Assessing the Market Benefits of Reducing Deforestation: A General Equilibrium Investigation

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Abstract

Deforestation is one of the major sources of greenhouse gases (GHG) emissions, accounting for around 17% of total global GHG discharges. As the role forests play in the global carbon cycle has been widely recognized, several studies analysing the potential contribution of avoided deforestation credits in a carbon market have already been performed, showing that these credits should play a substantial role in an overall portfolio of mitigation strategies. Using a dynamic, multiregional Computable General Equilibrium (CGE) model, the ICES model (Intertemporal Computable Equilibrium System), this paper follows a novel approach, since deforestation emission reductions are not linked to a global carbon market, as commonly used. Instead, we use a global warming approach which provides an additional valuation criteria: the market general equilibrium value of halting/reducing deforestation, based on climate change impacts. This exercise consists on the formulation of a scenario where carbon emissions from deforestation are reduced by 50% and 100%, thereby producing a different CO2 concentration levels in the atmosphere and a corresponding variation in temperature. Those changes in temperature in turn impact the economy at various levels, and the corresponding indirect effects are then assessed. Moreover, such an exercise may provide additional information to policy makers considering the creation/participation of an international fund to protect tropical forests. In fact, market valuation for avoided deforestation can be provided not only for a complete halt of deforestation but also for different reduction targets. Finally, and taking advantage of the dynamic feature of the model, different paths for a same global level of reduced deforestation are simulated, shedding new lights on the temporal value of reduced deforestation.

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1 Introduction

Forests are one of the richest biological systems on earth. Almost 90% of the total terrestrial biodiversity is found in these ecosystems encompassing a major plant and animal genetic bank. Moreover, forests play a major role on world carbon cycle, regulating climate by sequestering and releasing CO_2 into the atmosphere. A recent study estimated that around 1 trillion metric tons of CO_2 are currently stocked in wood biomass. This number increases to three or four times if also taken into account below ground carbon (UN FAO, 2006). On the other hand, deforestation is the second main cause of global anthropogenic greenhouse (GHG's) emissions, accounting for around 17% of total annual atmospheric carbon release (IPCC 2007).

A wide literature on forest ecosystem valuation is already available. Lindhjem (2007), through a meta-analysis approach, analyzed 20 years of stated preference research valuing non-timber benefits in Norway, Finland and Sweden. Using a hedonic price model, Chomitz et al. (2005) assessed the land use opportunity costs for land owners in southern coastal Bahia, an important part of the Atlantic Forest hotspot along the Brazilian coast. They found that remaining land under forest has a market value 70 per cent below comparable cleared land. Another line of research has analyzed how ecosystem services impact economic activity. Costanza et al. 2007, found strong positive relationship between biodiversity and Net Primary Production –NPP- under some temperature regimes, meaning that a biodiversity changes correlates with a change in NPP. Finally, Costanza et al. 1997 estimated that ecosystem services contribute approximately $42 Trillion /yr globally to human welfare in 2004US$.

While the valuation of forest ecosystems is once again at the centre of environmental economics literature, the prominence of the climate change debate on the international policy arena has triggered studies focusing on a very specific type of service – carbon sequestration. Several studies have estimated the costs of reducing carbon emissions trough deforestation. Kindermann et al. (2008) has compared these estimates from three different global forestry and land-use models. According to their analysis, lowest-cost avoided deforestation regions could provide 2.8-4.7 of Gt of CO_2 during the 2005–2030 period at a 100$ per ton of CO_2. Other analysis using integrated assessment models assessed the potential of deforestation and other forest/land use change mitigations in an overall portfolio of climate change options. Sohngen and Mendelsohn, 2003 and Tavoni et al., 2007 concluded that forestry could cost effectively account for 30% of overall abatement across the century. More recently, Bosetti et al. (2009), considering only avoided deforestation opportunities, found that the total costs of a program for stabilizing greenhouse gas concentrations at 550 ppmv of CO_2 equivalent are lowered by a 10-23%, depending on the considered set of avoided deforestation supply curves. Moreover, reduced emissions from deforestation and forest degradation could enable a reduction of 20ppmv of CO_2 equivalent concentration without policy costs increase.

In this study we also focus on carbon sequestration services but we follow a different approach, taking into account a global warming approach that can be translated into climate change impacts affecting our economic system. This paper is a first attempt to measure the value of reducing deforestation by considering the final indirect effects of climate change on regional economies. The following section explains first the valuation methodology based on an integrated climate change impact assessment within a computable general equilibrium framework. Section 3 describes the introduction of deforestation activities in ICES, the CGE model used for this exercise, while section 4 presents a summary of the values obtain with this method. Finally section 5 concludes.

2 Carbon sequestration service valuation in a climate change scope: The temperature equivalent methodology

For the valuation of the carbon sequestration service provided by forests, this paper follows a novel approach, since deforestation emission reductions are not linked to a global carbon market, as commonly used nowadays. Instead, we consider a global warming approach which, to the best of our knowledge, has never been performed under a CGE modelling framework. With this methodology it is possible to provide an additional valuation criteria based on the climate change impact assessment methodology. Furthermore, we could call this criteria the market general equilibrium value of halting/reducing deforestation, since the evolution of that activity will have an influence on future global warming.

Changes in deforestation alter the GHG's balances between land sinks and the atmosphere, thereby producing a different CO2 concentration level in the atmosphere and a corresponding variation in temperature that can be defined over a period of time. That change in temperature in its turn impacts the economy at various levels that can then be assessed through the use of the methodology developed for climate change impact assessment within a CGE framework described in detail in the next section. Accordingly, that assessment methodology takes advantage of the hypothesis about changes in temperature to formulate possible economic effects. Moreover, the evolution of deforestation will provoke variations in temperature according to the GHG release of that activity.

With these facts in mind it is possible to estimate the expected impacts according to different deforestation paths and consequently compute the corresponding effects on the economy. To compute the different temperature changes according to the deforestations rates we use a reduced climate module such as the one present in the DICE 2007 model (Nordhaus, 2008). This climate module allows changing the emissions related to land use and deforestation and then compute what would be the variations in temperature taking into account the carbon cycle and anthropogenic GHG emissions.

Then we use a dynamic, multiregional CGE model (ICES) to first build a scenario where all climate change impacts are assessed assuming business as usual deforestation rates. We then proceed to a second one, where emissions from deforestation are reduced and consequently there is a lower increase in temperature. On the basis of this new information, we then re-estimate all of the impacts considered within the new deforestation scenarios and recalculate new macro-regional GDP effects. The differences between climate-change impacts on GDP considering the original and the new carbon sequestration levels and temperatures are used as an approximation of the general equilibrium value of the changes in forest's carbon sequestration service.

2.1 Climate change impact assessment

There are some studies that assess the economic effects of different climate change impacts using a static computable general equilibrium (CGE) model (Berritella et al., 2006; Bosello et al., 2006; Bosello et al., 2007; Bosello and Zhang, 2006) and also a recursive dynamic one (Eboli et.al., 2009). This paper builds over that experiences to provide a more comprehensive valuation of impacts in a more detailed regional economic system, not just restricted to direct costs but considering in addition, the economic reactions triggered within economic systems by those impacts.

The peculiar feature of CGE models is market interdependence. All markets are linked, as factors of production are mobile between sectors and internationally, each change in relative prices induces a cost-minimizing input reallocation in the entire economic system. This is also true for the demand side: responding to a scarcity signal in one market, utility-maximizing consumers readjust their entire consumption mix. As a consequence, CGE models can capture and describe the propagation mechanism induced by a localized shock onto the global context via price and quantity changes, and vice versa. Moreover, they are able to assess the "systemic" effect of these shocks, or more specifically, the final welfare or general equilibrium outcome which is determined after all the adjustment mechanisms at play in the economic system have taken place. The final impact on national GDPs summarizes these “higher order” effects which are usually very different from the initial impacts; this last difference quantifies market-driven adaptation.

In this approach we quantify market-driven adaptation, applying a CGE model developed for this purpose: ICES which is a recursive dynamic model, running from 2001 to 2050. It has been calibrated to replicate regional GDP growth paths consistent with the A2 IPCC scenario and has then been used to assess climate change economic impacts for a 1.2 °C and a 3.2 °C increase in 2050 wrt 2000, which is the likely temperature range associated to that scenario. The average world temperature data has been downscaled to ICES regions through data elaboration from Giorgi and Mearns (2002). The regional and sectoral detail of ICES adopted for this exercise are reported in annex 1.

It is evident that economics is not independent from other disciplines; it comes into play only after climatic changes have been translated into physical consequences (impacts) which are then able to induce a change in human activities. This study initially assessed the physical implications of an extended set of climate change impacts through a comprehensive survey and meta analysis of the available literature. It then proceeded to transform them into appropriate changes in key economic variables, suitable to be used as an input to the ICES model. This was done representing climatic impacts as changes in productivity, supply or demand for different inputs and/or outputs of the model, as reported in Table 1.

Table 1: Climate-change impact analyzed within this assessment

Supply- side impacts
Impact on labour quantity (change in mortality – health effect of climate change)
Impacts on labour productivity (change in morbidity – health effect of climate change)
Impacts on land quantity (land loss due to sea level rise)
Impacts on land productivity (Yield changes due to temperature and CO2 concentration changes)
Demand-side impacts
Impacts on energy demand (change in households energy consumption patterns for heating and cooling purposes)
Impacts on recreational services demand (change in tourism flows induced by changes in climatic conditions)
Impacts on health care expenditure

To determine the economic consequences of the different impacts considered with the ICES model, these need first to be translated into changes in economic variables existing in the model. Accordingly, land losses due to sea level rise have been modelled as percent decreases in the stock of productive land by region (Bosello *et al*., 2007); changes in mortality/morbidity have been modelled as changes in regional labour productivity (Bosello *et al.,* 2006); changes in land productivity by crop is already in the format of suitable input as ICES includes factor specific productivity as an exogenous parameter (following Tol, 2002). In these three cases, variables exogenous to the model are involved and their modification is straightforward.

Changes in tourists expenditure are modelled as changes in demand addressing the “market services sector” which includes recreational services (Bigano *et al.*, 2005); changes in health care expenditures are translated into changes in the public and private demand for the “non market services” sector which includes health services (Bosello *et al.,* 2006); changes in regional demand for oil, gas and electricity are modelled as changes in the demand for the output of respective industries (De Cian *et al*. 2007). In these last cases, variables which are endogenous to the model are concerned. To model their changes we adopted the following procedure; the computed percentage variations in the demands have been imposed as exogenous shifts in the respective demand equations. The implicit assumption is that the starting information refers to partial equilibrium assessment thus with *all prices and income levels constant*. The model is then left free to determine the *final* demand adjustments. Modification in demand structure however, imposes to comply with the budget constraint, so we compensated the higher level of public consumption with a lower lever of aggregate private consumption and, within the latter, we compensated the changed consumption of healthcare and tourism services and energy with opposite changes in expenditure shares for all other sectors. Table 2 summarizes the results of the direct impact assessment exercises (we report only year 2050 for exemplification) once they have been translated in suitable inputs for the ICES model.

It is evident that impacts are highly differentiated across regions and by typology. First, except for the case of land losses to sea level rise, they are not all necessarily negative. For instance, labour and land productivity could decrease in some regions, whilst increasing in others responding to regionally differentiated climatic stimuli and to different health characteristics of the labour force or crop and land characteristics. Consistently with a consolidated literature, land productivity tends to increase in mid to high latitude countries and decrease in low latitude countries. Labour productivity decreases where vector borne diseases dominate (the developing world) and tend to increase elsewhere where reduced cold related mortality overcompensates the increased heat related mortality. Second, impacts concern both the supply and the demand side of the economic system. In the first case they can be defined as “good” or “bad” quite unambiguously .[1] For instance a decrease in labour productivity due to adverse health impacts or in the availability of productive land due to sea-level rise are sure initial losses for the economic system. In the second case, when agents’ preferences change, determining the “quality” of the impact is more difficult. Indeed, when the demand for a given good or service (say e.g. energy demand) decreases, consumer expenditure is typically reallocated towards all the other goods and services. Consequently, the final impact on utility cannot be determined a priori, but only at the end of a fully fledged general equilibrium exercise.

Table 2: Climate change impacts as inputs for the ICES model (% change wrt baseline, reference year 2050 reference temperature +1.2, 3.1 °C wrt 2000)

Region	**Health**						**Land Productivity**					
	Labour Productivity		Public Expenditure		Private Expenditure		Wheat		Rice		Other Cereal Crops	
	1.2°C	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***
USA	-0.06	-0.18	-0.15	-0.28	-0.02	-0.03	-5.66	-18.89	-6.19	-20.37	-8.18	-25.15
Med_Europe	0.01	0.01	-0.10	-0.18	0.00	-0.01	-1.14	-8.33	-4.62	-18.94	-2.00	-11.84
North_Europe	0.06	0.16	-0.35	-0.88	-0.01	-0.03	1.50	-7.74	-5.90	-26.01	50.00	107.82
East_Europe	0.09	0.23	-0.47	-1.18	-0.01	-0.02	-1.13	-10.50	-2.64	-13.57	-4.60	-18.35
FSU	0.16	0.40	-0.41	-1.03	-0.01	-0.03	-6.12	-21.92	-7.47	-24.64	-9.73	-30.10
KOSAU	-0.43	-1.14	0.57	1.62	0.04	0.11	-7.78	-17.00	-2.90	-7.41	-3.11	-7.38
CAJANZ	0.09	0.22	0.03	0.24	0.00	0.00	-0.74	-12.33	-1.87	-14.31	-2.24	-15.17
NAF	-0.28	-0.69	2.02	4.42	0.10	0.23	-12.81	-42.14	-10.78	-41.00	-12.62	-45.97
MDE	-0.22	-0.34	1.34	1.82	0.10	0.14	-8.40	-32.40	-11.73	-38.52	-13.60	-43.12
SSA	-0.31	-0.84	0.47	1.34	0.07	0.19	-9.89	-26.33	-7.17	-21.43	-8.81	-25.36
SASIA	-0.11	-0.30	0.28	0.76	0.06	0.17	-2.96	-14.92	-4.89	-18.89	-6.61	-22.99
CHINA	0.14	0.37	0.65	1.80	0.06	0.17	0.93	-2.30	0.50	-3.61	-1.42	-8.25
EASIA	-0.11	-0.32	1.05	2.96	0.06	0.17	2.45	-0.54	0.34	-4.98	-1.15	-8.50
LACA	-0.14	-0.39	0.68	1.98	0.07	0.19	-6.69	-21.71	-6.61	-23.38	-8.25	-25.78

Region	**Sea-Level Rise**		**Tourism**				**Households' Energy Demand**					
	Land Losses		Market Services Demand		Expenditure Flows		Natural Gas		Oil Products		Electricity	
	1.2°C	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***	***1.2°C***	***3.1°C***
USA	-0.03	-0.05	-0.68	-1.76	-0.04	-0.11	-13.67	-35.31	-18.52	-47.84	0.76	1.96
Med_Europe	-0.01	-0.01	-1.86	-4.82	-0.02	-0.07	-12.68	-32.76	-15.84	-40.91	0.76	1.96
North_Europe	-0.02	-0.04	7.54	19.47	0.18	0.48	-13.75	-35.51	-15.52	-40.09	-2.20	-5.68
East_Europe	-0.02	-0.05	-2.46	-6.37	-0.006	-0.02	-12.93	-33.41	-17.39	-44.92	0.76	1.97
FSU	-0.01	-0.01	0.00	-0.01	0.00001	0.00003	-13.02	-33.65	-17.39	-44.92	0.75	1.94
KOSAU	-0.01	-0.01	-1.31	-3.39	-0.007	-0.02	nss	nss	-13.03	-33.66	12.31	31.81
CAJANZ	0.00	-0.01	5.54	14.30	0.13	0.35	-5.05	-13.04	-12.63	-32.63	-4.80	-12.40
NAF	-0.02	-0.04	-2.52	-6.52	-0.005	-0.01	-8.60	-22.22	-13.25	-34.22	5.95	15.37
MDE	0.00	-0.01	-4.67	-12.07	-0.50	-0.13	-13.12	-33.89	-17.39	-44.92	0.74	1.92
SSA	-0.07	-0.14	-4.43	-11.46	-0.008	-0.02	nss	nss	-6.51	-16.83	16.35	42.23
SASIA	-0.20	-0.43	-1.21	-3.12	-0.007	-0.02	nss	nss	nss	Nss	20.38	52.65
CHINA	-0.05	-0.09	-4.99	-12.90	-0.076	-0.20	nss	nss	nss	Nss	20.38	52.65
EASIA	-0.32	-0.66	-4.69	-12.11	-0.03	-0.07	nss	nss	nss	Nss	20.38	52.66
LACA	-0.02	-0.05	-2.68	-6.92	-0.06	-0.16	nss	nss	nss	Nss	21.37	55.20

Notes:
nss non statistically significant.
Expenditure flows in US$ trillions

[1] In this statement we disregard distributional implications across income groups or classes within the same country.

As said, demand-side impacts involve changes in demand for market services, changes in households’ energy demand and changes in non market services demand. The first two are somewhat larger than other impacts and affect sectors of the economy which generate high value added. Consistently with changes in tourism flows, the demand for market services increases in colder regions whose climatic attractiveness also increases. The result of the CAJANZ aggregate is dominated by the Canada effect. Market services’ demand decreases elsewhere; note particularly the negative impact on the “hotter” Mediterranean Europe. The use of gas and oil products declines everywhere as less products are necessary for heating purposes, while electricity demand increases especially in hotter regions reflecting a higher use of air conditioning.

This general picture points out that negative impacts are clearly concentrated in developing countries. This highlights their greater vulnerability to climate change with respect to developed economies which is a combination of a higher exposure and sensitivity.

2.2 Indirect economic effects

The economic implications of the impacts calculated in Table 2 are reported in Figures 1 and 2 (for the +1.2°C and +3.1°C warming scenarios respectively) and summarized for 2050 in Figure 3, which also shows the relevance of each single impact category. For the world as a whole, all the impacts jointly considered, can impose an additional cost ranging from 0.3% to 1% of GDP in 2050. However, these global figures hide important regional differences. While developed regions lose slightly, or even gain, as in the case of Europe and especially its northern part, developing regions can lose considerably more. For a temperature increase of 3.1 °C wrt 2000 for instance, South Asia, East Asia, Sub Saharan Africa and Northern Africa can experience a GDP contraction of 4%, 3%, 2.6%, 2.4%, respectively.

This final effect can be decomposed in its different determinants. For instance, it is interesting to note that the bulk of losses in developing countries is due to negative impacts on GDP driven by the dynamics in agricultural and tourism markets, while for developed countries climate change impacts on tourism activity, affecting the service sector, are of paramount importance. It is also interesting to note the time pattern of GDP impacts. In the case of Mediterranean Europe, eventually gaining from climate change, GDP performances with climate change are lower than those of the benchmark until 2035. They are higher only afterwards when positive terms of trade effects and international capital inflows counterbalance negative impacts.

It is worth commenting on the negligible impact on GDP exerted by land losses due to sea-level rise and those related to the health impact. This depends mainly on the fact that GDP measures the flow-value of goods and services produced within a region, and accordingly does not directly measure endowment (stock) losses. These are recorded only "indirectly" in GDP as long as they change the region's ability to produce goods and services.

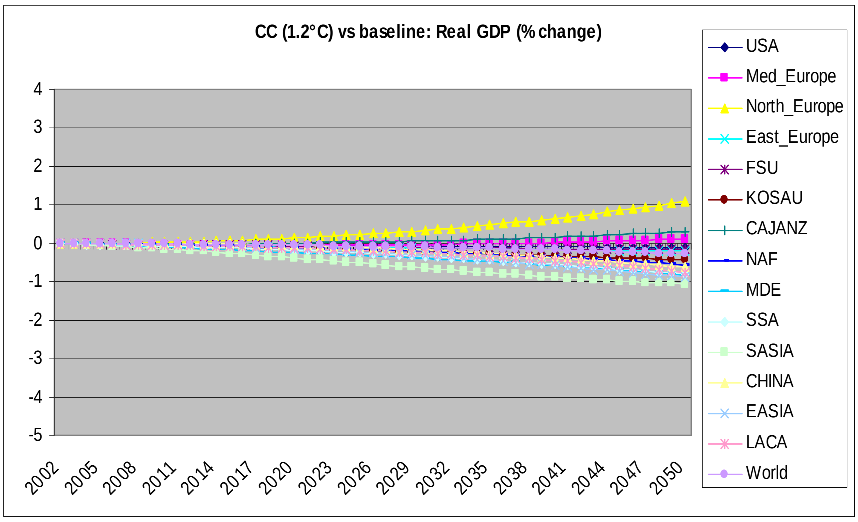

Figure 1. Final climate change impact +1.2°C wrt 2000: GDP

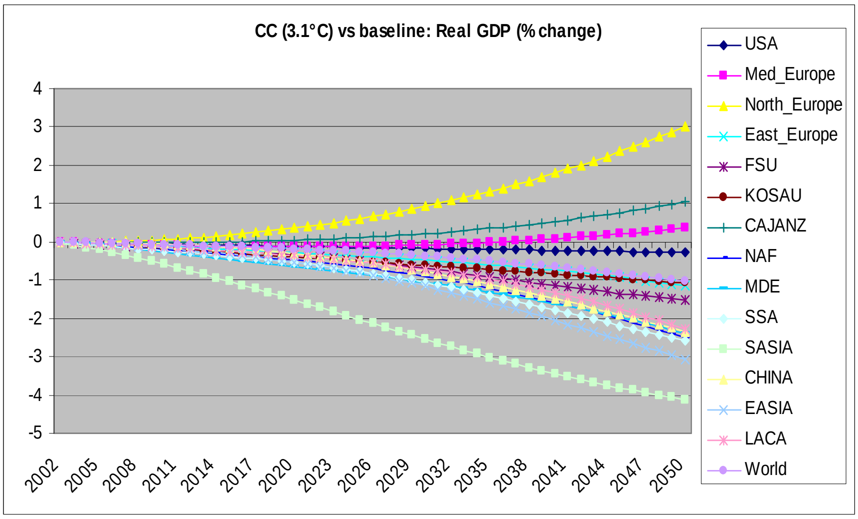

Figure 2. Final climate change impact +3.1°C wrt 2000

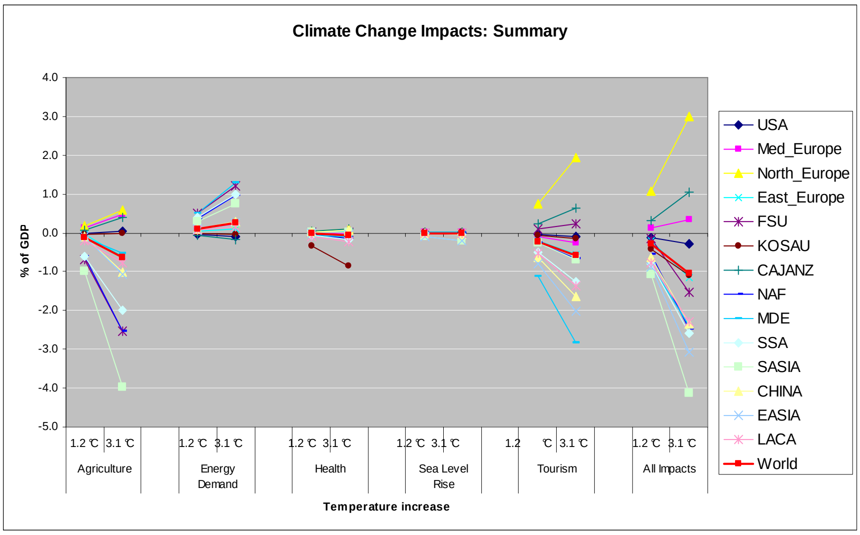

Figure 3. Final climate change impact:
% change in regional GDP wrt no climate change baseline (ref. year 2050)

This is why, for instance, catastrophic events deploying their effect on property values typically determine negligible impacts if measured in GDP changes. In addition, our assessment cannot capture other important cost determinants, for instance, displacement costs and not to mention the value of human life and capital losses are only partially considered.[2] As said, these could, at least in principle, be evaluated by a direct costing approach. Thus, the cost of climate induced sea level rise can be measured by multiplying the quantity of land (and/or capital and/or population "dwelling" that land) loss, times its "value"; health impact of climate change can be economically assessed multiplying disability adjusted life years (DALY) by a "value" of life. With a general equilibrium assessment costs are instead quantified by the different performance that the economic system can attain because of those initial losses.

However, a systemic assessment can capture the economic system's ability to adapt to the initial loss. Market-driven adaptation mechanisms are indeed crucial in determining the final cost of climate change as shown in Figure 4 which compares a "direct" with a "welfare" assessment.

[2] Indeed the simulation does include also some effect derived from capital losses. These however are simply modelled imposing the same percent of land stock losses to the capital stock. This was meant to capture some capital deterioration due to sea-level rise. We restrained from estimating more detailed capital losses from sea-level rise as any calculation is highly controversial involving often the evaluation of damages to urban, highly populated areas and rich of cultural values.

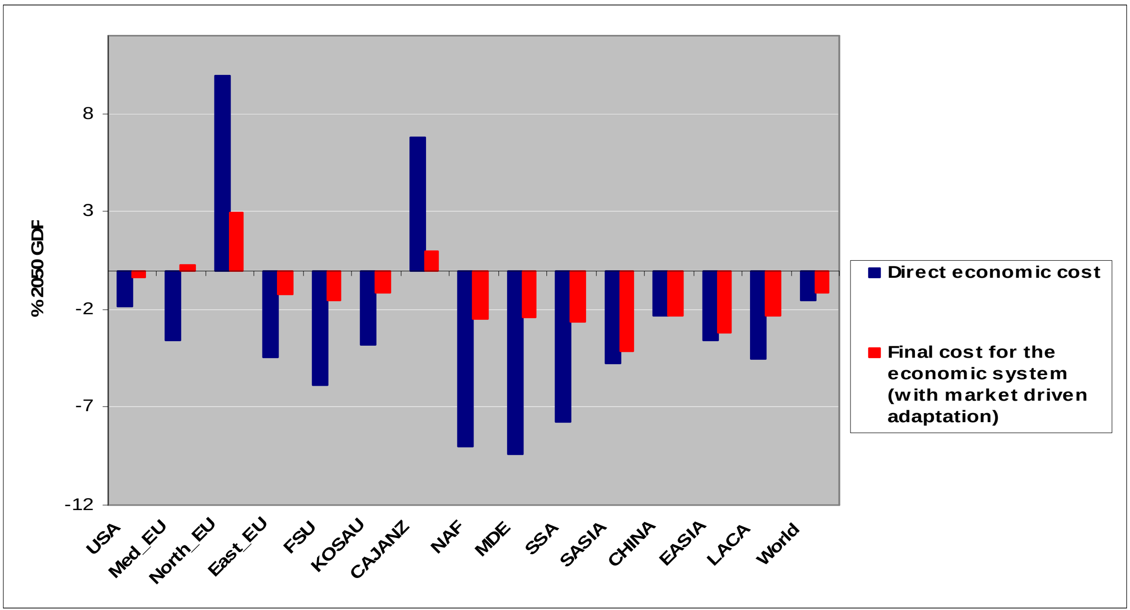

Figure 4. Direct vs final climate change costs (+3.1°C wrt. 2000 ref. year 2050)

Note: Direct economic costs are expressed as a % of 2050 GDP; final costs are expressed as % changes in 2050 GDP wrt the no climate change baseline value

Social economic systems show a substantial capacity to smooth out initial impacts. In general, when a factor of production becomes scarcer and thus more costly or less productive, it tends to be substituted with others which are cheaper or more productive. This also happens with goods and services in consumers' preferences. Thus, following market signals, market-driven adaptation operates as a partial buffer of initial shocks. This mechanisms is however "neutral" as it works indifferently with positive and negative shocks as can be appreciated in Northern Europe and CAJANZ.

In addition to factor and good substitution processes which always smooth out the initial impacts, our exercise captures another two adaptive mechanisms which can smooth or amplify the initial impact: terms of trade effects and international capital movements.

Compared to the benchmark, climate change impacts induce higher food prices, driven by the net decrease in agricultural productivity and lower fossil fuel prices, determined by the decrease in world energy demand in consequence of lower production. On international markets, this tends to favour developed regions which, can be defined as energy importers and sometimes food exporters as well, and to penalize energy exporters and more generally, developing countries. Indeed, terms of trade effects are particularly negative for the Middle east and North Africa, and positive for CAJANZ, USA, the three European aggregates and KOSAU.

The different penalization of economic activity also determines a different ability in attracting foreign investment. In the model these flows originate from the equalization of returns to capital which are higher in those regions where aggregated demand, and thus, prices increase (decrease), more(less). This is again the case of Northern Europe, CAJANZ and Mediterranean Europe which experience a net capital inflow.

Thus, developed regions, which have already experienced lower direct negative impacts than developing countries and as a result lower direct costs (if not gains), can also benefit from improved terms of trade and capital inflows showing a greater autonomous adaptive capacity. The implications of this can be grasped in the particularly enlightening case of Mediterranean Europe where initial negative impacts (of around 4% of GDP in 2050) are even turned into gains.

3 Including land use effects linked to deforestation

Like in every scheme where activities are interlinked and one action may have different repercussions in the rest of the system, reducing emissions from deforestation will affect directly and indirectly many economic activities. In the case of a CGE model as ICES it is more important to identify the sector which will be directly affected by the deforestation activities and then rely on its structure to elucidate the indirect effects. Following this line of reasoning, direct effects of REDD are related to i) Emission abatement thanks to reducing deforestation, ii) Land uses effects on agriculture, and iii) Land use effects on forestry.

Reducing emissions from deforestation brings about trade offs not only with timber production but also with agricultural output since deforested land could be used for agriculture. To model the effect of competition in land use we take into account the share of agricultural land coming from deforestation, so we have two land endowment types related to: a) a new stock of agricultural land coming from deforestation, and b) the stock of land previously devoted to agriculture. With this distinction it is possible to set exogenously the behaviour of these two land types and, moreover, correct the evolution of agricultural land coming from deforestation according to our assessment hypothesis. To do this we translate the tonnes of CO2 not emitted because of the reduced deforestation into the land endowment not used because it would not be available any more for agriculture, and calculate the net stock of deforested land freed for agriculture.

For the case of land use effect on forestry activities, we opt for a similar approach as agriculture. Timber can be produced either in managed forests plantations or just by exploiting primary forests through deforestation. For this reason we consider two types of sources for timber and establish their share for the initial year using IIASA data. Consequently we can set exogenously the behaviour of forest plantations and primary forest, and then calculate the net contribution of deforested primary forest for timber production. Actual timber production is the result of timber harvested in plantations and from the net production of deforestation.

4 The economic values of reducing deforestation at different rates

The assessment of climate change impacts performed on section 3 allows formulating a range of temperature increase which will be the base of the valuation of reducing deforestation in the future. Therefore we can count on a range with the lower bound related to the increase of 1.2 °C while the upper bound will be an increase of 3.1 °C, both with respect to 2000. These two initial estimations represent a state of the world in which deforestation follows a Business as Usual path. Furthermore, we have computed the correspondent variations of temperature in the case of two hypothetic deforestation scenarios. The first one represents a reduction of 50% of deforestation activities along the assessment period (2002-2050) with a correspondent decrease in temperature of 0.05 °C. The second scenario assumes that all deforestation activities have been completely halted in the same period, and correspondingly global temperature in 2050 decreases by 0.10 °C.

Curbing emissions through avoiding deforestation entails a reduction in global warming which in its turn reduce the climate change impacts in every region of the world. The final indirect effect on World's gross output has been computed for these additional scenarios and is illustrated as the net present value for the whole period with a discount rate of 3% in panel a) of figure 5. Global losses related to impacts for the lower bound of temperature increase (1.2°C) are close to 1.5 US$ trillion, while for the upper bound (3.1°C) are higher than 5.3 US$ trillion, depending on the deforestation rate hypothesized.

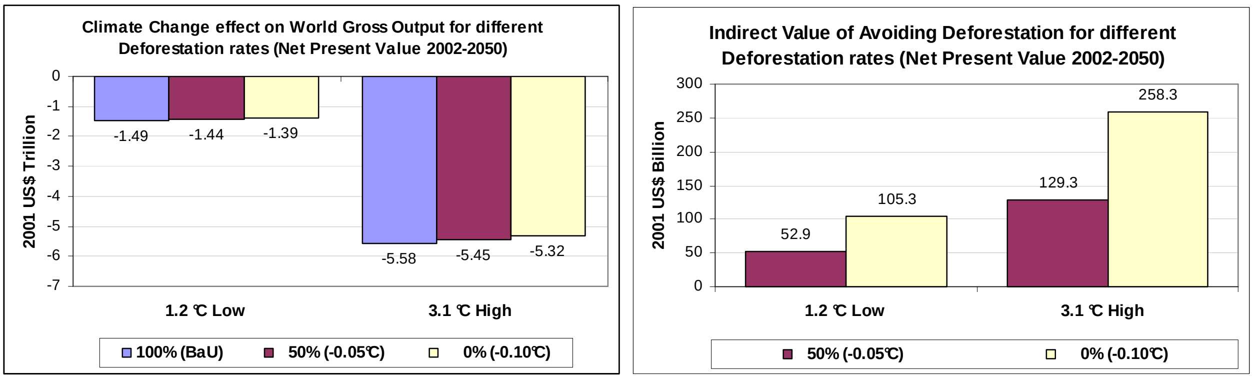

Figure 5. Indirect effects of reducing deforestation for the period 2002-2050

Those figures at the global level let us compute what could be the indirect market general equilibrium value of halting or reducing deforestation, just by comparing the business as usual deforestation with the other two scenarios. Panel b) of figure 5 illustrates these values for the lower and upper bounds of temperature variation along with the deforestation path. For the lower bound of 1.2 °C reducing deforestation to 50% of BaU represents a positive value of 53 US$ billion while completely halting it gives a benefit of 130 US$ billion as net present value for 2002-2050. When we consider the upper bound of 3.1°C those estimations are about 105 and 258 US$ billion respectively.

If we would like to compare these numbers with the existent valuation of carbon sequestration services we could use the value expressed as US$ per tonne of Carbon as shown in table 3. First it is possible to see that discounting the indirect effects on GDP produces a unitary value of 2.2 to 5.4 US$/TC that are about one third the undiscounted values 6.6 to 16.4 US$/TC. Notwithstanding, we believe that the values that this exercise provides should be regarded as an additional source of information for the carbon sequestration valuation and for climate policy assessments.

Table 3: Indirect value of avoiding deforestation (2001 US$ per tonne of carbon)

Avoided Deforestation	*Discounted*		*Undiscounted*	
	1.2 °C	*3.1 °C*	*1.2 °C*	*3.1 °C*
100%	2.22	5.44	6.57	16.44
50%	2.23	5.45	6.60	16.46

While the figures discussed above refers to a global value of reducing deforestation, it is possible to analyze the decomposition of that value since impacts have been estimated according to the regional disaggregation of ICES and their effects will be different depending on the geographic situation of every region and also on their market adaptive capacity. Figure 6 illustrates such decomposition showing that most regions in the world benefit from reducing deforestation through lower negative impacts from a reduced climate change. This is not the case of Northern Europe and CAJANZ since they belong to the compact group of countries that actually have more benefits than losses due to climate change. Even though these last mentioned regions register a loss, the order of magnitude is small compared with the benefit accrued to the rest of the world.

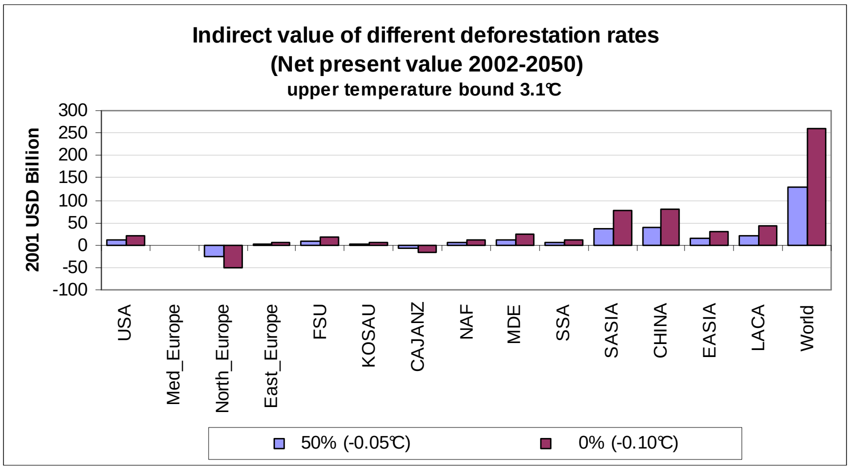

Figure 6. Regional decomposition of the Indirect effects of reducing deforestation

Apparently, developing regions are the most benefited from the reduction or even halting deforestation, but in order to analyse in detail this result and elucidate the final outcome it is important to consider also the effect of reducing deforestation specially in regions where deforestation is widely diffused such as SSA, EASIA and LACA. Looking at figure 6 it is possible to see that the benefit accrued to these regions is not as high as China or South Asia where deforestation activities are not so important as in those regions.

5 Conclusions

A wide number of studies have concluded that carbon sequestration should take part of a cost effective portfolio for climate change mitigation. In addition, as emissions related to deforestation account for about 17% of total annual atmospheric carbon release due to anthropogenic causes, it is not surprising that reducing this source of emissions has been in the centre of policy debate. While there are several studies focusing on the costs of reducing emissions trough avoided deforestation, this paper offers a first attempt to capture the indirect value of reducing or even halting deforestation by using a different approach based on global warming and climate change impacts. In doing so we compare a path of business as usual deforestation with a reduction of 50% of that activity and another one where deforestation is completely halted.

Considering the net present value for changes of Gross World Product (GWP) in the period 2002-2050 within a range of future increase in temperature of about 1.2°C to 3.1°C, we found that reducing deforestation to 50% of BaU represents a positive value of 53 US$ billion while completely halting it gives a benefit of 130 US$ billion for the lower bound of 1.2 °C. Estimations for the upper bound of 3.1°C are about 105 and 258 US$ billion respectively. Since these figures represent the final indirect effect of regional and global GDP, they should be considered as additional information to the carbon sequestration valuation and not as an alternative valuation. We also found that the discounted the indirect effects on GDP produces a unitary value of 2.2-5.4 US$/TC.

Moreover it is possible to decompose those values in regional terms to elucidate which are the regions that benefit the most of reducing deforestation. Regions that benefit the most are developing ones. Notwithstanding this fact, some regions where deforestation activities are more diffused like East and South Asia along with Latin America, report a reduced gain although their relative opportunity cost of deforestation would be higher.

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Annex 1: Economic model and benchmark

The economic implications of climate change have been determined using a multi-country world CGE model: ICES. Based on the Global Trade Analysis Project (GTAP) database version 6 and core model (Hertel, 1996), ICES develops a recursive-dynamic growth engine where a sequence of static equilibria are linked by the process of capital accumulation driven by endogenous investment decisions. The specification of the supply side of the model follows Burniaux and Truong (2002), which increase the detail in the description of energy production. The model runs from 2001 to 2050 in one year time steps.

As a first step, the benchmark for the period 2001-2050 has been built. Investment choices and thus capital stock are determined endogenously and other key economic variables in the calibration dataset of the model have been exogenously updated, to identify a hypothetical general equilibrium state in the future (this methodology is described in Dixon and Rimmer (2002)).

Our chosen reference is the social economic scenario A2 of the IPCC.

Since we are working on the medium to long term, we focused primarily on the supply side variables projecting changes in the national endowments of population/labour, land, natural resources, as well as variations in factor-specific and multi-factor productivity.

We obtained estimates of future regional labour stocks from UNDP (2008) whereas estimates of land endowments and agricultural land productivity have been obtained from the IMAGE model version 2.2 (IMAGE, 2001). A rather specific methodology was adopted to get estimates for the natural resources stock variables. Due to the uncertainty in the determination of their “true” amount we preferred to exogenously fix the price of the natural resources, making it a variable over time, in line with the GDP deflator, while allowing the model to endogenously compute the stock levels. In the specific case of oil, coal and gas we set their price evolution to mimic what was forecasted by EIA (2009).

By changing the calibration values for these variables, the CGE model has been used to simulate a general equilibrium state for the future world economy. This is the benchmark for all subsequent exercises. Therefore, this benchmark corresponds to the case in which no economic impacts of climate change have taken place, whereas the counterfactual scenarios consider the effects generated by one or more impacts. The regional and sectoral detail of ICES adopted for this exercise are in table A1.

Table A1. Regional and sectoral disaggregation of the ICES model

REGIONAL DISAGGREGATION	
USA:	United States
Med_Europe:	Mediterranean Europe
North_Europe:	Northern Europe
East_Europe:	Eastern Europe
FSU:	Former Soviet Union
KOSAU:	Korea, S. Africa, Australia
CAJANZ:	Canada, Japan, New Zealand
NAF:	North Africa
MDE:	Middle East
SSA:	Sub Saharan Africa
SASIA:	India and South Asia
CHINA:	China
EASIA:	East Asia
LACA:	Latin and Central America
SECTORAL DISAGGREGATION	
Rice	Gas
Wheat	Oil Products
Other Cereal Crops	Electricity
Vegetable Fruits	Water
Animals	Energy Intensive industries
Forestry	Other industries
Fishing	Market Services
Coal	Non-Market Services
Oil	