Renato Rosa
Univ Coimbra, CeBER, Faculty of Economics, Coimbra, Portugal
renato.rosa@fe.uc.pt
orcid.org/0000-0002-1155-9681
Ramiro Parrado
RFF-CMCC European Institute on Economics and the Environment (EIEE)
and Centro Euro-Mediterraneo sui Cambiamenti Climatici, Università Ca' Foscari,
Venice, Italy
ramiro.parrado@cmcc.it
orcid.org/0000-0002-0951-1013
Francesco Bosello
RFF-CMCC European Institute on Economics and the Environment (EIEE),
Centro Euro-Mediterraneo sui Cambiamenti Climatici, Università Ca' Foscari, and
Department of Environmental Sciences, Informatics and Statistics University Ca' Foscari
of Venice, Italy
francesco.bosello@cmcc.it

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Trading REDD Credits in International Carbon Markets: Interactions among International Trade, Carbon and Agricultural Markets

Transação de Créditos *REDD* em Mercados Internacionais de Carbono: Interações entre Comércio Internacional, Mercados de Carbono e Mercados Agrícolas

Renato Rosa
Ramiro Parrado
Francesco Bosello

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ABSTRACT
While several economic studies have looked into the role of REDD in climate policy, the interlinks between climate policy, international trade and agricultural markets have been only marginally considered. This paper adds to that discussion by developing a policy simulation exercise in which REDD credits can be traded in an international carbon market using a recursive dynamic computable general equilibrium model. The model was extended to incorporate abatement cost curves of avoided deforestation from a partial equilibrium study, and to account for the corresponding induced effects on land and timber markets. We conclude that REDD may significantly reduce policy costs. A large number of REDD credits entering the carbon market would allow regions pertaining to the climate policy agreement to systematically emit above their targets. These results confirm that policy design may require limits to the use of REDD credits along with the creation of long-term incentives to promote a greener economy. Finally, when international competitiveness effects are taken into account, we show that the use of REDD as a means to foster developing countries' participation in climate policy may not be sufficient.

Keywords: Reduced emission from deforestation and forest degradation; climate change policy; carbon markets; agricultural markets; general equilibrium.

JEL Classification: Q4; Q5; F1.

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1. Introduction

Forests are a two-edged sword in global climate policy. On the one hand, the reduction of forested areas is one of the major contributors to increasing average global temperatures. Tropical deforestation has been recognized as the second largest driver of anthropogenic global warming (IPCC 2007, 2014), accounting for roughly 17% to 20% of greenhouse gases (GHG) released during the 1990s (Gullison et al., 2007; Strassburg et al., 2010). On the other hand, by keeping current forest stocks, increasing forest areas or changing timber management practices, forests may help stabilize or even decrease current GHG concentrations.

Given the significant role played by forests in regulating climate and their potential contribution to an optimal climate change policy, it is not surprising that they have since long been central in international climate negotiations. Historically, however, issues like permanence, uncertainty or additionality have seriously hindered the inclusion of forests-based carbon sequestration activities into climate agreements. Despite those concerns, REDD has been supported by a large number of economic studies. These can be divided into two major categories. The first uses partial equilibrium forest/land use models to derive costs of reduced emissions from avoided deforestation. By comparing three global forestry and land use models Kindermann et al. (2008) offers a good synthesis of that literature. According to those authors, regions with the lowest avoided deforestation costs could provide 2.8-4.7 of Gt of reduced CO_2 emissions during 2005–2030 at 100$ per ton of CO_2. The second branch of that literature combines/links forest/land use models with macroeconomic models, which provide a more comprehensive description of the economic system. By doing so, these studies can jointly investigate the potential of forest-based carbon sequestration with other carbon mitigation options. Sohngen and Mendelsohn (2003), Tavoni et al. (2007) and Bosetti et al. (2011) provide good examples of such studies. The sectorial disaggregation in those studies, however, tends to be rather coarse and international trade absent or marginally taken into account. These two aspects are, however, particularly important to capture when examining the policy impacts of REDD. In fact, REDD directly affects carbon prices (and therefore energy-intensive sectors) and agricultural land availability (consequently, agricultural sectors). Impacts that will not only be differently disseminated throughout the production chain but that directly affect two sectors where international trade is particularly relevant and intense.

This study addresses those issues building upon a Computable General Equilibrium (CGE) model improved to take into account land use change and timber effects resulting from REDD activities. The explicit representation of international and intersectoral trade flows make CGE models particularly apt to this task. Factors of production are mobile between sectors within a country while commodities are exchanged in international markets, responding to scarcity signals provided by changes in relative prices. Therefore, when some ‘perturbation’ is applied to the economies under investigation, the model provides the induced final implications on their GDP, which is considered market-driven adaptation (all adjustments at work in the economic system that could smooth or amplify the initial impact).

The CGE land use modelling approach in this study builds upon a previous methodology developed in Bosello et al. (2015). Business-as-usual deforestation rates and carbon emission reduction resulting from financing REDD activities are provided by a global forest land use model, the IIASA model cluster (Gusti et al., 2008). The original CGE model is thus modified to account for new regional carbon emissions and changes in both agricultural land availability and timber flows due to avoided deforestation. Our methodology shares therefore some common aspects with that of Hertel et al. (2009). In contrast to that study, however, we do not apply the so-called Agro-Ecological Zone (AEZ) approach (Lee et al., 2009), but develop an alternative methodology enabling us to capture the trade-offs resulting from avoided deforestation, as reduced deforestation translates both in less land available to agricultural activities and to a lower natural resource input to the timber industry.

The role of forest carbon sequestration in global mitigation of climate change has been studied in Hertel et al. (2009), Golub et al. (2009), Golub et al. (2012) and Hussein et al. (2013) using a modelling approach considering the mitigation potential from CO_2 and non-CO_2 emissions as well as a carbon sequestration incentives. These studies use a comprehensive approach considering afforestation, avoided deforestation, and forest management, which correspond to the REDD+ definition. Golub et al. (2009) extends the analysis of Hertel et al. (2009), considering land-based and industrial mitigation, and find that land based sectors could contribute up to half of near-term mitigation at modest carbon prices, with most of the abatement coming from forests. Golub et al. (2012) find that a forest carbon sequestration incentive in developing countries is effective in controlling emission leakage in agricultural sectors under a unilateral mitigation policy only in Annex I countries. Hussein et al. (2013) conduct a disaggregated CGE analysis of the impacts of forest carbon sequestration incentive on poverty in developing countries and find that the overall effect of the incentive is to raise poverty in the majority of developing countries.

Only a restricted number of studies analyses REDD using a CGE framework. At the same time, most of them focus on assessing REDD mitigation potential and its associated costs.[1] Rose et al. (2012) analyze the implications of Total Factor Productivity growth patterns on deforestation. Overmars et al. (2014) couple a CGE model (LEITAP) with an Integrated assessment model (IMAGE) to estimate the opportunity costs of protecting forested areas. In contrast, Gurgel et al. (2007) uses a CGE framework that accounts for deforestation for policy analysis, but focuses on the economic consequences of biofuel's potential production. In fact, to the best of our knowledge, only Bosello et al. 2015 explicitly addresses the role of REDD in an international climate policy. The authors offer, however, a static exercise to investigate the mitigation potential of avoided deforestation resulting from introducing REDD credits in the European Trading Scheme. In this paper, we improve that analysis by using a refined version of the CGE model in a recursive dynamic setup with yearly time steps. In particular, our goal is to develop a simulation exercise that allows for the study of the interlinks between climate policy, international trade and agricultural markets when REDD credits can be traded in an international carbon market. To that end, we setup a policy scenario where a comprehensive climate agreement is in place assuming the Copenhagen Accord pledges. While this policy scenario does not correspond to the most recent state of affairs in international climate negotiations, note that it still serves the purposes of our analysis. It is in that context that the baseline and policy scenarios used in this study should be considered.

[1] For summarized reviews of these studies, we refer to Bosello et al. (2015) regarding REDD and climate policy and to Overmars et al. (2014) for the effects avoided deforestation and mitigation potential.

By using the above-mentioned framework, we add to the literature on the role of REDD in climate policies by studying the following questions: (i) to what extent the use of REDD credits can reduce deforestation rates? (ii) will REDD credits eventually flood international carbon markets? (iii) How will the selling of REDD credits affect REDD regions? (iv) What are the effects of using REDD on economic/carbon leakage? (v) What are the likely effects of REDD on world food production and prices? To answer these questions, we design a policy scenario where an international carbon market is implemented and all countries within the Copenhagen Accord have committed themselves to their announced high pledges. While this may seem a somewhat optimistic assumption, it provides a background that better enables us to assess the consequences of using REDD credits in an international climate policy agreement as: (i) REDD is most likely to be introduced into an international agreement involving a large number of participants; (ii) avoided deforestation has been often presented as an incentive to bring developing countries into the climate policy zone; (iii) concerns on an eventual flood of REDD credits in the carbon market require ambitious mitigation goals. Finally, taking into account this last political concern, different scenarios in which the use of REDD credits is limited are also considered.

Finally, taking into account this last political concern, different scenarios in which the use of REDD credits is limited are also considered. Section two introduces the CGE model and the corresponding modifications to include REDD as a carbon abatement alternative. Section three describes the selected scenarios for policy analysis, while section four discusses the implications of introducing REDD credits exchange in an international carbon market. Section 5 discusses the study's main findings.

2. Modelling Framework

The present analysis relies on ICES (Intertemporal Computable Equilibrium System), a recursive-dynamic CGE model. It is based on the Global Trade Analysis Project (GTAP) model (Hertel, 1997) as well as the GTAP-E model (Burniaux and Truong, 2002), and has been widely used for climate change impact and policy analysis (Bosello et al., 2015; Parrado and De Cian, 2014; Bosello et. al. 2012; Bosello et. al. 2011; and Eboli et, al. 2010). For this particular analysis, ICES has been modified to assess the implications of introducing REDD credits in a carbon market. A detailed model description of the model with the corresponding modifications are described in Appendix 1 and can be found as well in Bosello et al. (2015) and Parrado and De Cian (2014). More details about the aggregation, production tree and baseline assumptions are available on the Supplementary Materials.

On what follows we reproduce a summarized description of the main modifications done by Bosello et al. (2015), highlighting additional changes made to improve the modelling of avoided deforestation and its implications on an international carbon market. The climate policy module originally designed to induce emission reductions from fossil fuel use has been extended to account for emission reductions from avoided deforestation and the trading of the corresponding carbon credits. In addition, the effects of avoided deforestation have been taken into account through three different channels.

First, following Bosetti et al. (2011), we introduce avoided deforestation marginal abatement cost curves estimated by simulations of the International Institute for Applied Systems Analysis (IIASA) model cluster (Gusti et al. 2008), prepared for the Eliasch (2008) report. These abatement curves are time specific, providing the mitigation response to different carbon prices, changing every five years and are available for the following areas: Africa, Central and South America and Southeast Asia. These regions, according to Kindermann et al. (2008), correspond to the areas where avoided deforestation may be supplied at lowest possible costs. In addition, according to the deforestation rates reported by the model cluster (Gusti et al. 2008), these areas cover more than 94% of total world deforestation activity (2000 data). Emission reductions (abatement) from REDD ($REDD\_CO_2$) are a function of the abatement cost in terms of price per ton of CO_2 (pco_2) as in equation (1):

$$REDD\_CO_2 = f(pco_2). \tag{1}$$

This abatement is then subtracted from gross total emissions ($GROSSTCO_2$) originated by the ICES model in each region to get total emissions (TCO_2) following equation (2):

$$TCO_2 = GROSSTCO_2 - REDD\_CO_2. \tag{2}$$

In addition, we allow, for each region providing abatement from REDD, to sell $REDD\_CO_2$ credits in the international carbon market in exchange of emission reduction efforts. The revenues associated to the selling of REDD credits add to sellers' national income and reduce that of the buyers. This implies that the initial gross quota set for each region participating to a carbon market ($GROSSQCO_2$) is corrected by the abatement accomplished thanks to REDD efforts, and therefore in the carbon market the quota (QCO_2) becomes:

$$QCO_2 = GROSSQCO_2 - REDD\_CO_2. \tag{3}$$

Secondly, changes in deforestation due to REDD activities decrease available land for agricultural, forestry and pasture uses. This reduction in available land is defined with respect to baseline land availability under "business as usual deforestation rates". Data for baseline regional land availability were estimated using the IIASA model cluster. These data consist in baseline emissions from deforestation that were converted to additional available land for agriculture and pasture using information from the Food and Agriculture Organization (UN FAO, 2006).

Then, land availability is endogenously corrected in response to (lower) deforestation under different carbon prices according to the following equation:

$$LANDAGR_{r,t} = LANDAGR_{r,t}^{BAU} - LANDAGR_{r,t}^{REDD}, \tag{4}$$

where for each region r, at time t, the amount of available agricultural land in each simulation (LANDAGR), is corrected by subtracting from the available agricultural land under business-as-usual ($LANDAGR^{BAU}$), the amount corresponding to policy induced change in land due to avoided deforestation ($LANDAGR^{REDD}$).

We refine the land effects modelling from Bosello et al. (2015) to correct the fact that not all the land cleared from deforestation ($LANDREDD^{REDD}$) becomes available for agricultural purposes. To calculate the amount of land entering large scale agriculture after deforestation ($LANDAGR^{REDD}$) we use the conversion coefficient $\alpha_r<1$ in equation (5) following UN FAO (2001), and multiply it by the total land related to REDD. According to UN FAO (2001), roughly 10% of deforestation in Africa was due to conversion to this type of land use, while for Latin America and Asia this numbers is equal to 46% and 30%, respectively:

$$LANDAGR_{r,t}^{REDD} = \alpha_{r,t} * LANDREDD_{r,t}^{REDD}. \quad (5)$$

It is important to highlight two points: i) only α_r is valid for land use effects, therefore the remaining (1-α_r) simply represents land not used for agriculture, and ii) all abatement related to REDD efforts is considered when calculating net CO_2 emissions as well as for the exchange of REDD credits.

Thirdly, reduced deforestation decreases the volume of timber entering timber markets (TIMBSUPP). This is captured in the model following the same methodology as in equation (4):

$$TIMBSUPP_{r,t} = TIMBSUPP_{r,t}^{BAU} - TIMBSUPP_{r,t}^{REDD}. \quad (6)$$

Business as usual timber supply ($TIMBSUPP^{BAU}$) is endogenously adjusted to account for lower harvesting ($TIMBSUPP^{REDD}$) resulting from lower deforestation rates. To calculate the impact of non-harvested hectares on timber production from primary forest (cubic meters) we coupled data from FAO (UN FAO, 2006) with Brown (2000). This last provides information on harvesting from both primary forests and forest plantations.

3. Scenarios Description

In this section, we present the scenarios used in our simulation exercises. As mentioned above, the primary goal of this study is to shed new light on the interactions between international trade, carbon and agricultural markets resulting from the introduction of REDD credits in an international carbon market. The avoided deforestation marginal abatement cost curves estimated using the International Institute for Applied Systems Analysis (IIASA) model cluster (Gusti et al. 2008) are region and time specific. The cost curves, however, have been simulated for time steps of five years ending in 2020. Having that in mind, and for the sake of consistency, the model baseline year and scenarios for the world economy in this study thus refer to projections available during that period. In particular, we assume the national emission-reduction commitments following the Copenhagen Accord. More details are provided in the text below. While we acknowledge that using more recent data and emission reduction targets may be of higher interest, note that the assumptions here considered still serve our study's purposes. Finally, and to avoid misinterpretations, when presenting the results of our analysis in section 4, we refer to time periods instead of the corresponding calendar time.

Our simulations compare four different scenarios. The first one is the Reference scenario which is a no climate policy, business as usual benchmark spanning from 2001 to 2020. It is obtained perturbing the calibration year equilibrium (2001) in order to replicate the regional GDP growth paths of the A2 IPCC SRES scenario. This baseline also incorporates medium-term price evolution of major fossil fuels according to EIA (2009).

In the second scenario, under the name High Pledges, all countries commit themselves to the high pledges defined in the Copenhagen Accord (see Table 1), but REDD policies are not implemented. A fully integrated carbon market in the form of an Emission Trading Scheme (ETS) is implemented only for countries with emission reduction targets. Accordingly, China and India, whose targets are defined in carbon intensity terms, pursue independent domestic policies consisting in the introduction of a carbon tax to comply with their pledges. Both SSA and ROW regions have no commitment nor participate to the carbon market.

Table 1: Emissions reduction from High Pledges scenario for the ICES regions

Region	Target for 2020	With respect to 2001 levels
Australia	25% against 2000 levels	-33,3%
New Zealand	20% against 1990 levels	-51,9%
China	GDP carbon intensity reduction: 45% with respect to 2005	-
Japan	25% against 1990 levels	-41,2%
South Korea	30% against baseline	-22,1%
India	GDP carbon intensity reduction: 25% with respect to 2005	-
Canada	17% against 2005 levels	-24,5%
USA	3% against 1990 levels	-20,3%
EU27	30% against 1990 levels	-37,3%
Russia	25% against 1990 levels	7,7%
South Africa	34% against baseline	-31,8%
NORICE	39% against 1990 levels	-69,4%
EASIA *	(Indonesia)*	63,9%
LACA *	(Brazil and Mexico)*	7,8%
SSA	No target	-
ROW	No target	-

Note: For the regions flagged with * the target is defined imposing the emission reduction required for the individual countries inside it that have a commitment under Copenhagen: EASIA – Indonesia 26% emission reduction against baseline by 2020; LACA – Mexico 30% emission reduction against baseline by 2020; Brazil 39% emission reduction against baseline by 2020.

In the third scenario, High Pledges + REDD, mitigation policy targets are defined as above, but with the additional possibility for SSA, LACA and EASIA thereafter to enter the ETS selling REDD credits. Therefore, LACA and EASIA can potentially sell emission reduction credits coming from both reduced emissions compared to their targets and REDD activities. SSA that does not hold any pledge on emission reductions is, however, allowed to sell REDD credits on the basis of proven reduction in its "business as usual" deforestation activities. This option has been chosen as it provides the highest incentive for REED countries to engage in avoided deforestation actions and allows us to better evaluate its role in this policy context. Finally, in the fourth scenario, we simulate different restrictions to the use of REDD credits (High Pledges + Limited REDD).

A final remark regarding the policy modelling procedure. Given the dynamic nature of the model it is assumed that the desired mitigation target is gradually imposed starting from 2010 and becoming linearly more stringent until 2020 when all regions comply with their respective commitments. In what follows we refer to time using "time-periods" instead of calendar time, implying that our scenarios start at period 1, end at period 20 and climate policy is enacted at period 10.

4. Trading REDD Credits in the Carbon Market

4.1. Climate policy without redd – high pledges scenario

To better understand the implications of a climate change policy, and in particular of an international carbon market, it is first necessary to evaluate how the different regional annual emission targets compare to their business-as-usual emissions. Therefore, in this section we compare the "High Pledges" and the "Reference" scenarios. In absolute terms, the top 3 regions with higher emission reduction levels vis-à-vis to BAU are the USA, EU27 and Japan with a decrease of, respectively, 2695, 2108 and 675 Million Tons of CO_2 in period 20 (see Table A3 in the supplementary materials). This could be referred to as the absolute mitigation effort made by those countries. In relative terms however, where annual relative reduction is defined as percentage of the BAU emission scenario, this ordering changes to NORICE, New Zealand and Japan with a decrease of 69%, 60% and 46% in period 20, respectively (see Table A4 in the supplementary materials). This represents their relative mitigation effort.

The mitigation policy implemented originates a carbon price rising from 4.4$/t CO_2 in period 10 to 77$/t CO_2 in period 20 (see Table 2). The magnitudes of transactions, and the respective role different regions play in the international carbon market, tend to reflect the relative positions of their targets with respect to business-as-usual emissions. The main buyers of carbon credits in absolute terms are EU27 and Japan, while the main sellers are USA, EASIA and Russia (see Table 3). In relative terms, defined as the percentage of emissions traded credits with respect to the annual target, the main buyers are NORICE, New Zealand, Japan and EU27; while USA no longer ranks among the top 3 sellers that are now constituted by South Africa, EASIA and Russia.

Table 2: GDP and CO_2 prices with respect to BAU in period 20

		High Pledges	High Pledges + Limited access to REDD credits in the ETS market				High Pledges
		Without REDD	25%	50%	75%	100%	unlimited REDD
GDP % w.r.t B.A.U	Australia	-1,96%	-1,91%	-1,86%	-1,81%	-1,76%	-0,84%
	New Zealand	-1,39%	-1,36%	-1,32%	-1,28%	-1,24%	-0,60%
	China	0,49%	0,46%	0,43%	0,41%	0,38%	0,00%
	Japan	-0,58%	-0,57%	-0,55%	-0,54%	-0,52%	-0,21%
	South Korea	-2,70%	-2,63%	-2,56%	-2,48%	-2,41%	-1,24%
	India	0,99%	0,96%	0,93%	0,90%	0,87%	0,39%
	Canada	-1,32%	-1,28%	-1,24%	-1,20%	-1,16%	-0,47%
	USA	-1,10%	-1,07%	-1,04%	-1,01%	-0,99%	-0,48%
	EU27	-0,65%	-0,62%	-0,60%	-0,58%	-0,55%	-0,15%
	Russia	-8,99%	-8,75%	-8,51%	-8,28%	-8,05%	-3,98%
	South Africa	-6,76%	-6,61%	-6,46%	-6,31%	-6,17%	-3,27%
	NORICE	0,18%	0,17%	0,17%	0,17%	0,16%	0,20%
	EASIA	-2,11%	-2,05%	-1,99%	-1,93%	-1,88%	-0,98%
	LACA	-0,80%	-0,76%	-0,72%	-0,68%	-0,64%	0,00%
	SSA	2,12%	2,15%	2,16%	2,17%	2,17%	1,39%
	ROW	2,54%	2,48%	2,41%	2,35%	2,28%	1,38%
	Climate Policy Region	-0,87%	-0,85%	-0,82%	-0,80%	-0,77%	-0,34%
CO_2 Price I (period 20)	CO_2 ETS Price $/t	76,7	74,9	73,1	71,4	69,7	36,2
	% reduction w.r.t. policy without REDD	-//-	-2%	-5%	-7%	-9%	-53%
	China's Carbon tax $/t	7,5	7,5	7,5	7,4	7,4	6,9
	India's Carbon tax Price $/t	10,0	9,9	9,8	9,8	9,7	8,0
	REDD in period 20 as % of BAU Deforestation	-//-	3%	5%	8%	11%	75%

The resulting cost for the policy-participating countries as a whole equals a loss of 0.87% of GDP compared to baseline. Whilst in absolute terms the USA and the EU27 are the regions bearing higher policy costs; in relative terms as % of GDP, losses are higher in Russia, South Africa and South Korea (9%, 7% and 3% respectively – see Table 2). Interestingly enough, India and China observe a higher GDP growth in the policy than in the baseline scenario (1 and 0.5% respectively). Note that both regions pursue domestic polices targeting carbon intensity, which in fact allow them to increase emissions even though less than in the baseline. Consequently, they face significantly lower carbon prices than those observed inside the ET market (7.5$/t CO_2 for China and 10$/t CO_2 for India in period 20). As a result, these two regions become relatively more competitive, they produce more, especially carbon intensive commodities, (the so-called economic leakage effect), and enjoy more growth overcompensating the cost of reducing carbon intensity. This effect is even stronger in those regions without any pledge (ROW and SSA). Emissions outside the "climate policy zone" increase with a carbon leakage effect of 9% if measured against reductions from countries with emission targets, and 7% considering also the mitigation effort from China and India.[2]

Table 3: Carbon market trading in period 20

	ETS TRADE (Mtons of CO_2) *				ETS TRADE (2001 US$ million)			
	NO REDD	REDD			NO REDD	REDD		
		unlimited REDD	restriction			unlimited REDD	restriction	
			100%	50%			100%	50%
Australia	-5.87	61.73	2.92	-1.50	450	-2234	-203	110
New Zealand	12.77	18.27	13.57	13.17	-979	-661	-946	-963
Japan	329.70	485.82	353.29	341.57	-25277	-17582	-24632	-24980
South Korea	-49.83	39.75	-37.32	-43.58	3820	-1439	2602	3187
Canada	10.11	98.85	23.06	16.61	-775	-3578	-1608	-1214
USA	-488.78	646.88	-339.36	-414.41	37473	-23411	23660	30306
EU27	955.44	1437.12	1027.48	991.72	-73250	-52011	-71637	-72527
Russia	-263.39	64.09	-216.55	-240.01	20193	-2319	15099	17552
South Africa	-86.55	-20.34	-78.39	-82.52	6636	736	5466	6035
NORICE	31.02	35.65	31.79	31.41	-2378	-1290	-2217	-2297
EASIA	-341.34	-639.10	-356.15	-338.06	26169	23130	24831	24723
LACA	-103.28	-1985.40	-278.52	-196.84	7918	71853	19419	14395
SSA	0.00	-243.32	-145.81	-77.57	0	8806	10166	5673

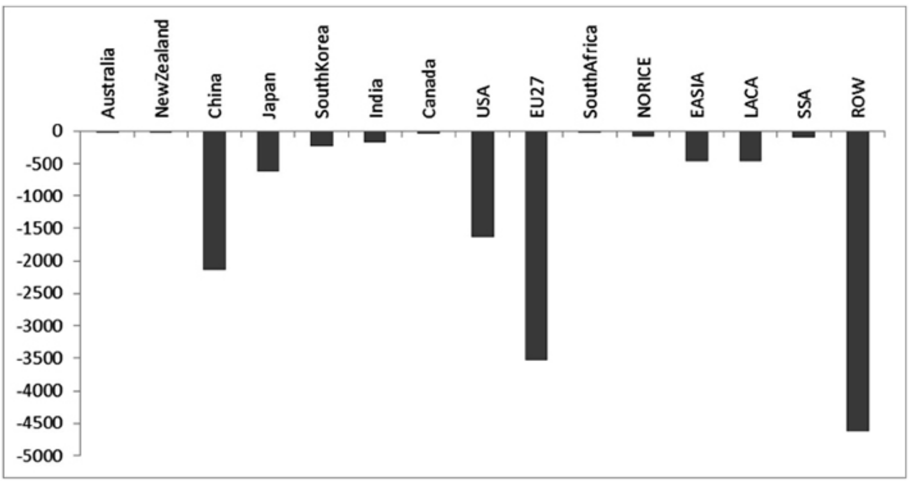
Note: Negative numbers are credit supplies.

The high policy costs occurring in Russia and South Africa deserve a more detailed analysis. The Russian sectors that most contribute to national exports, and that also rank highly in terms of total production, are all energy intensive. In particular, the main destination of these exports is EU27, that highly decreases its imports from Russia when climate policy is implemented, substituting them from regions outside the "climate policy zone". This decrease in Russian exports towards EU27 is particularly strong for Energy intensive industries (see Figure 1). In addition to this, China and ROW are, after EU27, the other two most important destinations of Russian exports. As EU27, these regions also sharply reduce their imports from Russia. In fact, together with EU27, they make up the top 3 regions with higher decrease in Russian exports. The reduction of Russian imports in these regions are due to a substitution of imports of energy intensive products for national production, a direct result of their productive systems being more competitive as they are outside the implemented carbon policy. In a nutshell, carbon leakage severely damages Russian production as, on the one hand its mains importers shift their demand towards areas not subject to carbon price and, on the other hand, regions outside the "carbon policy zone" substitute

[2] We present this difference due to the divergence of targets between China and India (defined as carbon intensity) with respect to the remaining countries inside the Copenhagen Accord (quantitative emission reduction targets)

their imports for domestic production. The importance of these industries in the Russian economy, combined with the major role played by climate policy free riding economies in Russian bilateral trade, make this country particularly vulnerable to carbon leakage under this policy design and explain the high policy costs observed for this region.

Figure 1: Russian energy intensive industries exports change wrt BAU in period 20 (2001 Million U.S. dollars)



In a similar way, the vulnerability of South Africa to carbon leakage explains its high policy costs. The main destination regions for South African exports are EU27, USA, Japan, and SSA. After the policy has been implemented these regions decrease their imports of energy intensive products from South Africa, and source them from relatively more competitive exporting regions.

4.2. Climate policy with redd – high pledges + redd

As expected, and in line with previous literature, we observe that climate policy costs can be significantly reduced by opening the carbon market to an unrestricted use of REDD credits. Those are now only 0.34% of GDP compared to baseline. The carbon price starts from 2.5\$/t CO_2 in period 0 to reach around 36\$/t CO_2 in period 20. The large number of REDD credits entering the carbon market allows regions participating to the climate policy agreement to systematically emit above their targets. Had the announced targets be met without REDD, total emission of the countries with pledges would have equalled 14.3 billion tonnes of CO_2 in period 20. Under the unrestricted REDD scenario, they reach 17.1 billion. This implies that the 2.8 billion tonnes of CO_2 emissions increase is compensated by avoided deforestation. REDD revenues as a share of GDP could represent up to 2% for LACA and SSA and 1% for EASIA (see Table A6 in the supplementary materials). The only seller of carbon credits that is not a REDD region is South Africa (note that South Africa was already the main seller in the market in the No REDD credits scenario). From the REDD regions group only EASIA sell carbon credits in addition to the ones resulting from REDD, and LACA sells only a fraction of the abatement attained with REDD using the rest to offset emissions within the region (see Table 4). While it is economically sounding that abatement is shifted to lower abatement costs activities, these results confirm that policy design may require the creation of long-term incentives to promote a greener economy. In effect, the option of limiting the number of REDD credits allowed in the market has been widely proposed in the policy arena. We discuss this option in the next subsection.

Note also that REDD reduces the costs of all countries initially loosing with the climate policy, but decreases the benefits of those gaining (i.e. SSA, China, India and ROW). Exceptions are Norway and Iceland that remain basically unaffected (see table2). This result is related with carbon leakage and international competitiveness effects. By reducing the abatement effort of countries with binding emission reductions, REDD alleviates the burden on their energy intensive industries, goods and services. These are thus more competitive in international markets as there is a less stringent environmental policy (read a lower carbon price signal). Conversely, for regions without emission reduction targets benefiting in the policy scenario due to the existence of a leakage effect, REED credits generates higher indirect costs than direct benefits, as they face regions with binding emission reduction that are now more competitive in the international market. Thus, for instance, SSA, would prefer not to sell REDD credits and loose the related financial inflows than to sell REDD credits to a group of countries whose products would consequently become cheaper and more competitive. This is a typical situation in which higher order effects, through competitiveness, prevail over first order effects (cost savings or direct money inflows). In fact, almost all agricultural sectors deteriorate their trade balances when comparing the No REDD scenario versus the REDD one (see Table A5 in the supplementary materials). Finally, REDD also helps to mitigate the increase in emissions occurring outside the climate policy zone. This is now equal to 4% if measured against reductions from countries with emission targets, compared to a 9% increase in the scenario without REDD credits.

4.2.1. *Effects on agricultural production and prices*

We start this section by first observing the effects on agricultural production and prices of a climate policy without REDD credits (*High Pledges scenario*). The introduction of a carbon price reduces world production of energy intensive sectors but increases the demand for agricultural products. Looking to this with more detail, one finds that agricultural production actually decreases in regions pertaining to the global carbon market (ETS zone), but that this reduction is compensated by the increase in demand occurring in the rest of the world (see Figure 2a). The aggregate increase in world production is therefore triggered by economic leakage resulting from climate policy implementation. Regions outside the climate policy zone experience higher GDP growth and consequently increase their demand, including the one for agricultural products. This increase compensates the reduction in regions pertaining to the policy area and, as a result of a higher demand, global agricultural products' prices increase (see Figure 3a). The only exception to this occurs in the rice sector, where the increase in demand of regions outside the carbon market is not enough to balance the reduction occurring in important producing regions belonging to that zone like Japan, South Korea and EASIA.

Figure 2: Change in production

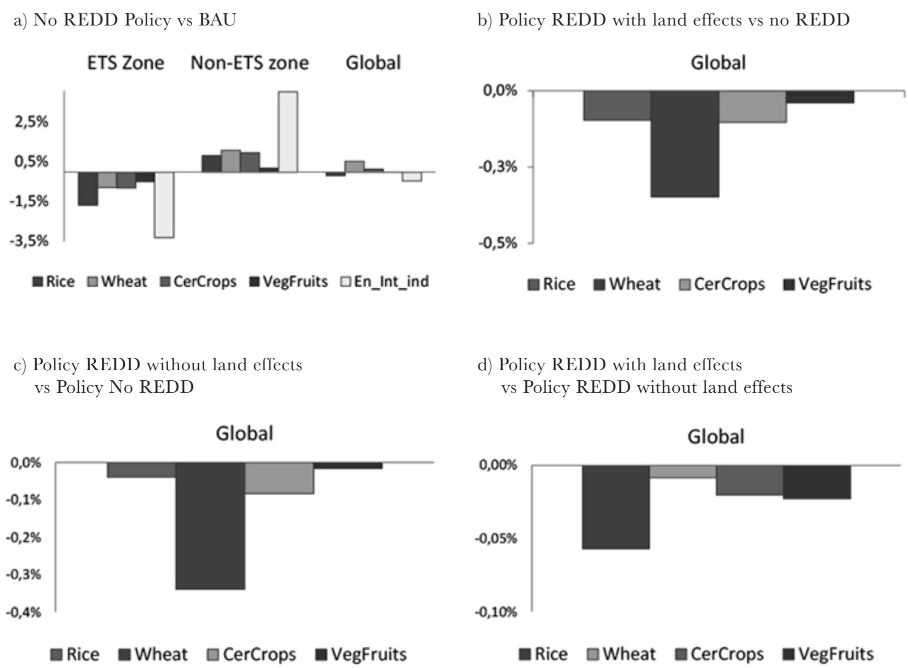
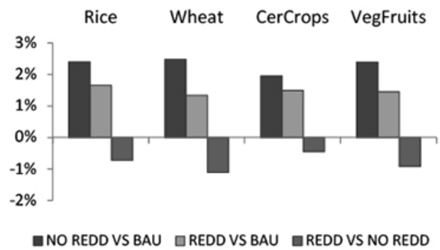


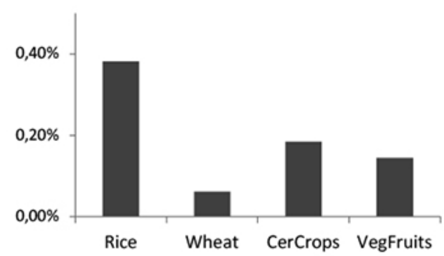
Figure 3. Change in world agricultural prices

a) Policy scenarios vs BAU



b) Policy REDD without land effects vs Policy No REDD

c) Policy REDD with land effects vs Policy REDD without land effects



When REDD credits are allowed to enter the international carbon market one should note that two conflicting impacts occur:

(i) The first is a supply effect. REDD reduces the total amount of available agricultural land and negatively impacts agricultural supply. C*eteris paribus*, this reduces world agricultural production and increase prices vis-à-vis a no REDD scenario.

(ii) The second is a demand side effect consisting of two parts. On the one hand, as carbon price decreases, economic leakage reduces. Regions not pertaining to the carbon market therefore experience lower GDP growth rates compared to a no REDD scenario and, as a result, reduce their demand for agricultural products. On the other hand, regions within the policy zone benefit from a lower carbon price and grow at higher rates than under a No REDD scenario, thus increasing their demands for agricultural products. The demand side effect is therefore ambiguous. Whether the final effect on world aggregate demand for agricultural products will be positive or negative will depend on which of these forces dominate.

How the introduction of REDD credits affect world agricultural production and prices is, therefore, ultimately an empirical question. In case the reduction of economic leakage dominates the demand effect, i.e. world agricultural demand is lower vis-à-vis to a no REDD scenario, world agricultural production will be lower under the REDD scenario while the effect on prices in unclear Alternatively, if world demand for agricultural products increases vis-à-vis to a no REDD scenario then prices should increase while changes in production are uncertain.

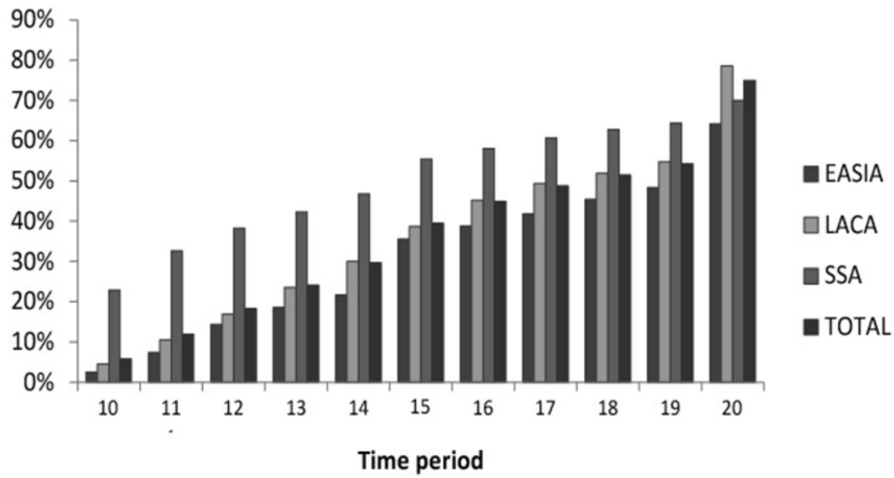
To disentangle these counteracting effects we run an additional simulation using the original ICES model, i.e., when the modifications described in section 2 are not active. By doing so, REDD credits will be available in the carbon market but will not affect agricultural land availability, i.e., we control for the supply effect identified in (i).

Results from this simulation reveal that world agricultural production decreases (see Figure 2c), reducing also agricultural products' prices (see Figure 3b). The demand side effect identified in (ii) is therefore negative. The reduction in agricultural production triggered by reduced economic leakage is stronger than the increase in demand occurring in the regions that benefit from a lower carbon price. This is a point that is noteworthy to highlight: the reduced leakage effect resulting from the introduction of REDD credits reduces world agricultural production vis-à-vis to a policy scenario without REDD credits, even if agricultural land availability remains unchanged.

It remains to answer, however, if lower agricultural land availability may still induce higher agricultural products' prices. Running now a simulation allowing for REDD credits, and using the modified model including land effects, we observe that global agricultural production further decreases while prices only marginally increase with respect to the simulation using the original ICES model simulation (see Figures 2d and 3c). This slight increase being so small that world agricultural product prices are still inferior to the climate policy scenario without REDD credits (see Figure 3a).

Concluding, the lower global demand of agricultural products induced by lower carbon prices outweighs the reduced land availability triggered by REDD credits. As a result, and while this may at first seem counter-intuitive, the introduction of REDD credits reduces both world agricultural production and prices vis-à-vis to a policy scenario without REDD (see Figures 2b, and 3a). As expected, the only exception to this general conclusion occurs on REDD regions (EASIA, LACA and SSA), where the land effect prevails and agricultural production decreases but prices increase due to higher scarcity of agricultural land. Globally, however, we have once again a fine example where indirect effects (carbon price reduction) of a climate policy prevail over direct ones (reduction in agricultural land).

Figure 4: Avoided deforestation (% BAU deforestation rates)



Finally, note that despite the sharp carbon price reduction, the use of REDD credits is still enough to trigger substantial amounts of avoided deforestation. In fact, even if in period 10 only 6% of business as usual deforestation is avoided, this number rapidly increases to 75% in period 20. While in absolute terms LACA is the region with higher avoided deforestation levels, SSA is the region with the highest avoided deforestation rate defined as a percentage of BAU deforestation (see Figure 4).

4.3. Introducing limits to the use of redd credits

In the unrestricted scenario a fairly large number of REDD credits enter the market and the carbon price drops to 36$ per tons of CO_2 in period 20. In order to prevent such a flooding into the carbon market, it has been often proposed the imposition of restrictions to the use of this type of credits. Such a policy envisages regulating carbon prices' decrease keeping thus incentives sufficiently high to foster research and development of renewable and more efficient technologies but also as an incentive for early participation of REDD countries in global climate policy.

In the present analysis, REDD restrictions are defined in terms of emission reduction efforts. According to our business-as-usual scenario, in the year immediately before climate policy implementation the aggregate emissions of regions participating in the international carbon market amount to 18676 million tonnes of CO_2. By period 20 this number has to decrease to 14305. A restriction of 100% therefore implies that during the time policy horizon the total amount of REDD credits allowed to enter the market cannot be superior to the required reduction, i.e. 4371 million tonnes of CO_2. Accordingly, for a restriction of 25% this last figure is equal to 1092 million tonnes of CO_2. With this in mind we have considered 4 restriction levels, 25%, 50%, 75% and 100%. We observe that, for the restrictions here considered, the carbon price decrease is significantly reduced. For a restriction equal to 25%, carbon price drops only by 2% in period 20 while this number equals 9% if the level of restriction is 100% (see Table 2). As expected, including REDD credits restrictions still generates policy costs savings, but to a much lower extent if compared to the unrestricted scenario. For the 25% restriction scenario, policy costs equal 0.85% in terms of GDP, while for the 100% restriction scenario GDP is reduced by 0.77% in period 20. Finally, a heavy restriction in the use of REDD credits also undermines the use of such a policy as a way to significantly reduce deforestation rates. For the 100% restriction scenario, avoided deforestation amounts to 6% of period 10 business as usual deforestation, rising only to 11% in period 20.

In light of the discussion made in the previous subsection, we conclude that EASIA and LACA are increasingly worse off as the restriction to REDD credits is more stringent (see table2). Accordingly, while such a policy aiming to control for carbon price decreases may create a more favourable economic environment to the development of cleaner technologies, conversely it may prevent countries with higher deforestation rates from entering into a global climate policy agreement. On the other hand, however, SSA who does not have a binding emission reduction target is actually unambiguously better off under the restriction scenarios here considered. In section 4.2 we have observed that the introduction of REDD vis-à-vis a policy scenario without REDD credits, actually damaged this region as it reduced carbon leakage. In contrast, however, when the use of REDD credits are limited, carbon prices only slightly reduce allowing this region to still reap the benefits resulting from the leakage effect. In addition, REDD revenues are still high for this region under restriction scenarios, as for SSA the reduction in quantities of sold REDD credits is almost compensated by the carbon price increase. By period 20, this last effect is actually so strong that SSA REDD revenues are higher under the 100% restriction scenario than under the unrestricted one.

5. Final Remarks

By using a modified global CGE model to take into account avoided deforestation induced effects this paper sheds new light on the use of REDD credits in an international carbon market. In addition to confirm previous results on the major role that such credits may play in climate change policy, we also reveal that changes occurring in international markets, namely in energy intensive sectors, are crucial in the design of optimal REDD policies. Those changes may be so important that they can actually dominate direct effects resulting from avoided deforestation activities. Such an analysis is out of the scope of typical partial equilibrium models or macroeconomic models that do not explicitly take into account international trade. Two examples are noteworthy to highlight. First, indirect effects occurring on international carbon markets may prevail over direct impacts. This is for instance the case regarding impacts on agricultural markets. By reducing carbon leakage, the use of REDD credits reduces agricultural products demand by regions outside the climate policy zone vis-à-vis to a policy without such credits. This demand reduction effect turns out to be stronger than the direct impact of reduced agricultural land availability triggered by avoided deforestation activities. As a consequence, the use of REDD credits alleviates pressure on world agricultural prices. Second, the use of REDD as a means to foster developing countries participation into climate policy may not be sufficient. Financial flows accruing from REDD revenues may not be enough to compensate for a reduction in free riding benefits. REDD credits provide a sounding instrument to reduce the increase of emissions occurring outside the climate policy zone, significantly reduces climate policy costs, may provide an effective instrument to reduce deforestation rates but other instruments are likely to be necessary to make REDD countries positively engage in international negotiations.

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Appendix

Baseline assumptions and database aggregation

The regional and sectoral detail of the model used for this study are represented in the following:

Table A1: Regional and sectoral disaggregation of the ICES model

Region	Sectors	
Australia	Rice	Non-Market Services
New Zealand	Wheat	
China	Other Cereal	
Japan	Vegetable Fruits	
South Korea	Animals	
India	Forestry	
Canada	Fishing	
USA	Coal	
EU27	Oil	
Russia	Gas	
South Africa	Oil Products	
NORICE	Electricity	
EASIA	Water	
LACA	Energy Intensive industries	
SSA	Other industries	
ROW	Market Services	

Note: NORICE denotes Norway and Iceland; EASIA denotes East Asia; LACA denotes Latin America and the Caribbean; SSA denotes Sub-Saharan Africa; and ROW denotes Rest of the World.

ICES solves recursively a sequence of static equilibria linked by endogenous investment determining the growth of capital stock from 2001 to 2050. For the baseline or Business as Usual scenario we relied in exogenous drivers for population, energy efficiency as well as fossil fuel prices projections. Assumptions on the evolution of population were taken from UNPD (2008), energy efficiency from Bosetti et. al., (2006), while major fossil fuel prices are based on EIA (2007) and EIA (2009). Regarding GDP, growth rates for the selected regions are reported in Table A2, and we used as reference the IPCC A2 scenario. Labour stock grows at the same pace as population while capital is cumulated following the recursive dynamics of the model. Finally, we changed labour productivity in order to replicate the target GDP growth rates.

Table A2: Selected growth rates for BAU scenario (% 2001-2020)

Region	GDP growth	Population	CO_2 emissions
Australia	52.4	20.9	17.5
NewZealand	59.2	18.3	20.8
China	222.7	11.1	133.3
Japan	35.5	-2.2	8.4
SouthKorea	46.8	0.0	11.3
India	142.9	30.3	62.7
Canada	54.1	18.0	12.2
USA	57.9	19.0	25.2
EU27	42.7	3.0	9.3
Russia	95.9	-9.8	46.2
South Africa	37.4	11.8	0.3
NORICE	30.4	12.7	-1.7
EASIA	177.1	24.4	79.9
LACA	92.5	24.3	32.4
SSA	122.9	58.1	85.6
ROW	120.9	31.8	60.8
World	67.72	23.5	45.75

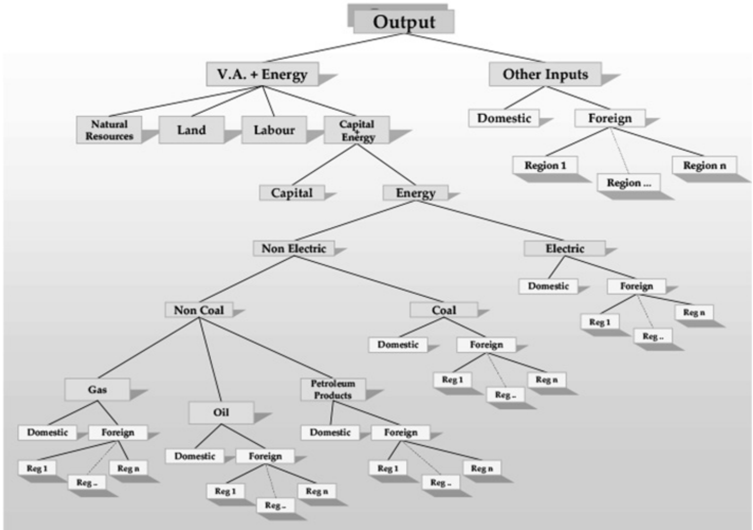
ICES technical description

ICES (Inter-temporal Computable Equilibrium System) is a top-down recursive-dynamic, multi-sector and multi-region CGE model developed mainly with the aim of analyzing climate change impacts and policies. In contrast to integrated assessment models, climate change damages are not endogenous to the model. However, ICES can be used to simulate the economy-wide impacts of climate change imposed as exogenous shocks to inputs of the model (Bosello et al., 2006, 2007, 2008; Bosello and Zhang, 2006; Eboli et al., 2010).

Supply side structure of firms

Each industry is modeled as a cost-minimizing representative firm taking prices as given. Output prices are given by average production costs. The production functions are specified via a series of nested CES functions. Domestic and foreign inputs are not perfect substitutes, according to the so-called "Armington" assumption. The production tree is reported in Figure A1.

Figure A1: Nested tree structure for industrial production processes of the ICES model



Regional subscripts have been omitted for convenience in the following equations. For a complete detail of all the remaining equations, interested readers may refer to Hertel (1997).

Final output of sector j (Y_j) is a function of a technological index (A_j), aggregate value added-energy composite (VAE_j), other intermediate inputs (M_j), and α_j are distribution parameters. The elasticity of substitution for the top nest (σ_M) has been set equal to 0, therefore, representing a Leontieff specification:

$$Y_j = A_j \left[\alpha_{VAE,j} VAE_j^{\frac{\sigma_{M-1}}{\sigma_M}} + \alpha_{M,j} M_j^{\frac{\sigma_{M-1}}{\sigma_M}}\right]^{\frac{\sigma_M}{\sigma_{M-1}}} \quad \text{(A1)}$$

Aggregate value added-energy output, VAE_j, is produced with Z_i primary factors (i = land, labor, natural resources, and a capital-energy composite, KE), with an elasticity of substitution σ_{VAE} and a distribution parameter, δ_{ij}:

$$VAE_j = \left[\Sigma_i \, \delta_{i,j} Z_{i,j}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}}\right]^{\frac{\sigma_{VAE}}{\sigma_{VAE}-1}} \quad \text{(A2)}$$

The capital-energy composite (*KE*) is produced by combining capital (*K*) and energy (*E*) as illustrated by equation A3:

$$KE_j = \left[\alpha_{k,j} K_j^{\frac{\sigma_{KE}-1}{\sigma_{KE}}} + \alpha_{e,j} E_j^{\frac{\sigma_{KE}-1}{\sigma_{KE}}}\right]^{\frac{\sigma_{KE}}{\sigma_{KE}-1}} \tag{A3}$$

The Energy (*E*) nest compounds Electricity (*EL*) with Non-Electric energy (*NEL*) and an elasticity of substitution ($\sigma_{ELY}=1$):

$$E_j = \left[\alpha_{EL,j} EL_j^{\frac{\sigma_{ELY}-1}{\sigma_{ELY}}} + \alpha_{NEL,j} NEL_j^{\frac{\sigma_{ELY}-1}{\sigma_{ELY}}}\right]^{\frac{\sigma_{ELY}}{\sigma_{ELY}-1}} \tag{A4}$$

Non-electric energy (*NEL*) is composed of Coal and Non-Coal energy, assuming an elasticity of substitution of $\sigma_{COAL}=0.5$:

$$NEL_j = \left[\alpha_{COAL,j} COAL_j^{\frac{\sigma_{COAL}-1}{\sigma_{COAL}}} + \alpha_{NCOAL,j} NCOAL_j^{\frac{\sigma_{COAL}-1}{\sigma_{COAL}}}\right]^{\frac{\sigma_{COAL}}{\sigma_{COAL}-1}} \tag{A5}$$

Liquid fossil fuels (*F*) are combined in a composite (*NCOAL*) also following a CES production function with the elasticity of substitution ($\sigma_{FF}=1$):

$$NCOAL_j = \left[\Sigma_i\, \beta_{i,j} F_{i,j}^{\frac{\sigma_{FF}-1}{\sigma_{FF}}}\right]^{\frac{\sigma_{FF}}{\sigma_{FF}-1}} \qquad i = \text{oil, gas, oil products.} \tag{A6}$$

The "Armington" assumption makes domestic (*DOM*) and foreign (*IMP*) commodities imperfect substitutes in accounting for product heterogeneity:

$$Mi = \left[\alpha_{dom,i} DOM_i^{\frac{\sigma_{dom}-1}{\sigma_{dom}}} + \alpha_{imp,i} IMP_i^{\frac{\sigma_{dom}-1}{\sigma_{dom}}}\right]^{\frac{\sigma_{dom}}{\sigma_{dom}-1}} \tag{A7}$$

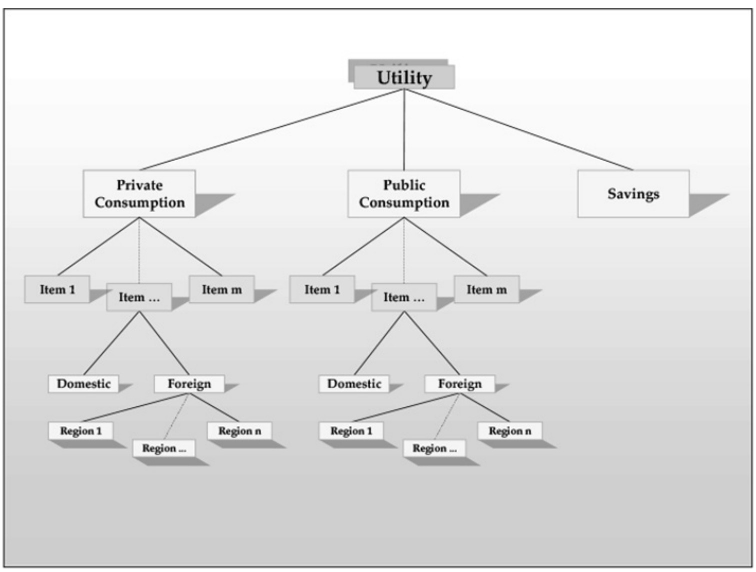
Imported commodities are a composite of commodity *i* from all source regions (*s*):

$$IMPi = \left[\Sigma_s\, O_{i,s} Y_{i,s}^{\frac{\sigma_{imp}-1}{\sigma_{imp}}}\right]^{\frac{\sigma_{imp}}{\sigma_{imp}-1}} \tag{A8}$$

Households' demand side structure

A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour, capital, see Figure A2). Capital and labour are perfectly mobile domestically but immobile internationally. Land and natural resources, on the other hand, are industry-specific. Income is used to finance three classes of expenditure: aggregate household consumption, public consumption and savings. The expenditure shares are generally fixed, which amounts to saying that the top-level utility function has a Cobb-Douglas specification.

Figure A2: Nested tree structure for final demand of the ICES model



The top-level demand system is described by a Cobb-Douglas utility function where the aggregate utility involves the per-capita utility from private and government consumption, and real savings:

$$U = CU_P^{w_P} U_G^{w_G} U_S^{w_S}, \tag{A9}$$

where U is the per-capita aggregate utility while U_P, U_G, and U_S are, respectively, the per-capita utility from private and government consumption, and real savings; whilst ω_i represent their distributional parameters. Public consumption is split in a series of alternative consumption items, again according to a Cobb-Douglas specification. However, almost all expenditure is actually concentrated in one specific industry: Non-market Services. Private consumption is analogously split in a series of alternative composite Armington aggregates.

However, the functional specification used at this level is the Constant Difference in Elasticities (CDE) form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods. The CDE demand system is characterized by an indirect utility function of the form:

$$1 = \Sigma_i \, B_i U^{Y_i R_i} \left(\frac{P_i}{X} \right)^{Y_i} \tag{A10}$$

with P_i, being price of commodity i, X the household expenditure, while B_i, y_i, and R_i are positive parameters.

Investment is internationally mobile: savings from all regions are pooled and then investment is allocated so as to achieve equality of expected rates of return to capital. In this way, savings and investments are equalized at the world, but not at the regional level. Because of accounting identities, any financial imbalance mirrors a trade deficit or surplus in each region.

Recursive dynamics: Capital and debt accumulation

The ICES model generates a sequence of static equilibria under myopic expectations linked by capital and international debt accumulation. Growth is driven by changes in primary resources (capital, labor, land and natural resources). Dynamics are endogenous for capital and exogenous for other primary factors. Capital accumulation is the outcome of the interaction of: i) investment allocation between regions and ii) debt accumulation. Savings are pooled by a world bank and allocated as regional investments according to:

$$\frac{I_r}{Y_r} = \phi_r \, exp\left[\rho_r \left(r_r - r_w\right)\right], \tag{A11}$$

where I_r is regional annual investment, Y_r is regional income, r_i is regional and world returns on capital. ϕ_r is a given parameter that represents the average propensity to save and ρ_r is a flexibility parameter related to investment supply sensitivity to return differentials. The rationale of equation (A12), follows the ABARE GTEM model (Pant, 2002). Capital stock accumulates over time in a standard relationship with a constant depreciation:

$$K_r^{t+1} = I_r^t + (1-\delta) K_r^t. \tag{A12}$$

There is no equalization of regional investments and savings from equation (A12), so any excess of savings over investments equals the regional trade balance (*TB*). The stock of debt evolves by considering the trade balance as follows:

$$D_r^{t+1} = TB_r^t + D_r^t. \tag{A13}$$

Finally, foreign debt is serviced every period on the basis of the world interest rate r_w.

CO_2 emissions

The GTAP-E model uses average emission coefficients for each fossil fuel (Coal, Oil, Gas and Oil products) which are constant across sectors and regions of the world economy (Truong and Lee, 2003). We applied the same average emission coefficients in ICES to compute the corresponding emissions to the combustion or use of fossil fuels, but not their transformation as in the case of oil being refined and processed to obtain oil products. This means that the database we used provides information about emissions released to the atmosphere when a fossil fuel is burnt during the production process of a commodity or final consumption by households.

Table A3: Absolute mitigation effort s with respect to BAU in period 20 (Mtons of CO2)

Region	Pledge	High Pledges	High Pledges + Limited access to REDD credits in the ETS market				High Pledges
		Without REDD	25%	50%	75%	100%	unlimited REDD
Australia	-200	-206	-204	-202	-199	-197	-138
NewZealand	-26	-13	-13	-13	-12	-12	-7
China	-	-1910	-1911	-1913	-1915	-1917	-1943
Japan	-675	-345	-339	-333	-328	-322	-189
SouthKorea	-183	-233	-229	-226	-223	-220	-143
India	-	-130	-131	-131	-132	-132	-140
Canada	-216	-206	-202	-199	-196	-193	-117
USA	-2695	-3184	-3147	-3110	-3072	-3035	-2048
EU27	-2108	-1153	-1135	-1117	-1099	-1081	-671
Russia	-584	-848	-836	-824	-813	-801	-520
SouthAfrica	-121	-208	-206	-204	-202	-200	-142
NORICE	-40	-9	-9	-9	-9	-9	-5
EASIA	-135	-477	-470	-464	-457	-450	-292
LACA	-341	-444	-435	-426	-417	-409	-216
SSA	-	31	32	33	34	35	20
ROW	-	635	622	610	597	584	330
World	-	-8698	-8613	-8528	-8443	-8357	-6221

Table A4: Relative mitigation effort s with respect to BAU in period 20 (in percentage)

Region	Pledge	High Pledges	High Pledges + Limited access to REDD credits in the ETS market				High Pledges
		Without REDD	25%	50%	75%	100%	unlimited REDD
Australia	-43%	-45%	-44%	-44%	-43%	-43%	-30%
NewZealand	-60%	-30%	-30%	-29%	-29%	-28%	-17%
China	-	-22%	-22%	-22%	-22%	-22%	-22%
Japan	-46%	-23%	-23%	-23%	-22%	-22%	-13%
SouthKorea	-30%	-38%	-38%	-37%	-37%	-36%	-23%
India	-	-8%	-8%	-8%	-8%	-8%	-8%
Canada	-33%	-31%	-31%	-30%	-30%	-29%	-18%
USA	-36%	-43%	-42%	-42%	-41%	-41%	-28%
EU27	-43%	-23%	-23%	-23%	-22%	-22%	-14%
Russia	-26%	-38%	-38%	-37%	-37%	-36%	-23%
SouthAfrica	-32%	-55%	-54%	-54%	-53%	-53%	-37%
NORICE	-69%	-16%	-16%	-15%	-15%	-15%	-8%
EASIA	-9%	-31%	-31%	-30%	-30%	-29%	-19%
LACA	-19%	-24%	-24%	-23%	-23%	-22%	-12%
SSA	-	11%	11%	11%	12%	12%	7%
ROW	-	15%	14%	14%	14%	13%	8%
World	-	-24%	-23%	-23%	-23%	-23%	-17%

Table A5: Changes in setoral trade balances in period 20 (REDD vs NoREDD) (2001 US$ million)

	Australia	New Zealand	China	Japan	South Korea	India	Canada	USA	EU27	Russia	South Africa	NORICE	EASIA	LACA	SSA	ROW
Rice	-0.1	0.0	0.3	8.2	-0.2	0.3	0.0	-0.7	0.8	-0.3	0.0	0.0	-10.0	0.6	-1.4	1.7
Wheat	-8.5	0.0	4.7	1.2	-0.3	8.7	4.7	-3.3	-3.2	-2.2	1.7	0.3	0.8	-13.4	-14.2	24.5
Other Cereal	4.6	0.8	56.2	15.3	-7.6	39.1	14.4	28.0	176.6	-11.5	18.6	0.9	-53.1	4.9	-354.9	98.5
Vegetable Fruits	12.0	2.4	167.7	15.7	-3.3	57.7	20.8	5.8	82.7	-35.5	22.5	1.2	-86.5	-119.6	-208.0	98.3
Animals	-21.9	-4.6	85.4	3.6	-0.1	12.8	-2.2	-17.9	2.5	-1.7	4.3	0.9	-18.9	-12.5	-36.1	14.6
Forestry	0.9	3.6	94.8	7.4	-2.7	23.2	4.1	15.5	58.7	-9.2	1.6	0.5	29.4	-1.4	-209.7	18.9
Fishing	-0.7	-0.3	3.7	18.8	4.3	1.2	0.1	4.2	20.9	-3.7	1.4	6.8	-3.5	-4.0	-35.4	-2.0
Coal	64.2	0.9	65.1	-108.4	-47.9	-7.9	-3.4	40.5	-124.7	-8.9	30.8	0.2	10.3	-14.3	-2.0	49.1
Oil	-71.4	**-19**.8	-141.9	-1357.5	-753.2	-212.0	-26.4	-3181.4	-3000.5	853.2	-154.4	674.8	-612.1	442.8	928.0	6498.5
Gas	29.5	0.0	-8.5	-273.2	-77.4	0.0	296.3	-276.8	-785.5	172.4	0.0	122.0	122.5	-20.4	32.2	610.3
Oil Products	1.5	-13.3	221.8	25.8	46.0	-47.5	45.2	-327.2	168.6	287.6	160.4	17.5	-234.0	-34.7	-308.4	-39.0
Electricity	0.0	0.0	-36.6	0.0	0.0	-1.3	-91.0	165.7	749.4	332.4	118.5	-38.4	28.1	58.5	-169.1	-1116.2
Water	-0.4	0.0	0.2	0.3	0.9	0.1	-0.2	4.4	-0.1	-0.5	0.2	-0.2	3.7	-1.3	-3.6	-3.4
Energy Intensive industries	278.4	27.5	-1529.4	244.4	470.6	-201.5	335.1	1720.1	492.5	1379.0	317.7	-87.3	904.7	-636.9	-1197.0	-2372.6
Other industries	28.0	**-41**.2	1268.4	1601.0	567.2	467.3	-264.5	10373.9	-2.5	-254.2	118.7	-359.5	-828.1	-7600.7	-4770.3	-101.1
Market Services	12.0	-2.4	390.9	375.8	92.2	106.6	27.8	1957.4	28.3	-201.1	37.8	-251.2	471.4	-1314.5	-1597.2	-326.8
Non-Market Services	-1.0	-0.8	52.9	27.7	15.0	13.1	-10.5	520.1	9.7	-59.5	3.0	-22.5	31.8	-194.2	-322.9	-61.8

Table A6: REDD revenues as a share of GDP for the High pledges and unlimited REDD scenario (in percentage)

Region	Period										
	10	11	12	13	14	15	16	17	18	19	20
EASIA	0.0%	0.0%	0.1%	0.2%	0.2%	0.4%	0.5%	0.6%	0.7%	0.9%	1.0%
LACA	0.0%	0.1%	0.1%	0.3%	0.4%	0.6%	0.8%	1.0%	1.2%	1.5%	2.0%
Sub Saharan Africa	0.1%	0.2%	0.4%	0.6%	0.8%	0.9%	1.1%	1.4%	1.6%	1.9%	1.9%

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