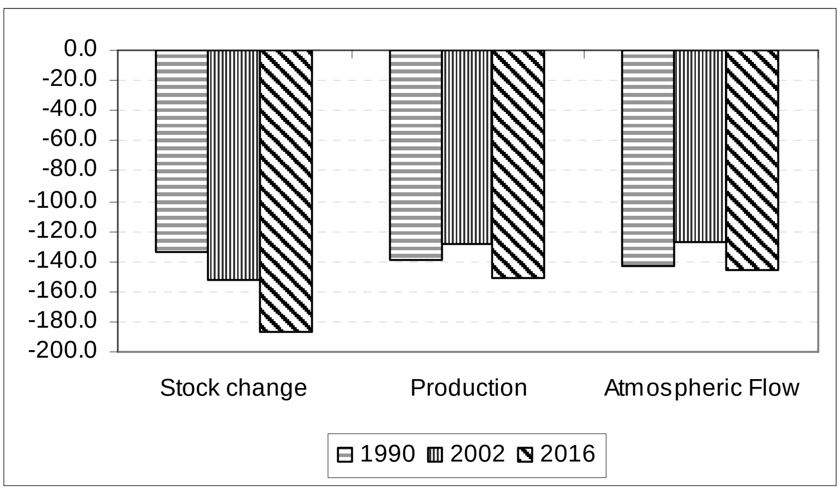

Figure 3b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

Compared to the emissions calculated using the default approach, the United States would reduce its emissions by 186 Tg of CO_2 in 2016 using the stock change approach, by 150 Tg using the production approach and by 145 Tg CO_2 using the atmospheric flow approach. This result exemplifies the stock change approach's key difference since the U.S. is a net importer of wood products. There is a greater emission reduction estimated using the stock change approach as more products are consumed in the U.S. than produced.

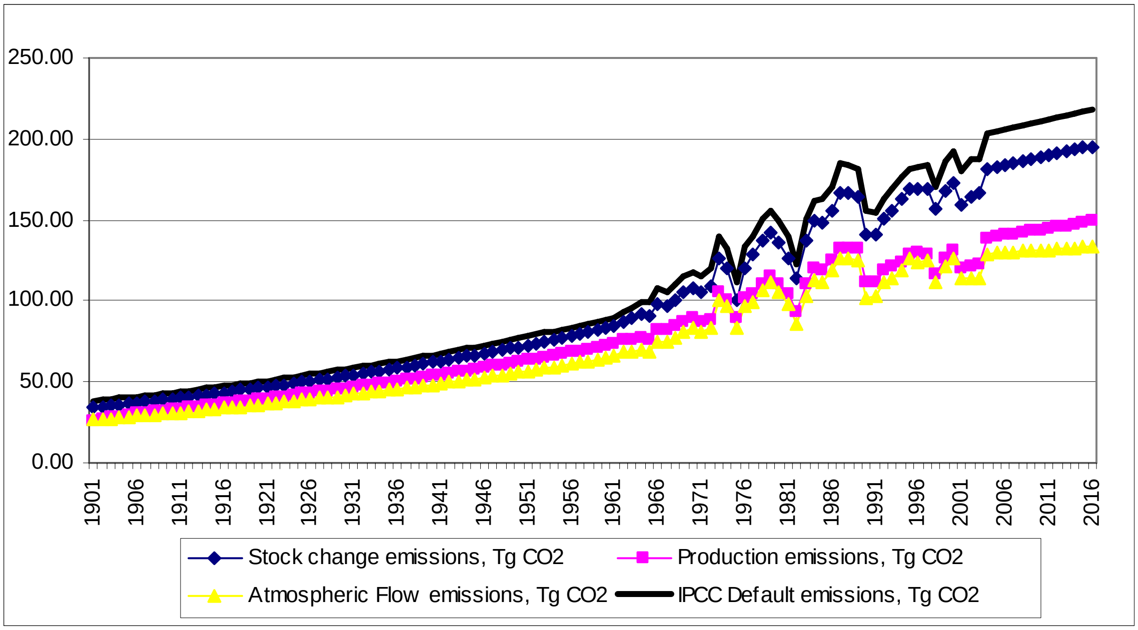

Figure 4a: Estimated emissions for Canada under the default approach and alternative accounting approaches.

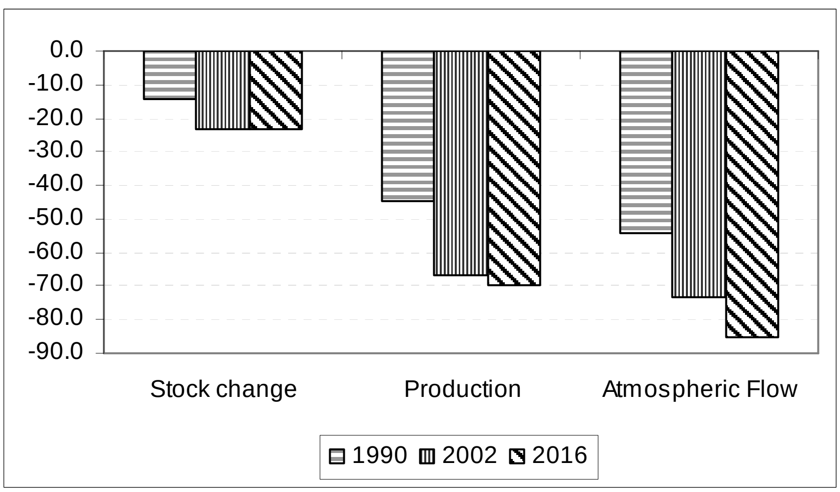

Figure 4b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

Compared to the default approach, Canada would reduce its reported emissions under the stock change approach by less than 25 Tg and 85 Tg under the atmospheric flow approach by 2016 (Figures 4a, b). The reduction in reported emissions using the production approach is 70 Tg. The differences in calculated emissions under the alternative approaches demonstrate the advantage of using the production approach for a country that exports much of its harvest as wood products. The relatively high harvest level versus small in-country HWP pools results in the small emission reduction under the stock change approach.

Japan imports large amounts of forest products relative to its domestic harvest (Figures 5a, b). In fact, the calculations indicate that the annual growth in the HWP carbon pool every year in Japan is greater than the amounts of carbon removed annually from domestic forests. This results in negative emissions being estimated using the stock change approach for Japan, considering the net effects of the HWP accounting approach on the combined forest and HWP carbon pools.

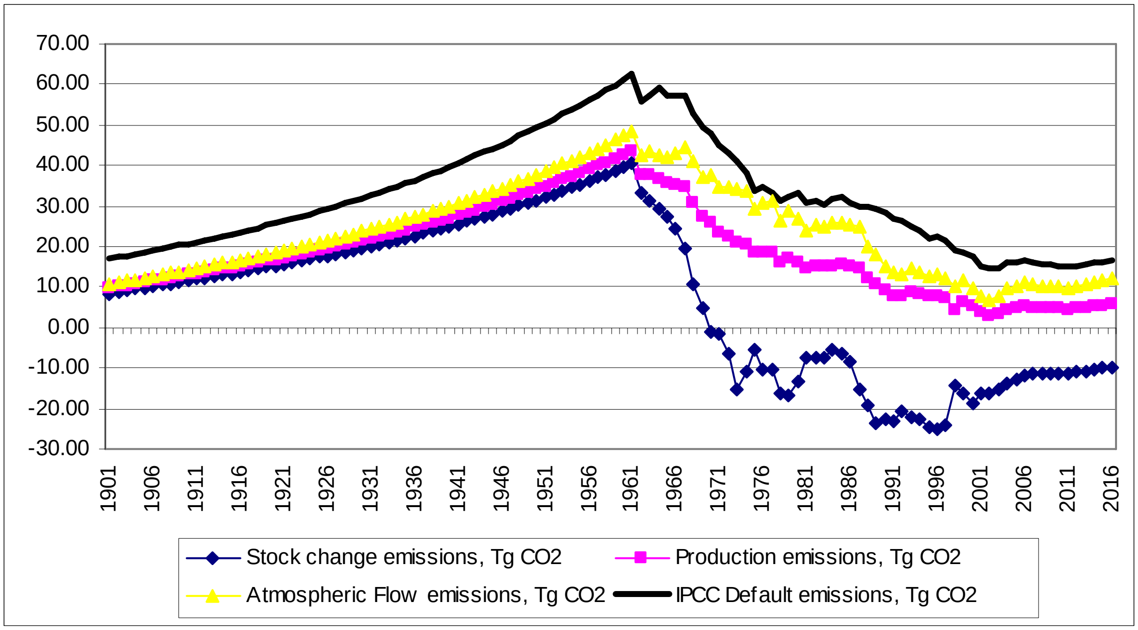

Figure 5a: Estimated emissions for Japan under the default approach and alternative accounting approaches.

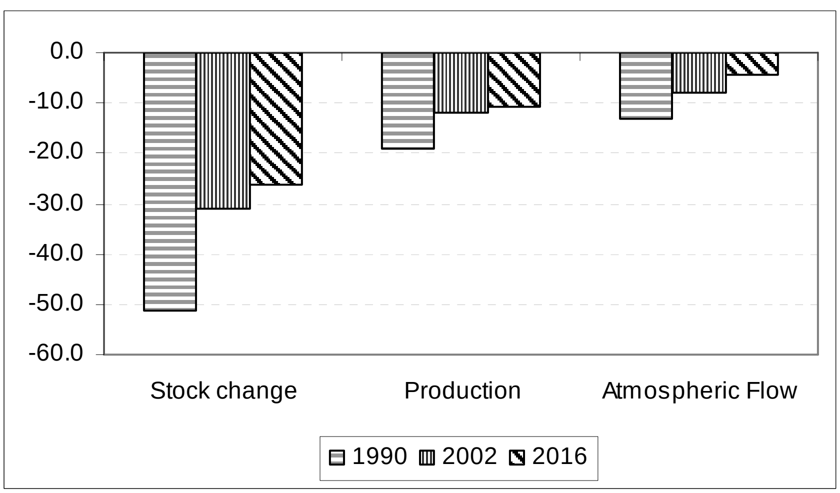

Figure 5b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

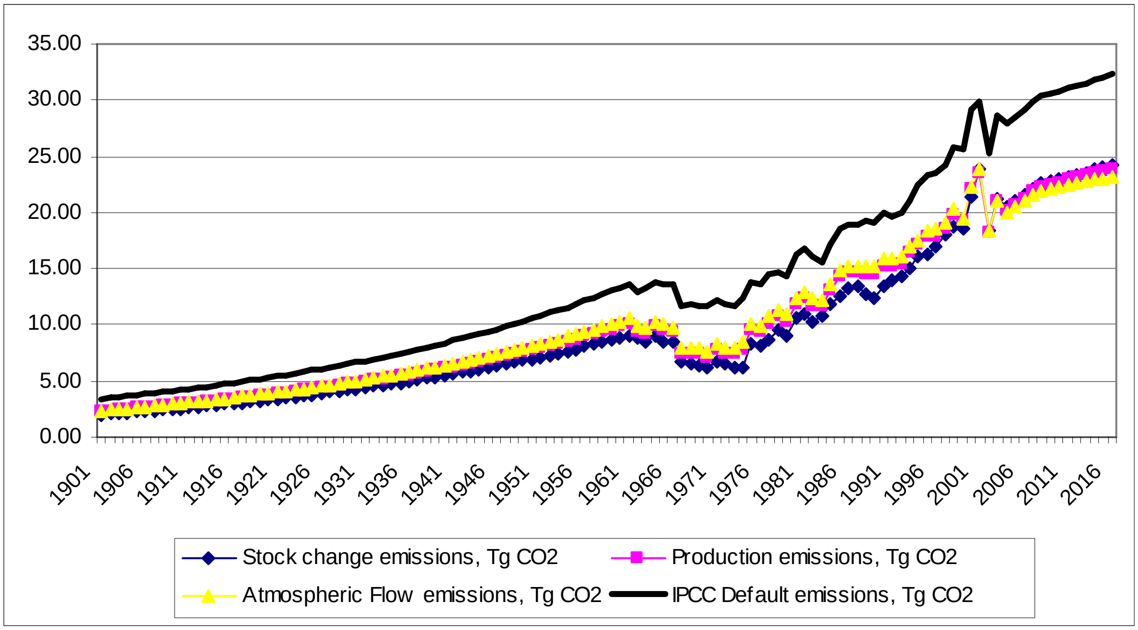

Figure 6a: Estimated emissions for Australia under the default approach and alternative accounting approaches.

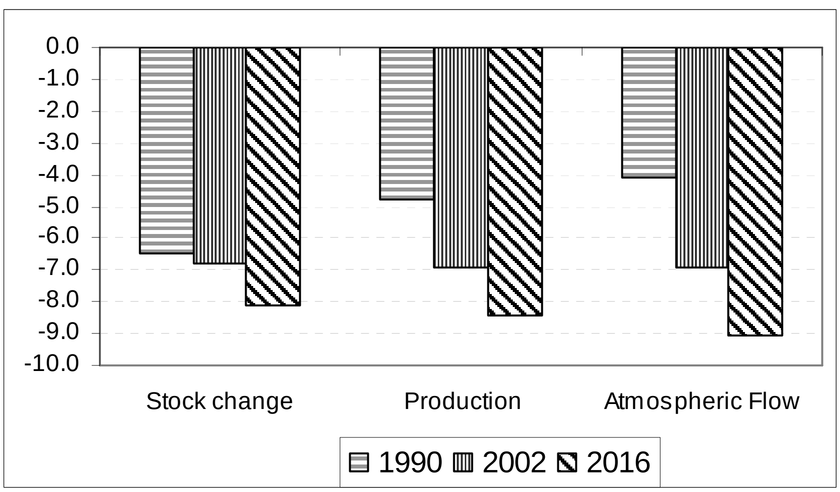

Figure 6b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

National accounts in Australia would also show a reduction in accounted emissions when alternative approaches were employed. Figure 6b reports the reduction in emissions under the three approaches. The effect of trade activity on the calculated emissions by alternative approaches continues to be reflected in the three approaches. In the case of Australia, its net importer status changed to a net exporter status between 1990 and 2016. The stock change approach, which favors net importing, leads to higher emission reductions over the default accounting approach in 1990. This result is no longer true by 2016, when Australia is projected to be a net-exporter of wood products.

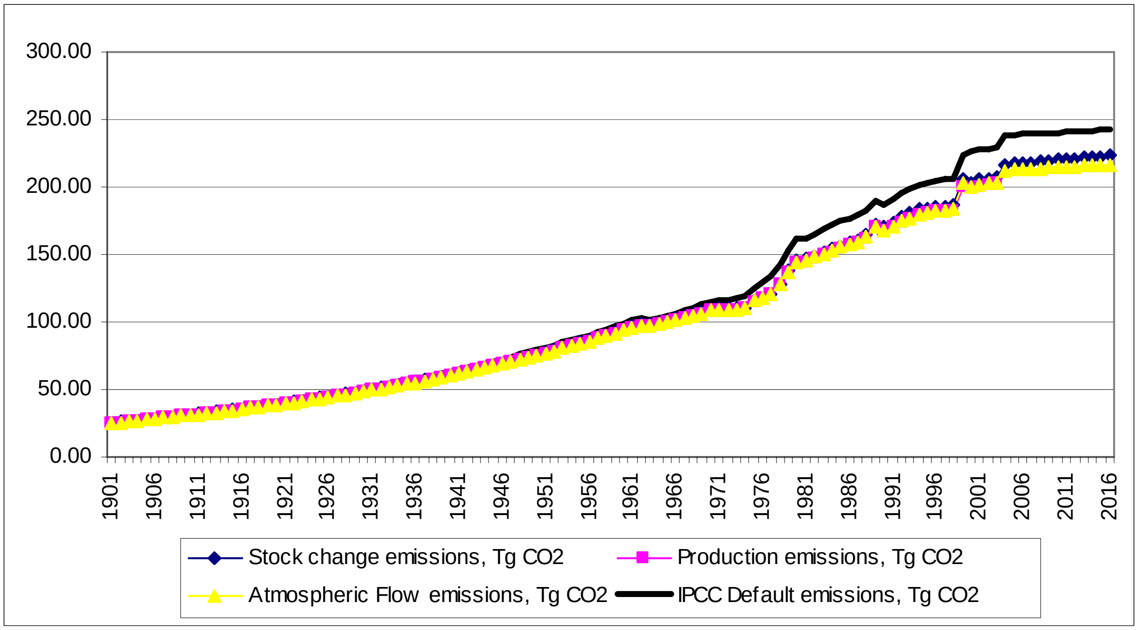

Figure 7a: Estimated emissions for Brazil under the default approach and alternative accounting approaches.

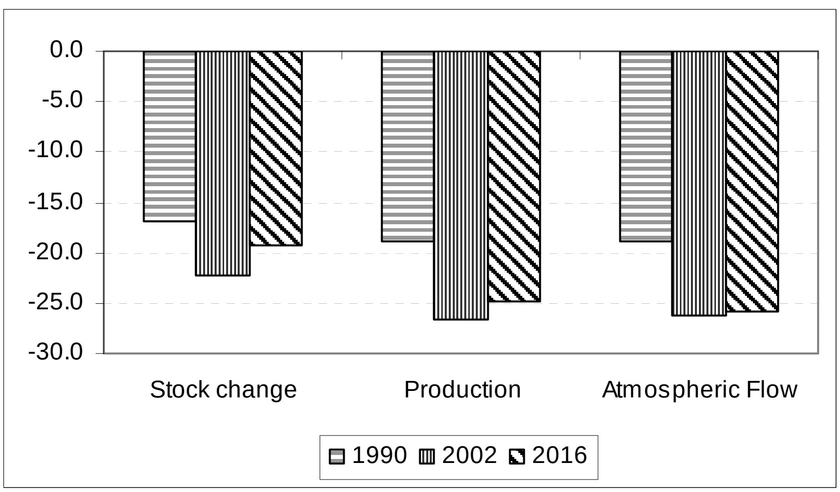

Figure 7b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

Emission reductions for Brazil were the smallest percentage-wise of the nations examined here (Figures 7a, b). While exporting several wood products, Brazil also consumes a large percentage of its harvests as short-lived products. Brazil's reduction in calculated emissions over the three years examined ranged between 8 and 12 percent. While in the other regions reported here the reduction averaged 34 percent, excluding Japan.

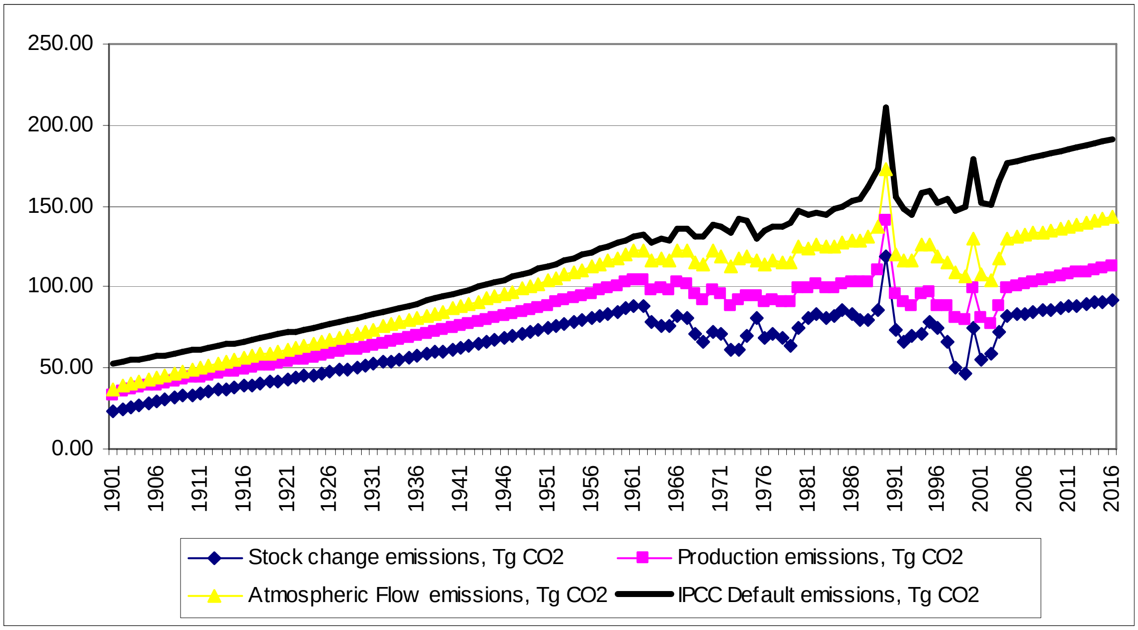

Figure 8a: Estimated emissions for Western Europe under the default approach and alternative accounting approaches.

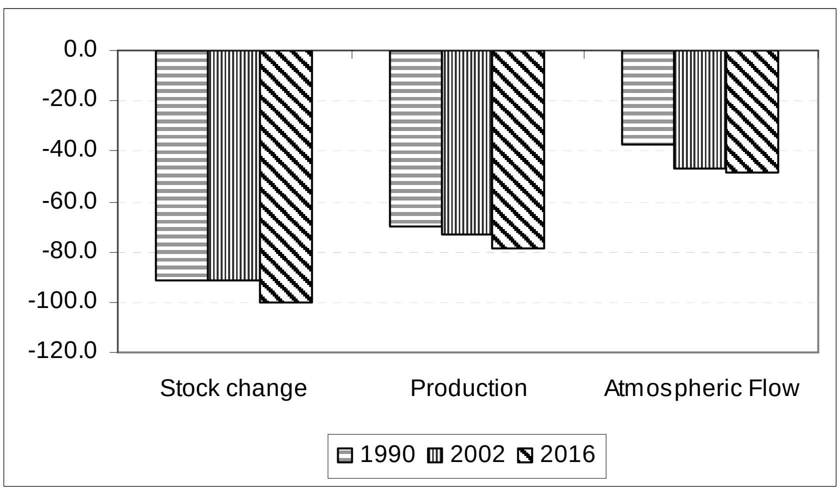

Figure 8b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

Emissions accounting for the European Union, the combined effect of western Europe Sweden and Finland (not shown), suggested that the stock change approach would produce the greater emission reduction (Figures 8a, b - 9a, b). While Western European nations excluding Sweden and Finland are net importers of forest products, the later two countries are part of the European Union and are net exporters, mainly to countries within the Union.

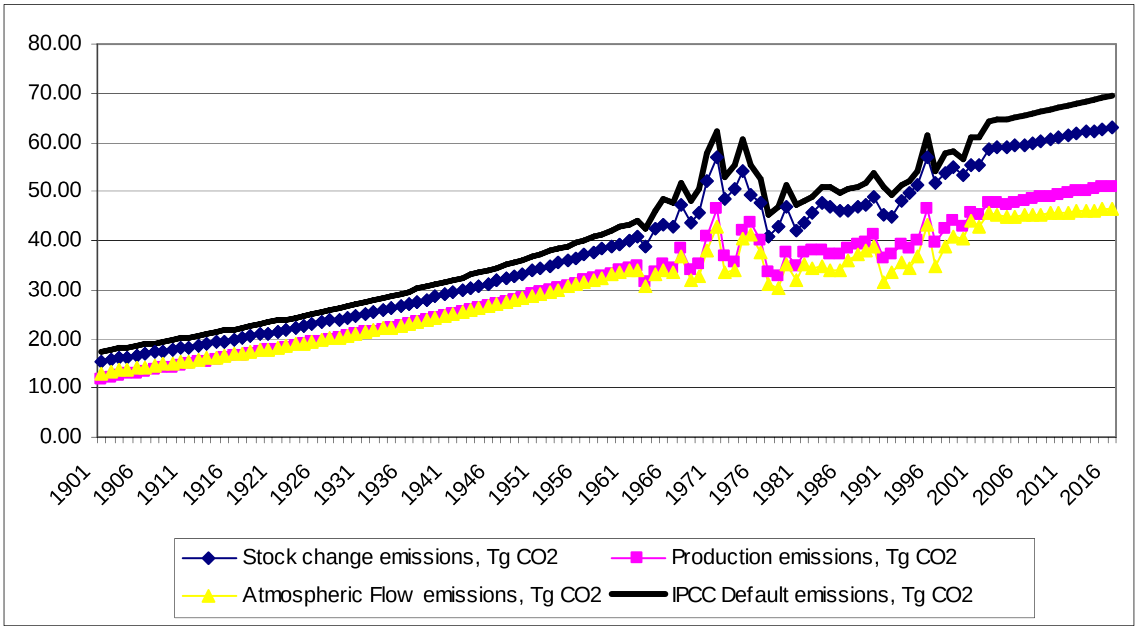

Figure 9a: Estimated emissions for Sweden under the default approach and alternative accounting approaches.

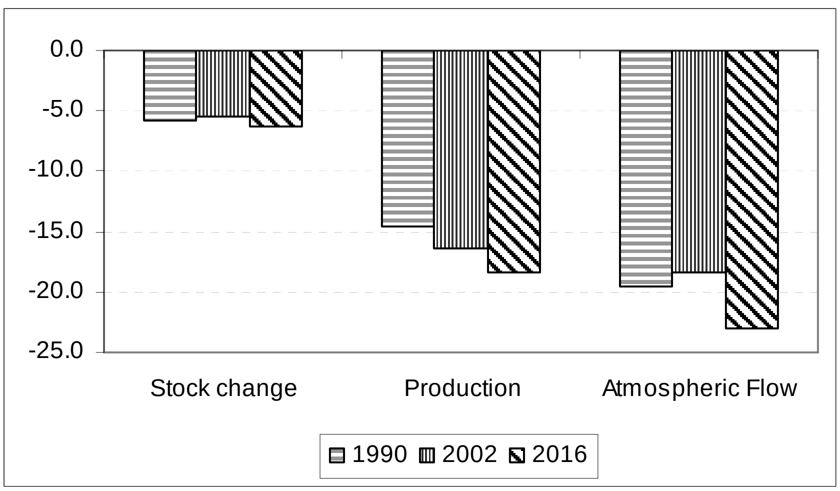

Figure 9b: Calculated reduced emissions associated with alternative HWP accounting approaches: 1990 and 2002 based on FAO data; 2016 based on projection of forest sector activity.

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LAND-FILL CALCULATION SENSITIVITIES TO ALTERNATIVE HALF-LIFE ASSUMPTIONS

We investigated the sensitivity to assumptions regarding the half-life of discarded materials in the land-filled pool. While many options exist to measure uncertainty in assumptions, we chose to investigate the half-lives since they contribute in an exponential way to growing HWP pools. We halved the half-lives to produce a shorter-lived, smaller land-filled pool scenario with greater emissions. We called this scenario the Low scenario in Table 6. We doubled the half-lives to increase the land-filled pool and created a land-filled pool with higher growth and lower emissions. We called this scenario the High scenario in Table 6.

Table 6: Percentage change in reductions from base levels for nations and alternative approaches

	Stock Change		Production		Atmospheric Flow	
Region	**Low**	**High**	**Low**	**High**	**Low**	**High**
Eastern Africa	-0.06	0.08	-0.05	0.07	-0.11	0.13
Northern Africa	-0.09	0.10	-0.10	0.12	0.23	-0.27
Southern Africa	-0.08	0.12	-0.10	0.13	-0.05	0.08
Western Africa	-0.05	0.06	-0.04	0.05	-0.02	0.02
Australia	-0.08	0.11	-0.08	0.10	-0.07	0.10
Brazil	-0.07	0.07	-0.06	0.07	-0.05	0.05
Central America and Mexico	-0.07	0.08	-0.07	0.09	1.04	-1.21
Canada	-0.05	0.06	-0.05	0.07	-0.01	0.02
Chile	-0.03	0.03	-0.04	0.05	-0.02	0.02
China	-0.07	0.08	-0.08	0.09	-0.10	0.11
Eastern Europe	-0.07	0.09	-0.07	0.09	-0.05	0.07
Western Europe	-0.06	0.08	-0.07	0.09	-0.13	0.17
Finland	-0.02	0.02	-0.07	0.10	-0.02	0.02
Indochina	-0.07	0.07	-0.07	0.07	-0.09	0.09
Indonesia	-0.10	0.11	-0.10	0.10	-0.06	0.06
India	-0.08	0.08	-0.08	0.08	-0.14	0.15
Japan	-0.12	0.18	-0.15	0.23	-0.76	1.13
Korea	-0.07	0.08	-0.09	0.09	-0.13	0.14
Malaysia	-0.10	0.11	-0.08	0.09	-0.04	0.05
Middle East	-0.07	0.07	-0.08	0.10	0.19	-0.20
New Zealand	-0.05	0.07	-0.05	0.06	-0.01	0.02
Oceania	-0.08	0.08	-0.07	0.07	-0.05	0.05
Philippines	-0.09	0.11	-0.15	0.23	0.98	-1.14
Papua New Guinea	-0.13	0.15	-0.07	0.07	0.00	0.00
Northern South America	-0.09	0.12	-0.08	0.11	-0.14	0.20
Southern South America	-0.05	0.07	-0.06	0.07	-0.04	0.06
Soviet Union West	-0.12	0.22	-0.10	0.16	-0.03	0.05
Sweden	-0.06	0.08	-0.06	0.09	-0.02	0.02
Taiwan Hong Kong	-0.18	0.22	--	--	0.62	-0.79
USA	-0.05	0.07	-0.07	0.09	-0.07	0.10
World	-0.07	0.09	-0.07	0.09	-0.07	0.09

Table 6 reports the percentage change in reduction from the base levels, which was defined by the default half-live values. Globally the changes averaged 7% under the Low scenario, and 9% under the High scenario. There is some variability around the averages. The more notable changes occur when small reductions in calculated emissions occurred. Other exceptions exist. For instance, there was an averaged 6% change in emission reductions for Canada under the stock change and production approaches, while atmospheric flow changes were less than 2 percent.

ECONOMIC EFFECTS OF COST INCREASES TO TIMBER HARVESTERS

The emission tax effect on harvesting cost was derived from the calculated emissions under each alternative approach and two assumed prices: $35 and $10 per tonne of CO_2. First the total value of emissions was calculated by multiplying the emissions times the tax. These values under the $35 tax scheme are reported in Table 7. Globally, emission values reach $120 billion in 2016 under the IPCC default approach. Calculated emission values were reduced to $97 billion under alternative approaches.

Table 7: Values of emissions@ $35 per tonne of CO2 in billions of dollars under base scenario.

Region	IPCC Default	Stock change	Production	Atmospheric flow
Eastern Africa	5.24	5.19	5.20	5.21
Northern Africa	4.81	4.67	4.77	4.86
Southern Africa	1.01	0.93	0.89	0.90
Western Africa	8.48	8.39	8.35	8.24
Australia	1.13	0.85	0.83	0.81
Brazil	8.48	7.81	7.61	7.58
Central America and Mexico	3.13	2.72	2.91	3.15
Canada	7.65	6.84	5.21	4.67
Chile	1.97	1.77	1.61	1.62
China	8.69	4.73	5.63	5.87
Eastern Europe	3.29	2.09	1.88	1.70
Western Europe	6.70	3.20	3.93	5.00
Finland	1.98	1.37	1.43	1.26
Indochina	3.85	3.55	3.54	3.62
Indonesia	3.76	3.48	3.18	3.22
India	13.32	12.76	12.85	13.01
Japan	0.58	-0.34	0.20	0.43
Korea	0.13	-0.40	0.03	-0.17
Malaysia	0.96	0.77	0.65	0.51
Middle East	0.24	-0.10	0.20	0.36
New Zealand	1.01	0.88	0.63	0.43
Oceania	0.04	0.03	0.03	0.02
Philippines	0.55	0.47	0.52	0.55
Papua New Guinea	0.23	0.23	0.21	0.15
Northern South America	1.61	1.50	1.51	1.54
Southern South America	0.68	0.55	0.55	0.53
Soviet Union West	7.66	7.02	6.42	4.88
Sweden	2.43	2.21	1.79	1.62
Taiwan Hong Kong	0.00	-0.02	--	0.01
USA	20.38	13.86	15.07	15.29
World	119.97	97.00	97.63	96.89

Next, the total costs were converted to unit values on a cubic meter basis based on industrial and fuel wood roundwood harvest in 2016. Table 8 presents the per cubic meter emission tax corresponding to the emission values presented in Table 7 and harvest levels presented in Table 8.

Table 8: Roundwood harvests and inputted cost increases to timber harvesters for four accounting approaches when emissions are valued at $35 per tonne of CO2

Industrial and fuel wood roundwood harvest in m3	Cost increase in $ on m3 basis				
	IPCC Default	Stock change	Production	Atmospheric flow	Region
155,399,180	$33.69	$33.42	$33.47	$33.53	Eastern Africa
142,780,062	$33.69	$32.69	$33.43	$34.06	Northern Africa
29,878,094	$33.69	$31.24	$29.92	$30.05	Southern Africa
251,642,665	$33.69	$33.34	$33.18	$32.73	Western Africa
33,526,194	$33.69	$25.25	$24.90	$24.22	Australia
251,802,564	$33.69	$31.00	$30.24	$30.11	Brazil
92,806,993	$33.69	$29.34	$31.31	$33.96	Central America and Mexico
226,988,282	$33.69	$30.13	$22.96	$20.57	Canada
58,562,223	$33.69	$30.29	$27.51	$27.58	Chile
258,004,915	$33.69	$18.34	$21.84	$22.76	China
97,722,333	$33.69	$21.43	$19.21	$17.37	Eastern Europe
198,842,898	$33.69	$16.11	$19.78	$25.14	Western Europe
58,828,367	$33.69	$23.28	$24.23	$21.40	Finland
114,170,866	$33.69	$31.09	$30.98	$31.72	Indochina
111,502,618	$33.69	$31.18	$28.54	$28.92	Indonesia
395,517,979	$33.69	$32.25	$32.50	$32.90	India
17,261,443	$33.69	$(19.88)	$11.56	$25.09	Japan
3,746,710	$33.69	$(107.29)	$8.03	$(44.51)	Korea
28,403,509	$33.69	$26.98	$22.80	$18.12	Malaysia
7,185,377	$33.69	$(14.55)	$27.83	$50.70	Middle East
30,092,269	$33.69	$29.16	$20.79	$14.23	New Zealand
1,155,251	$33.69	$24.32	$26.21	$17.41	Oceania
16,218,403	$33.69	$29.06	$31.99	$34.12	Philippines
6,898,613	$33.69	$33.35	$30.14	$21.63	Papua New Guinea
47,787,362	$33.69	$31.38	$31.59	$32.27	Northern South America
20,323,644	$33.69	$27.05	$26.83	$26.18	Southern South America
227,364,364	$33.69	$30.88	$28.23	$21.46	Soviet Union West
72,068,273	$33.69	$30.66	$24.78	$22.54	Sweden
604,838,907	$33.69	$22.92	$24.92	$25.28	USA
3,561,320,357	**$33.69**	**$27.24**	**$27.41**	**$27.21**	**World**

Four economic scenarios were examined using alternative calculated emissions to determine the tax level. They included the High 2 x half-life and Low ½ x half-life scenarios established to determine the sensitivity to default half-life parameters and the $10 and $35 per tonne of CO_2 emission. Combining the sensitivity scenarios and the two tax levels resulted in the four economic scenarios. We discuss the results of the $35, High 2 x half-life sensitivity scenario below. This scenario produced the largest differences between the alternative approaches and the default approach.

We present the results of our economic analysis for softwood lumber markets below. The softwood lumber markets represent nearly one half of the harvest volume globally. They are mostly competitive markets, making use of the competitive economic simulation model more appropriate. Understanding the effects of an emission tax on these markets can lead to possible insights into other markets such as plywood and paper and paperboard. However, since equilibrium prices are not determined for these other sectors, we did not examine the economic impacts in detail.

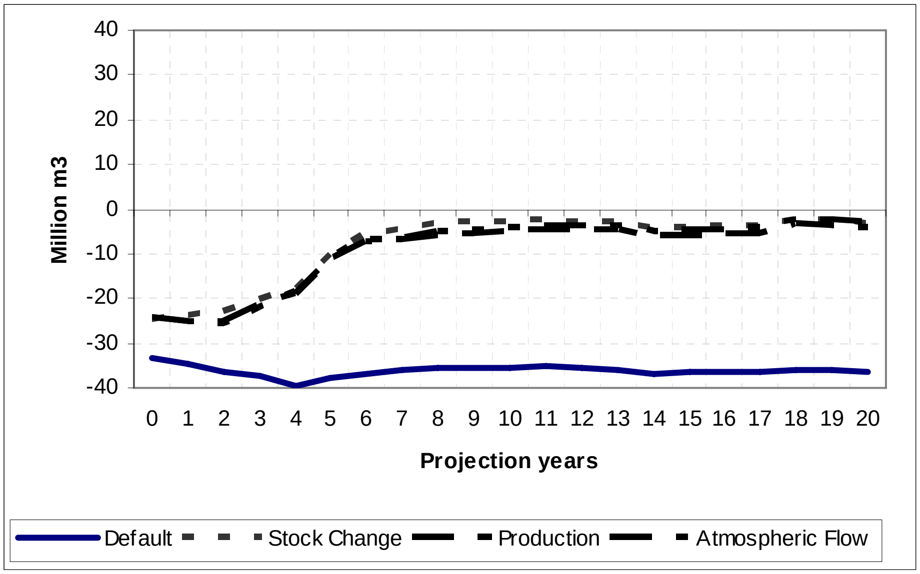

Figure 10: Changes in softwood industrial roundwood harvest levels following the imposition of a \$35 per tonne of CO2 tax on timber harvesters servicing softwood lumber markets.

As a result of higher costs imposed on timber harvesters through a \$35 emission tax, harvest levels of coniferous sawlogs declined under all four approaches (Figure 10). Observed harvest level declines were greatest under the default approach as expected. The decline persisted throughout the projection period, averaging about 6% of softwood industrial rounding harvest levels without the tax.

The alternative accounting approaches resulted in similar, but smaller reductions in this scenario. The variation among the alternative approaches was small and indistinguishable. Furthermore, the effect of the higher cost on coniferous sawlog harvest levels dissipated with time. A slightly different pattern of harvest level impacts over time were observed for the \$10 per tonne scenarios. Lower harvest levels were observed upon imposition of a \$10 per tonne emission tax, but the harvest levels drifted back to base levels over time for all approaches, including the default, under the lower tax scenarios.

An analysis of the market price effects for coniferous sawlogs showed a persistent price increase (Figure 11). Lower market prices were observed for the alternative approaches as expected. Unlike the effects on harvest levels, which reverted to base levels under the alternative approaches, market prices declined slightly overtime, but then increased to cover the additional cost to timber harvesters imposed by the emission tax.

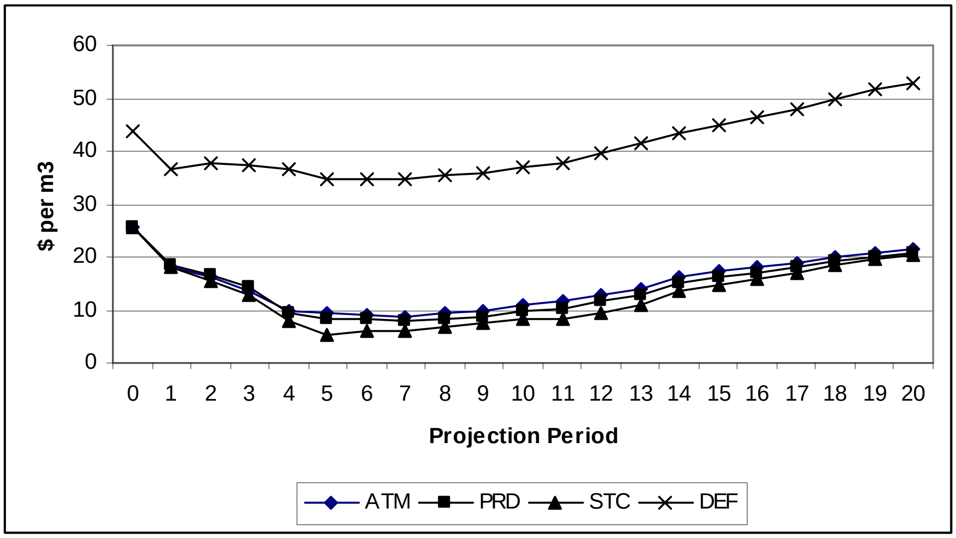

Figure 11: Price projectors over the projection period for the four approaches.

DISCUSSION

We calculated the stocks of HWP pools and their emissions under alternative approaches. The stock-change approach estimates the net change in carbon stocks in the forest and wood products pool within national boundaries. The production approach estimates net changes in the forest and wood products carbon stocks by producing nations. The atmospheric-flow approach estimates carbon flows between the atmosphere and forests and products pools within the national boundary. Producing nations account for forest growth carbon and consuming countries count emissions from wood and wood products under the atmospheric approach.

We also investigated alternative calculations. IPCC default assumptions for calculating in-use and land-filled HWP pools are based on published studies and expert judgment. We adopted a range of half-life parameters and reported their effect on emission estimates. Other sensitivities are possible but not pursued here.

Finally, we examined the effect of an emission tax on softwood lumber markets. We examined four scenarios based on the sensitivity analysis of alternative half-life parameters and two carbon prices.

Our results are based on recommended IPCC reporting guidelines and suggest substantial reductions in reported emissions under all three alternative approaches compared to the current IPCC default approach. The average national reduction is 34%. In only a few cases involving regions where much of the harvest is used for fuel wood, did the current IPCC default approach result in higher national emissions than the three alternative approaches.

The results indicate that HWP carbon pools are increasing. The increasing pools suggest emissions reductions over the default approach are growing over time.

There was substantial variation in calculated emissions under alternative approaches. Greater emission reductions were measured using the atmospheric flow approach for net exporters of HWP (see Canada, Sweden). The production approach also accounted for greater emission reductions for net exporters than the stock change approach. These results are consistent with our expectations since the atmospheric flow approach calculates emissions within national boundaries. Emissions from wood products produced in Canada but used in the U.S. would be counted in the U.S. The production approach would give credit to Canada for the increase in the U.S. stocks of wood products, i.e., a reduction in the Canadian forest account emissions.

We calculated greater emissions reductions under the stock change approach for net importers (see Japan, West Europe). Japan's high level of imports of wood products used to meet its consumptive needs, and the associated increases in HWP carbon stocks, resulted in negative emission estimates under the stock change approach implying that the growth in the HWP stocks were larger than their in-country harvest emissions.

Sensitivity to one important parameter -- half-life assumptions on discarded materials -- was explored. It suggested that changes in emission reductions were insensitive to large changes in half-lives. Halving or doubling half-lives resulted in an average 7% to 9% change in calculated emission.

The economic analysis revealed additional interesting results. Should carbon emissions reach a threshold value, its assessment on timber harvesters can lead to permanent lower harvest levels over time. Below this threshold value, harvest levels may return to near base levels over time. Either way, product prices will increase to reflect the lower harvest levels. That is to say that the emission charges on harvesters will lead to higher market prices. If charges are not substantial, consumption levels may continue near base levels, but at higher prices. If charges are substantial, consumption levels fall and higher market prices prevail. Both results suggest the potential for product substitution in the market place, depending on the substitutes available and their price sensitivity. In both cases, higher product prices would signal competing products to increase market share.

The economic analysis suggested that all three alternative approaches resulted in higher levels of industry output and lower lumber prices compared to the current IPCC default. The differences between the three alternatives, however, do not appear to be significant,

CONCLUSIONS

We summarize our conclusions as follows.

- Using available forestry data and IPCC accounting methods that consider carbon in HWP, it is demonstrated that HWP pools are increasing globally. By 2002, global carbon stocks in products in use had accumulated to approximately 4,508 Tg C, and were increasing at a rate of 1.2% per year. Global carbon stocks in landfills were estimated to be 3,447 Tg C and were increasing at 2.4% per year.
- Different accounting approaches (i.e. the current IPCC default, stock change, production, and atmospheric flow) led to different national accounts of emissions. Compared to alternative approaches, the IPCC default approach resulted in higher national emissions for all nations, with the possible exception of a few regions where much of the harvest is used for fuel wood. The stock change approach produced lower emissions for large net importers of HWP. The production and atmospheric flow approaches led to lower emissions for large net exporters of HWP.
- If the forest products industry became financially responsible for HWP carbon emissions, the selection of an accounting approach could significantly affect the industry. In particular, the current IPCC default approach could result in lower global industry output and higher lumber prices than the three alternatives (i.e. stock change, production, and atmospheric flow). The differences between the three alternative approaches, do not appear to be significant at the global level (differences in wood costs of \$0.25 per m^3 or less). In some countries, however, the differences between the three alternatives can be more than \$10 per m^3 of wood.
- The stock change approach can give rise to the elimination of accounted HWP emissions when import levels lead to increasing HWP pools that are greater than domestic harvest emissions.
- Calculating the land-filled pool using alternative values of half-lives led to relatively small changes in emission accounts. These changes were relatively constant across accounting approaches.
- The economic impact of emission changes depended on the level of these charges
- High carbon prices led to persistent change in coniferous sawlog harvest levels and higher prices in softwood lumber markets. We expect similar responses in other forest product markets including pulp and paper. Their raw material costs would increase since the emission tax increases harvesting costs, and lower output by the softwood lumber sector reduces residual supply to pulp mills.
- Low carbon prices led to higher price in these markets as consumption levels recovered.
- Higher prices under both low and high carbon values could signal product substitution.

REFERENCES

Borjesson, Pal and Leif Gustavsson. 2000. Greenhouse gas balances in building construction: wood versus concrete from life-cycle and forest land-use perspectives. *Energy Policy* 28:575-588.

Cooper, C.F. 1983. Carbon storage in managed forests. *Can. J. For. Res.* 13:155-166.

Dias, A.C., M. Louro, L. Arroja, I. Capela. 2005. The contribution of wood product to carbon sequestration in Portugal. *Ann. For. Sci.* 62: 903-909

Intergovernmental Panel on Climate Change. 2003. Good practice guidelines for land use, land use change and forestry, Chapter 3, Annex 3a1

Intergovernmental Panel on Climate Change. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories http://www.ipccggip.iges.or.jp/public/2006gl/ppd.htm Chapter 12, Volume 4.

Lippke, B., J. Wilson, J. Perez-Garcia, J. Bowyer and J. Meil. 2004. CORRIM : Life-cycle environmental performance of renewable building materials. *Forest Products Journal* 54(6): 249-255

Nabuurs, G. J., R. Sikkima. 2001. International trade in wood products: its role in the land use change and forestry carbon cycle. *Climatic Change* 49: 377-395

Schlamadinger, B. , G. Marland. 1996. The role of forest and bioenergy strategies in the global carbon cycle. *Biomas and Energy,* 10(5/6):275-300

Skog, K. E. and G. A. Nicholson. 1998. Carbon cycling through wood products: the role of wood and paper products in carbon sequestration. *Forest Products Journal 48,* 75-83

Winjum, J.K. , S. Brown, and B. Schlamadinger . 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44, 272-284