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Afforestation and Timber Management Compliance Strategies in Climate Policy. A Computable General Equilibrium Analysis

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Afforestation and Timber Management Compliance Strategies in Climate Policy. A Computable General Equilibrium Analysis. [1,2]

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Keywords: Climate Change, General Equilibrium Modelling, Forestry, Afforestation
JEL Classification: D58, Q23, Q24, Q52, Q54

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[1] *The opinions expressed by the authors do not necessarily reflect the position of the Fondazione Eni Enrico Mattei.*

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[2] *We are grateful to Andrés Carvajal for his suggestions. We also express our thanks to Ramiro Parrado and Francesco Bosello.*

Contents

1. Introduction and Motivation

Forests provide several economic and environmental services (e.g. Schulze-Heimann, 2000), such as water flow regulation, recreation, aesthetic values, and carbon sequestration. While forest lands still cover around 40% of the global surface (Deveny et al., 2009), high current deforestation rates seriously threaten their provision. According to FAO (2010), during the period 2000-2010, the globe has been losing around 13m ha of forests every year. The special report on emissions scenarios of the Intergovernmental Panel on Climate Change (IPCC SRES, 2000) projects deforestation of tropical forests to release 79-332 Gt CO_2, by 2050. In fact, the prominence of the climate change issue in the international political arena has fostered increasing concern regarding forests' ability to regulate climate.

Although a detailed carbon plan has not yet been articulated in any specific legislation, the direction of the international debate on forest carbon intends to strengthen the already existing policies on forestry, and to extend its contribution. Other than to the next phase (2013-2020) of the European Unions' Emissions Trading Scheme (EU-ETS), international forest carbon has been central for deliberations to the current climate change policies proposed in Brazil, which launched the Amazon Fund in 2008, in Australia, in Japan, and in the United States. The U.S. bill sets aside for international carbon activities, 5% of the revenues coming from auctioning emissions credits to achieve an emissions reduction of 720 MtCO_2-eq.[3]

Aiming to enhance the use of forest carbon sinks, in 2008, the United Nations created the Reducing Emissions from Deforestation and forest Degradation Programme (UN-REDD) and recognized the role of conservation, and sustainable management of forests to enhance forest carbon stocks in developing countries. In 2009, the

[3] For US, see Discussion Draft Summary, The American Clean Energy and Security Act of 2009, H.R. 2454, available at: http://energycommerce.house.gov/Press_111/20090331/acesa_summary.pdf.

Copenhagen Accord clearly stated the need to develop mechanisms to reward sustainable land-use practices developing forest carbon sequestration. Accordingly, the range of climate mitigation options of the forestry sector was expanded through the so called REDD+ mechanism, which is based on a payments system for developing countries that reduces emissions by avoiding deforestation and enhances forest carbon stock through forest sustainable management.[4] The REDD+ mechanism has been recognized, within the international debate, as a key target for a future binding agreement on climate change mitigation (UNFCCC, 2009). Within the first commitment period (2008-2012) of the Kyoto Protocol (e.g. the EU-ETS), only afforestation and reforestation (AR) in developing countries are recognized as REDD+ activities for which carbon credits can be accumulated. Measures of deforestation avoidance (AD) are, in fact, excluded from the picture, in order to limit the related leakage, non permanence, and additionality problems (see the Marrakesh Accords and the Marrakesh Declaration, 2001). The annual volume of transaction for AR projects, in both voluntary and compliance markets, has been growing in time, and it overtakes the value of AD projects. Today it represents 60% of the total volume of forest-based projects, corresponding to around 8 $MtCO_2$ (Hamilton, 2010).

The prevailing literature about the role played by the forestry sector in the commitment strategy acknowledges that forestry can contribute to 1/3 of total CO_2 abatement (e.g. Sohngen-Mendelson, 2003; Tavoni et al., 2007). On the economics of forestry mitigation opportunities, there is shared consensus that forestry provides cost-efficient mitigation options (Rose et al., 2008; Ruben et al. 2006).[5] However, recent estimates on costs and effects of forest carbon stabilization are generally focused only

[4] The sum of afforestation, reduction in deforestation (REDD), and forest management is referred to as REDD+ activities.

[5] The wide range of cost estimates suggests that major amounts of carbon can be sequestered for less than \$50 per metric ton of carbon (\$50/t C)

on the contribution of avoiding deforestation (see e.g. Bosetti et al., 2009; Eliasch, 2008; Kindermann et al. 2008). Alternatively, they make a unified assessment of the main forest activities, without disentangling the individual contribution of any of the forestry practices (see among others Sohngen-Mendelson, 2003).

Some studies have focused on afforestation-reforestation (AR) and timber management (TM) activities' potential to reduce CO_2 emissions, and on their effects (see for example, van Kooten et al., 2000; Stavins, 1999; Alig el al., 1997; Parks-Hardie, 1995; Nordhaus, 1991).[6] However, the majority of these analyses deals with specific geographic areas in the U.S. and normally relies on a partial equilibrium view, ignoring the general equilibrium aspects of the problem.

In this paper we use the global computable general equilibrium model (CGE) ICES to explore both direct and indirect socio-economic effects of AR-TM in Europe under an independent European commitment to reduce CO_2 emissions by 20 and 30% by 2020. In this way we contribute to the current discussion on carbon sinks by analysing the role of forests in Europe under a domestic climate change mitigation policy.

We add to the literature by analysing global effects and by taking into account the "higher order" or general equilibrium outcome determined once all adjustment mechanisms at play in the economic system have occurred. In fact, as CGE models are characterised by market interdependence, they are particularly pertinent to capture reallocation effects affecting the entire economic system.

Following Sohngen-Sedjo (2006) we do not restrain our analysis to afforestation practices but consider also timber management (TM) as an additional carbon abatement

[6] IPCC, SRES (2000) forecasts that 8-10% of the forest soil will be afforested-reforested in the tropics by 2050, leading to estimated carbon uptake of 40-199 Gt.

option. In doing so, we approach them separately as they reveal different underlying biology and economics.

Following the distinction in Richard-Stokes (2004), we investigate “secondary”, other than “primary” costs and benefits of AR-TM, and we contribute to shed light on issues not extensively addressed by the literature such as the effects of turning agricultural land into forests or extending the rotation period, as well as the direction of the leakage effect.

In particular we look at the changes in the *carbon stabilization costs*, in *carbon sequestered* given a certain carbon price, in *land use* (converting timber-forests or agricultural land into carbon-forest land), and *land* and *timber market prices.* Finally, we observe the magnitude of leakage for the case of AR activities, often neglected by the literature and addressed only to the AD practices.

The paper is organized in 4 remaining sections. Section 2 briefly presents the model, already described in several papers. Section 3 is devoted to describe the main changes implemented in the model, while section 4 draws the key results. Section 5 concludes.

2. Model Description

We rely on the ICES model (Inter-temporal Computable Equilibrium System) which is a multi-country and multi-sector, global Computable General Equilibrium (CGE) Model (Eboli-Parrado-Roson, 2010; Bosello et al., 2007).[7] ICES presents a flexible level of aggregation. The regional and sectoral details chosen for this exercise are reported below, in Table 1.

[7] The ICES model has been developed at the Fondazione Eni Enrico Mattei (FEEM) and its main features are described at the following website : http://www.feem-web.it/ices/

Table 1. Regional and sectoral disaggregation of the ICES model

N	*Country Label*	*Country Aggregation*	*Sector Aggregation*	*Factors*
1	USA	United States	Rice	Natural Resources
2	EU27	Europe 27 States	Wheat	Land
3	XEU	Rest of Europe	Other Cereal	Labour
4	FSU	Former Soviet Union	Vegetables/Fruits	Capital
5	KOSAU	Korea, South Africa, Australia	Animals	
6	CAJANZ	Canada, Japan, New Zealand	Forestry	
7	NAF	North Africa	Fishing	
8	MDE	Middle East	Coal	
9	SSA	Sub Saharan Africa	Oil	
10	SASIA	Southern Asia	Gas	
11	CHINA	China	Oil Products	
12	EASIA	Eastern Asia	Electricity	
13	LACA	Latin and Central America	Water	
14			Energy Intensive industries	
15			Other industries	
16			Market Services	
17			Non-Market Services	

Source: Own Elaboration

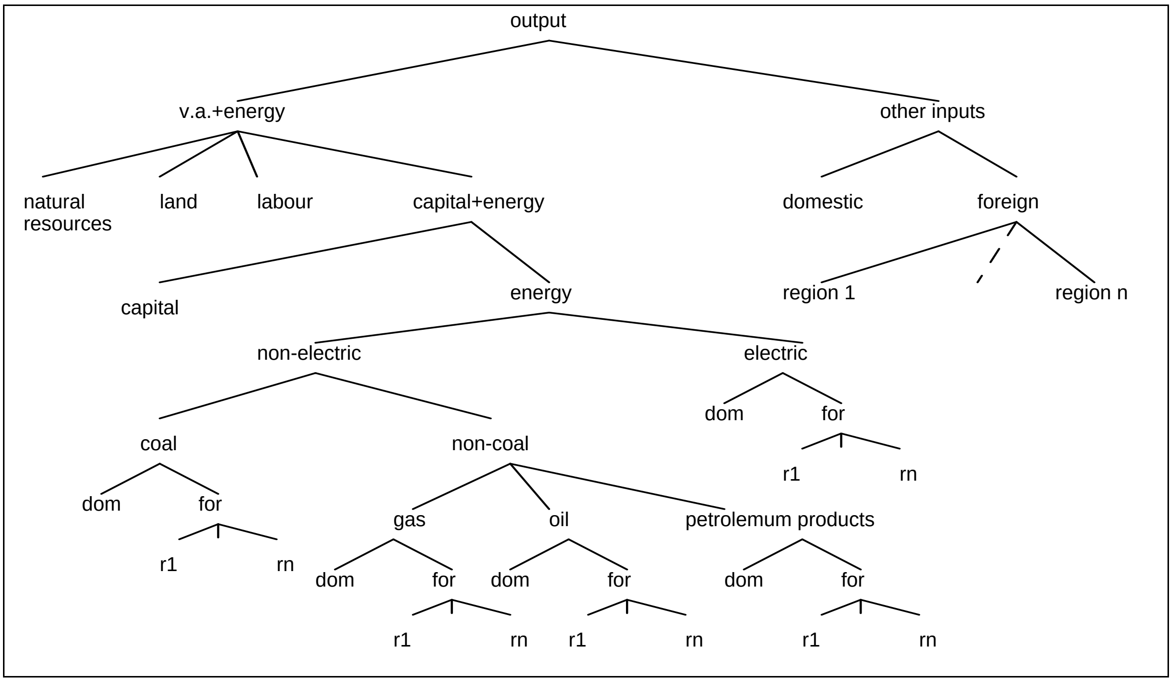
ICES is based on the Global Trade Analysis Project (GTAP) database, version 6 (Dimaranan, 2006).[8] The supply side comes from a refinement of the GTAP-E model specification (Burniaux-Truong, 2002), which improves the modelling of the energy production, accounts for a higher number of industries and sectors, and it also includes carbon taxes and an Emission Trading Scheme. The model is recursive-dynamic developing, under myopic expectations, a sequence of static equilibria, linked by the endogenous process of capital and debt accumulation.[9] Endogenous investments determine the expansion of the capital stock from 2001 to 2050. Although ICES can be used in its dynamic-recursive version, in the present study we employ a simplified structure, projecting all the system from 2001 (calibration year of GTAP 6 database) to 2020, which grows in just a one-time jump.

[8] The GTAP database is available at the following website: http://www.gtap.org

[9] For the description of its dynamics see Eboli-Parrado-Roson (2010).

For the production side a representative price-taker firm, for each industry, maximizes profits. The production frontiers develop in a series of nested CES functions where the "Armington" assumption makes domestic and foreign inputs not perfect substitutes enabling us to account for products heterogeneity. The nested structure, moreover, is convenient to adopt different assumptions about the sustainability between diverse pairs of inputs. It follows the production tree of the ICES model.

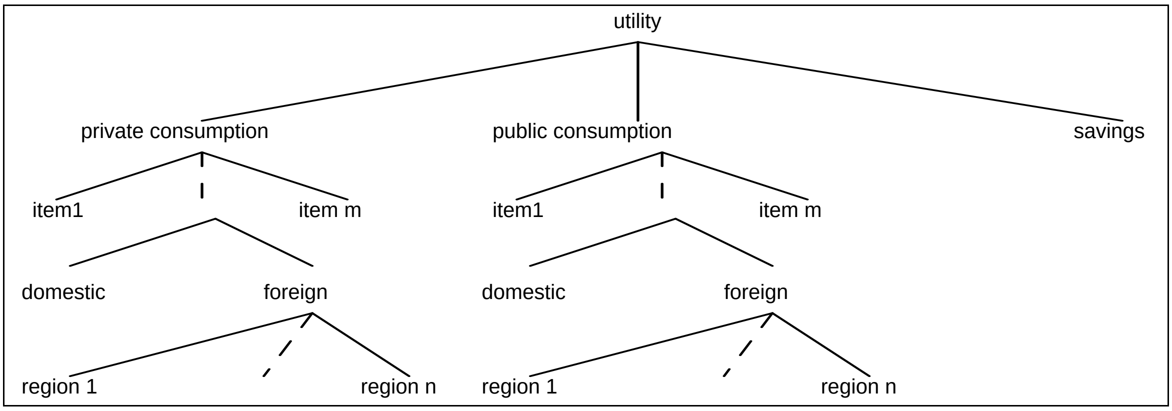
Figure 1. Nested tree structure for the production processes



Source: Bosello, Roson, and Tol (2007).

For the demand side, a representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour, capital). Capital and labour are perfectly mobile domestically but immobile internationally, while land and natural resources are industry-specific. This income is used to finance aggregate household consumption, public consumption and savings (see Figure 2). The expenditure shares are normally fixed, e.g., the top-level utility function has a Cobb-Douglas specification. Public consumption has been recognized to have the same functional form while private consumption is split in nested Armington aggregates, according to a Constant Difference in Elasticities functional form. This non-homothetic function enables accounting for possible differences in income elasticities for the various consumption goods. Saving is a constant share of the regional income and is firstly pooled and then invested by a virtual global bank. Investment, which is internationally mobile, 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. Finally, in each region, any financial imbalance reflects a trade deficit or surplus, due to accounting identities.

Figure 2. Nested tree structure for final demand



Source: Bosello, Roson, and Tol (2007).

3. Methodology

a. Modelling Afforestation & Timber Management Effects

European forest sector mitigation options are introduced into the model adding a forest-based carbon sequestration curve provided by Sohngen (2005). This study uses a global forestry and land use model to derive marginal costs of carbon sequestration for selected world regions under alternative constant carbon prices for the period 2005-2105. In this model carbon sequestration results from optimal response to choices over land use (e.g., AR, and AD), and changes in forest and timber management (TM). Given that these activities impact land use allocation and timber market flows differently, we distinguish between carbon sequestration provided by afforestation and changes in timber management. In fact, following Sohngen-Sedjo (2004), these are the two forestry mitigation options encompassing the total carbon storage provided by European forests.

As curves in Sohngen (2005) provide only total carbon sequestration without disentangling the contribution of different forestry activities we split it into AR and TM using information provided in Sohngen-Sedjo (2006), and Sohngen-Sedjo (2004). According to Sohngen-Sedjo (2006), the total amount of carbon stored by forests in temperate regions can be divided into two parts: 34-40% sequestered via AR (e.g. devoting more land to forests) and 54-63% stored via change in TM. (e.g. changing forest rotations). In this analysis we closely follow Sohngen-Sedjo (2004). According to these authors at a constant carbon price of $100 per ton C, the percentage of carbon stored as a result of land use change (i.e. AR) and TM in Europe is respectively 40%, and around 60%.[10]

Once forest carbon sequestration is divided into its two components we modify the model assuming the following hypotheses:

I. TM involves already existing forests and to a large extent it corresponds to changes in the rotation period. TM therefore does not impact land use change but only timber supply. A higher rotation period, in the short run, decreases timber supply as a part of the standing trees is not harvested to increase forest age.

II. Conversely, AR activities involve new plantations and have major impacts on land use change. Hence, they affect land price, agricultural product prices and

[10] These values refer to their 5th scenario which is the closest to ours.

eventually, timber price through greater future supply. However, given that our analysis is limited to a 20-year period we assume that new plantations will not be harvested during the time span of the current exercise.

Changes in land use occurring as a result of afforestation are modelled as a decrease in the available agricultural land vis-à-vis a business-as-usual (BAU) path. Given a carbon price, carbon emissions in Sohngen (2005) are converted into hectares using UN-FAO (2005) data. The *evolution of the agricultural land* is therefore adjusted by reducing the land devoted to agriculture according to the corresponding amount of hectares used for AR.

To model timber market effects we first convert the amount of carbon sequestered due to changes in timber management into cubic meters of wood. As curves in Sohngen 2005 represent the average carbon sequestered during the 2005-2100 period, it is not possible to correctly calculate the corresponding impact on timber supply due to forest dynamics adjustments. In this exercise we make the simplifying assumption that in 2020 timber supply will decrease by the corresponding amount of cubic meters previously calculated.

b. Policy Scenarios

We simulate two different near-term climate stabilization policies.

The first policy implies that Europe-27 (EU27) unilaterally commits to a 20% GHGs emissions reduction below 1990 values by 2020, which is consistent with a CO_2 concentration in the atmosphere of 550 ppm CO_2-eq. The second is a more stringent one, requiring a 30% reduction of the emissions, in line with a concentration of 450ppm CO_2-eq in the atmosphere.[11]

While the latter target is considered subject to the conclusion of a notably-wide climate change agreement, the current discussion on its feasibility has become extremely relevant under the hypothesis that the current financial-economic depression has lowered climate mitigation costs.[12,13] Although in this analysis the growth paths do not account for the crisis, it is still significant to analyze its cost effectiveness once the AR-TM activities are enabled.

Through a comparative static exercise ICES will provide us with three sets of results in 2020 for each of the policy exercises (2020-20% and 2020-30%).

The first set relates to a BAU, or baseline growth path for the global economy, in which either the climate policy or the AR-TM opportunities are ignored. This baseline scenario is common to both climate policy exercises and is needed as the costs and impacts of the forest-based carbon sequestration program must be evaluated relative to what would happen if such a program did not take place (from now on, we will relate to this as to the BAU scenario). The second set of results differs from the BAU as the stabilization policy is simulated for the two different climate scenarios (Policy scenario, from now on). Finally, the latter also includes the higher degree of freedom that the forestry option provides to comply with the emissions reduction targets. Again, we will evaluate this scenario for both policy exercises (AR-TM scenario).

The outcomes enable us to define the magnitude of the *socio-economic costs* of the stabilization policy, calculated as the variation in GDP with respect to the baseline,

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[11] See *An Energy policy for Europe*, COM(2007) 1 final; *Limiting Global Climate Change to 2 degrees Celsius - The way ahead for 2020 and beyond*, COM(2007) 2 final.

[12] The European embarking on the 30% target is conditional on the other developed economies undertaking comparable reduction targets.

[13] See *Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage*, COM(2010) 265 final.

following the inclusion of the policy. We also infer the effects of the higher level of flexibility in achieving the policy target, entailed by forestry.

The baseline has been calibrated in order to endogenously reproduce the trends proposed by the IPCC scenario A2 for GDP and the fossil fuel prices trend from EIA's projections (EIA, 2007 & 2009). The stock of Natural Resources, for Fossil Fuels such as Oil, Coal, and Natural Gas is endogenously determined by fixing their prices according to exogenous price projections. Finally, results also depend on exogenous settings for i) the evolution of population (UNPD, 2008), ii) the energy efficiency (Bosetti et. al., 2006), iii) and the land productivity dynamics (IMAGE 2.2, B1 Scenario according to RIVM, 2001). The major dynamics mentioned are summarized in Table 2, below.

Table 2. Major variables growth rates for the BAU (% 2001-2020)

Region	*GDP*	*Population*	*Energy Efficiency*
USA	55.13	18.9	12.8
EU27	41.48	3	17.1
XEU	32.62	3.4	40.4
FSU	89.23	-3.2	36.6
KOSAU	39.18	10.4	27.5
CAJANZ	37.36	2.1	17.3
NAF	192.48	31.9	26.8
MDE	126.56	38.0	26.8
SSA	113.77	58.1	22.0
SASIA	134.48	32.9	44.7
CHINA	210.90	11.1	47.5
EASIA	170.25	24.3	43.5
LACA	91.54	24.4	23.5

Note: In red the endogenous behaviours.
Source: Own Elaboration.

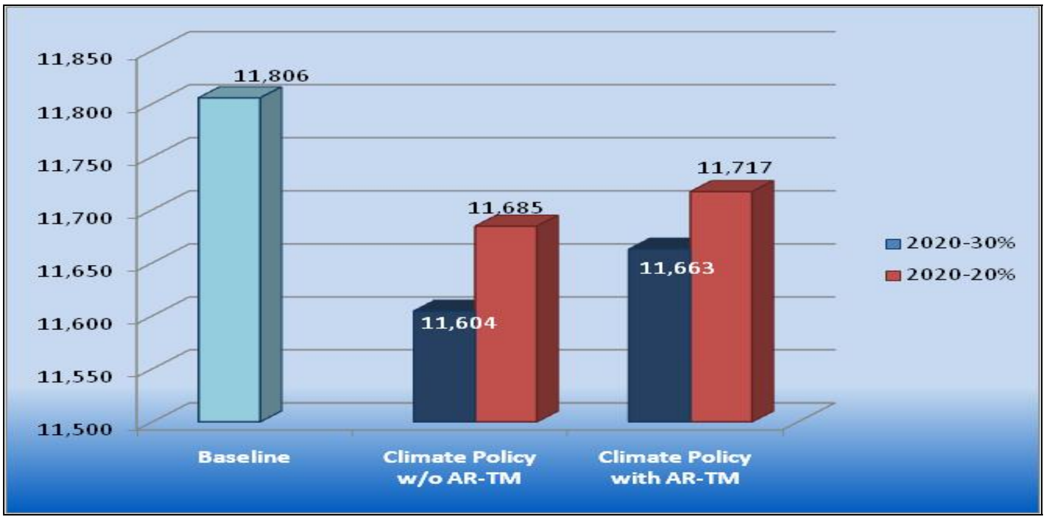
4. Major Results and Policy Implications

All the following results, unless differently specified, are to be considered compared with the baseline (BAU). Additionally, when two results are specified they relate, in order, to the 20% and 30% commitment policies.

a. Policy Cost, Carbon Price, CO_2 Sequestration, and Carbon Leakage

Carbon stabilization cost for EU27 is measured as the reduction in real GDP in 2020 compared with the baseline for both policy exercises (see Figure 3). When forest-based carbon sequestration is not included, it is equal to around $121bn, (just above 1%), and $201bn, (less than 2%), for the 20% and 30% policy scenarios (see Figures 4), respectively.[14] For the 20% commitment, for which a wider range of studies is available, our results are in line with the literature. For example, the European Commission (2008), assuming no recession, and excluding land use, land use change and forestry (LULUCF) activities from the climate package, calculates a direct economic cost around 0.6% in terms of European GDP in 2020. It is important to stress that our GDP projections have not been calibrated to account for the current economic contraction, which has lowered climate mitigation costs. For this reason our cost estimates could result to be higher compared with the outcomes presented in recent literature sources.

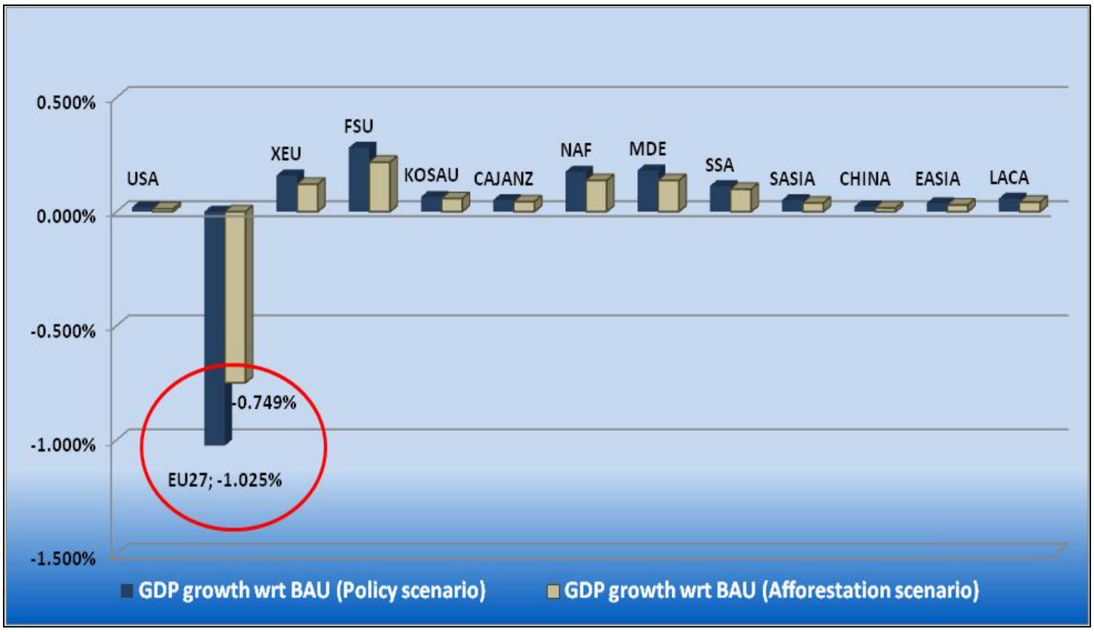
Figure 3: Real GDP for EU27 by 2020 (2001-US billion $)

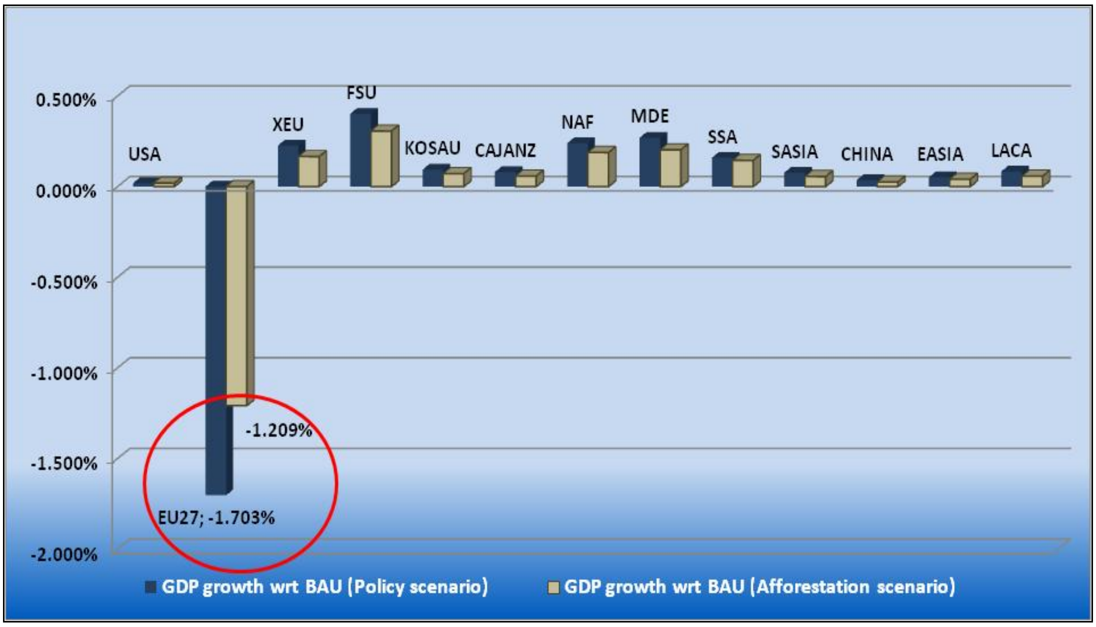


Source: Own Elaboration.

[14] Carbon stabilization cost is measured as the reduction in real GDP in 2020 compared with the baseline for both policy exercises, and it is expressed in 2001USD-$.

Figure 4: Cost of policy (-20% & -30%) in real GDP (% values)





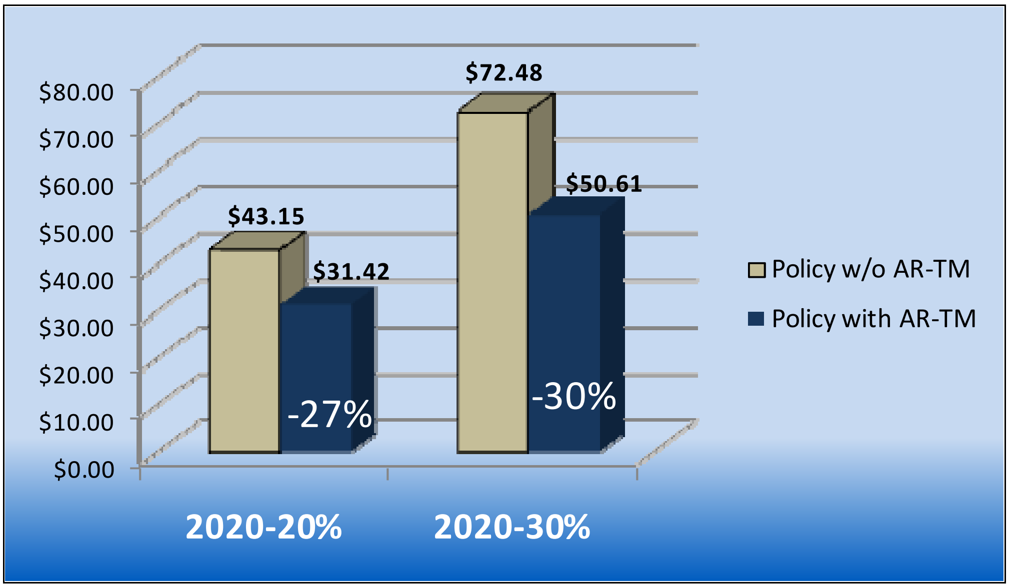
Source: Own Elaboration.

Climate policy implementation implies a decline in the use of fossil fuels generating a big drop in coal, oil, and gas demand and prices (falling by 13.3%, and 16.2% on average). In spite of this, agricultural food production is also reduced driving a decline in prices of about 0.6% and 1%. Depending on the chosen emission reduction target, European demand for agricultural land also plunges to -1.6% and -2.3%, while the price of land in the rest of the world increases by 0.5 and 0.6% as a result of the leakage effect which drives a greater production.

The inclusion of mitigation opportunity of the forestry sector, notably lessens the policy costs, allowing a saving of \$32.5bn (27% less), and \$58.4bn (29% less). Additionally, forestry allows the achievement of a more stringent emissions reduction target at almost the same policy cost. The 30% emissions reduction represents, in fact, an additional effort for Europe of only 0.2% compared with the cost of a 20% mitigation policy without forestry.

The falling path of the policy costs is mimicked by the carbon prices which markedly drop by 27% (\$31.42/t CO_2 versus \$43.15/t CO_2) and 30% (\$50.61/t CO_2 versus \$72.48/t CO_2) (See Figure 5). Price figures corresponding to our policy scenario without forestry are rather close to recent results. For example, by using the model FAIR the Netherland Environmental Assessment Agency (2008), estimates a price of carbon in 2020 equal to €41.23/t CO_2 and €74.04 /t CO_2, respectively. Tol (2009) presents similar results with a carbon price of €39.75/t CO_2, and €64.07/t CO_2.

Figure 5: Reduction in carbon price (\$/t CO_2)



Source: Own Elaboration.

Exploiting AR-TM opportunities EU27 gains an additional abatement option which partially alleviates the compliance effort especially in the energy sector. According to our results in EU27 non-forestry sectors are enabled to release into the atmosphere a higher quantity of carbon corresponding to 59.02 and 80.28 Mt of CO_2 emissions. These quantities, in fact, represent the emissions capture coming from AR-TM, corresponding to an average absorption of 110 tCO_2 per hectare.[15] This more efficient burden-sharing consents to save $551.4 and $727.6 for each tonne of CO_2 sequestered.

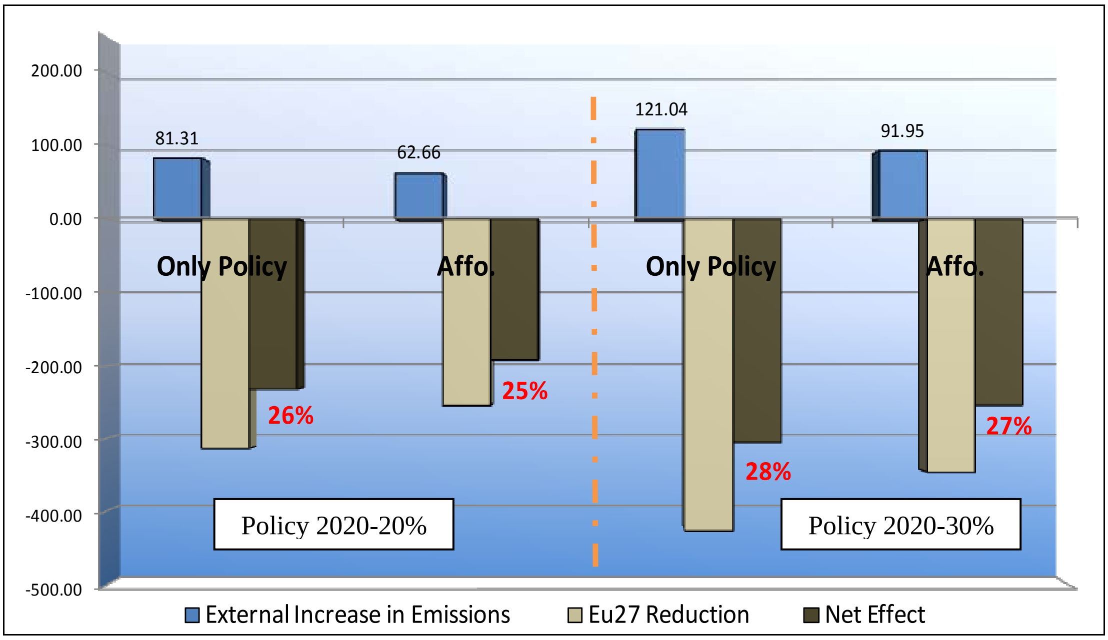
The unilateral EU27 mitigation policy entails the well-known leakage effect, that we address linking it to the aspects of afforestation and timber management. In our results this equals 0.2% and 0.03%. Although the real picture could shortly be different, in our simulated world only one region implements climate stabilization policy. The production of goods in countries where less severe or no targets are required, turn out to be more competitive than in Europe, which is charged with an environmental tax. The increasing demand boosts production and therefore carbon emissions outside EU27. Hence, non European emissions grow by 1%, and 1.5% offsetting globally 81.31 and 121.04 $MtCO_2$ of the European emissions reductions. According to the IPCC (2007) definition of leakage this effect counterbalances 26% and 28% of the EU27 reduction, respectively (see Figure 6).

The inclusion of forestry mitigation opportunities lessens this increase in emissions outside the geographic boundary of the policy of 0.8% and 1.1%, offsetting 62.66 $MtCO_2$ and 91.95 $MtCO_2$ (20% and 22% following IPCC's definition, 2007). Forest-based carbon sequestration equals 19% and 26% of total European emission reduction. The regions contributing the most to carbon leakage are USA (10% of the

[15] This figure falls exactly in the range of estimated average carbon storage in temperate regions which is 30-175 tCO_2/ha (Dixon-Schroeder-Winjum, 1992).

total increase), FSU (7%), KOSAU (7%), and CAJAN (5%). Curiously, these regions would have the greatest capacity to invest in GHGs mitigation, given their high GDP per capita. This sheds light on the unfair and inequitable aspects of the leakage distribution across the world, for which countries with a high, rather than low, GDP per capita are emitting more.

Figure 6: Leakage effects (Mt C)



Note: In red the magnitude of the external emissions offsetting according to IPCC (2007).
Source: Own Elaboration.

b. Land Competition Effects, Food and Timber Prices

Successfully reducing emissions from TM, and in particular from AR activities, could put additional pressure on global food security, by constraining the expansion of agricultural lands into existing and new forest areas. At the same time, different harvesting patterns and rotation rates would impact on timber supply. Hence, it is of extreme relevance to understand to what extent forest-based carbon would affect land and timber markets. Our results reveal that carbon sequestration from AR is associated with a decrease in the supply of agricultural land of 0.5% and 0.6%, respectively.

When afforestation is allowed, unilaterally reducing emissions by 20% implies a slight increase in the price of agricultural land for EU27 (0.1%) which becomes more scarce. This effect does not apply if the effort in reducing emissions is greater. In that case, the impact of a lower GDP, driving demand of agricultural products down, more than compensates the land competition effect. As a result, the price of land declines by 0.2%. In the rest of the world a general increase in the price of land takes place (with global average of 0.5% and 0.6%), and the same is observed for the price of agricultural products (0.3% and 0.5%). This is caused by their demand rise, clearly due to the leakage effect.

The latter effect to be considered is the timber price reaction given the contraction in the timber supply, once abatement through forestry is enabled. European timber supply falls by 25 and 34% compared with BAU. As a consequence, EU27 experiences a rise in timber prices of three (20% policy) and almost five times (30% policy) the price in the baseline.

It is important to note, however, that the impact on timber prices strongly depends on how timber supply is affected by adjustments in timber management. In this study we have assumed that the latter is entirely represented by changes in the rotation period, which is totally translated into a contraction of the timber supply (see Paragraph 3.b.I). However, as timber management encompasses other forestry activities, the final effect on prices presented here may be overestimated.

5. Conclusions

In this paper, using a modified version of the ICES model we study the socio-economic impacts of introducing the European forest mitigation options, within the EU27 portfolio of stabilization strategies. Two independent mitigation policies are simulated for EU27, namely, a 20% and 30% GHGs emissions reduction by 2020, ending year of the first commitment period of the Kyoto Protocol. To this aim ICES has been modified in order to include a forest-based carbon sequestration supply function, derived from a partial equilibrium model of the forestry sector. In this way we include a higher flexibility in our model adding a further mitigation opportunity to the already existing reduction from the energy sector. Further adjustments allowed us to assess land competition effects in terms of changes in agricultural land availability and prices, agricultural products prices, and timber supply change.

Results show that stabilizing climate with a 20% reduction in emissions by 2020, when forestry is not included in the overall mitigation portfolio, implies a reduction in the EU27 GDP of around 1% compared with the baseline, a cost which rises up to almost 2% when the target is more stringent (30%). The corresponding contraction of fossil fuels use drives a drastic drop in their prices, over 13% in both policy cases. More modest is the decline of the prices of agricultural goods, 0.6% and 1%, while the price of land in EU27 is subject to a decrease of 1.6%, and 2.3%, respectively. The independent EU27 policy raises the competitiveness of foreign-produced goods. Fossil fuels use increases in the regions outside the policy boundaries generating the well-known leakage effect. Nevertheless, this effect seems to be low, equalling +1%, and +1.5%. The low impact level of the leakage does not prevent from reaching a positive net global CO_2 emissions reduction, at a reduced policy cost.

The inclusion of the AR-TM activities generates several important results. Firstly AR accounts for around 20% of the EU27 emissions mitigation efforts, and it makes possible to achieve the 30% emissions reduction target with an additional European effort of only 0.2% of GDP compared with the cost of a 20% emissions reduction without afforestation. Secondly, AR-TM together lessen policy costs allowing a saving of 28% on average for both targets. Their contribution translates into a marked drop in the carbon price which falls by 27% ($31.42/t CO2) and 30% ($50.61/t CO2), and in a reduction of the leakage effect by around 0.2% for both emissions reduction cases.

Although forestry mitigation should be part of a cost-effective climate mitigation policy forestry alone is not sufficient to achieve ambitious emissions cut targets. Accordingly, forestry ability to sequester carbon has to be considered as complementary to the development of an energy-based abatement strategy.

This paper constitutes a first attempt aiming to address the role of European forests in climate change policy within a computable general equilibrium framework. Accordingly, the lack of other CGE studies on this subject does not allow us to establish a direct comparison of our results. Finally, a more complex analysis would require endogenous land competition and forest-based carbon sequestration. Such an improvement could be undertaken by coupling ICES with a land use model or by directly changing the model to the GTAP-AEZ database. While we recognize its importance we leave that for future work.

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