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Climate Change Mitigation in Temperate Forests : The Case of The French Forest Sector

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Within the framework of policies aiming to reduce greenhouse gas emissions, France now relies largely on energy substitution mechanisms. This results in the implementation of projects involving fuelwood or heat production from biomass. On the other hand, due to the very partial consideration of in-situ sequestration in the international climate policies ensuing from the Kyoto treaty, State action hitherto has not relied on measures favoring forest carbon sequestration. Researchers from the Nancy Laboratory of Forest Economics developed the French Forest Sector Model (FFSM), a bio-economic model of the French forest-wood sector, used for simulations of climate policies and impact analysis. The main results of FFSM presented in this paper are that: (i) a sequestration policy presents a better carbon balance through to 2020 than a substitution policy; (ii) an ambitious policy of substitution may cause tensions on resources and wood industry markets; (iii) the implementation of a generalized carbon tax would have a globally positive effect on the French forest-wood sector.

Keywords: Forests, Sequestration vs Substitution, FFSM, Mitigation

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1/ Introduction

The Intergovernmental panel on Climate Change (IPCC) estimates that forests could have an important role for climate change mitigation. Indeed, worldwide potential emission reductions equal 1,1 Gt eq CO_2/yr for a carbon price of 20 US$/t$CO_2$ and 4,2 Gt eq CO_2 /yr for a carbon price of 100 US$/t$CO_2$ (Nabuurs et al. 2007).

Those potential emission reductions rely on two mitigation channels, namely sequestration and substitution (see frame 1). Those two options have very diverse implications in terms of forest management and for the forest sector. Indeed, while the sequestration option relies mostly on decreasing wood production intensity in order to benefit from carbon sequestration in standing forests, the substitution option aims at increasing the intensity of wood production, in order to replace fossil fuels by biomass use.

So far, and in order to reach its ambitious mitigation targets, the French Government has opted to base its policy-mix on substitution mechanisms through sectoral policies. These policies aim at (1) structuring the French fuelwood sector through economic incentives, (2) changing domestic heating systems, for example, through the development of collective boilers, and (3) encouraging the development of medium- to large-scale biomass energy plants. The overall objective is to increase fuelwood consumption by 6 Mm3 /yr by 2020 (Puech, 2009).

It is important, however, to better understand the potential of forest sectors to contribute to those mechanisms and, reversely, potential impacts of those mechanisms on forest sectors. Those effects have to be assessed consistently, in order to deal with potential adverse effects and being able to have a good appreciation of trade offs and synergies. Those impacts are twofolds. First, environmental criteria encompass the evolution in the forest resources and carbon results; second economic criteria consider the equilibria of national markets, the balance of trade, and surplus analysis.

For that purpose, bio-economic models of forest sectors may be helpful, in order to provide projections prospective thoughts and impact forecasting. the French forest sector modeling team of the Laboratory of Forest Economics (LEF, Nancy, France) built a regionalized bio- economic model of the French fuelwood sector: FFSM, French Forest Sector Model. This model represents the whole French forest and wood sector by downscaling the representation of the forest resources and the economy on the level of each French administrative region (see frame 2).

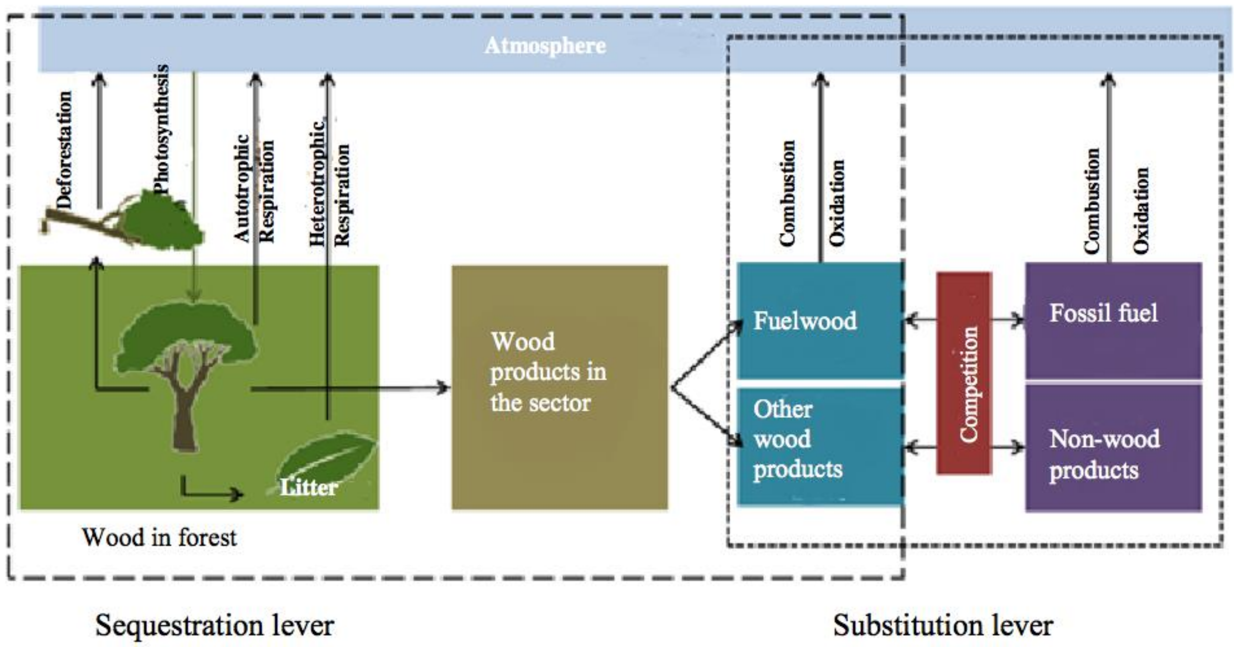
Developed since 2008, FFSM has provided several insights for those impacts. First, Lecocq et al. (2011) compares outcomes of policies focusing on the sequestration and substitution drivers. Second, Caurla et al. (2013a) presents impacts of several substitution policies aiming at increasing fuelwood consumptions. Finally, Caurla et al. (2013b) presents the potential impact of an economy-wide carbon tax on the forest sector. Those results and their implications for the economics of the forest sector, as well as for the forests potential for climate change mitigation, are presented in this paper.

Frame 1: Substitution and sequestration, the two physical levers of GHG emission mitigation

Sequestration: management of forest areas influences the amount of carbon sequestrated in the forest biomass. Forest densification, afforestation, reforestation and reductions to deforestation allow an increase in net carbon sequestration in forest ecosystems. Furthermore, carbon sequestration in long-life-cycle wood products, wood structural frames for instance, delays carbon release into the atmosphere (sequestration lever in figure 1).

Substitution: emissions linked to wood-product consumption are generally lower than those created by consumption of non-wood substitute products. Wood-fuel product consumption (substitution for fossil energies) and wood-product consumption (substitution for products coming from other sectors for building, insulation, packing or furniture) consequently allow a reduction in fossil energy emissions (substitution lever in figure 1).

Figure 1: Simplified diagram of carbon flows between the atmosphere reservoir, earth reservoir and fossil reservoir. Here are the two mitigation levers in the wood-forest sector.



Frame 2: The FFSM model (French Forest Sector Model)

FFSM (figure 2) is the first model representing the French wood-forest sector (Caurla et al., 2011) and a disaggregated economic module with three sector levels in a specific and exhaustive way.

The resource module is recursive-dynamic and captures the development of the national and regional forestry resource disaggregated into 132 field case-studies: breakdown per diameter class, region, type of forest population and deciduous or resinous species. It also calculates the results of emissions for the whole sector, taking the substitution effects between products in the sector into account.

The economic module is resolved in static partial equilibrium (figures 2 and 3) The resolution in partial equilibrium implies that the retro-action effects between forest-wood sector and the rest of the French economy are not taken into account, an acceptable assumption due to the low proportion represented by the forest-wood sector in the French economy (less than 1% of PIB). In the end, international prices are considered as exogenous in this model.

The module conducts an annual simulation of the price/quantity equilibria of national markets for three raw wood products and nine processed wood products (see figure 3), from which the calculations of the producers' and consumers' aggregated surpluses can be deduced. It also enables assessment of trade volumes between French regions and between France and the rest of the world. Domestic trade between regions is modelled via a "Samuelson 1952" spatial representation (see Caurla et al., 2010) while international trade is based on the Armington theory of imperfect substitutability (1969) (see Sauquet et al., 2011). The use of two different methodologies makes it possible to show the various levels of substitutability between products. Woods from France and abroad are less substitutable than French woods among themselves, because of variations between species, consumption habits and transaction costs.

FFSM allows the simulation of public policy implementation and assessment of their impacts against (i) environmental criteria, such as the evolution in the forest resources and carbon results; and (ii) economic criteria such as the equilibria of national markets and the balance of trade. The time horizon taken for simulations is 2020.

Figure 2: FFSM economic module represents 3 sector levels and 9 wood products

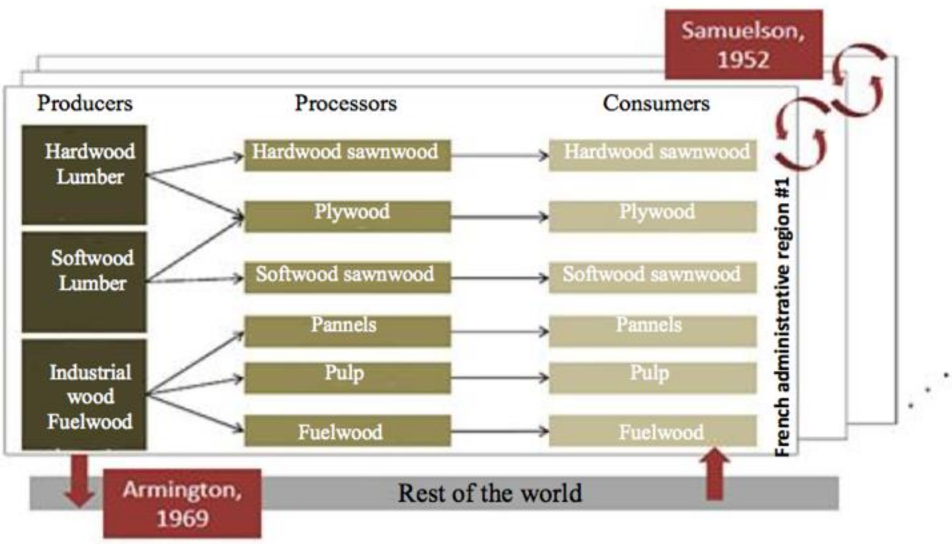
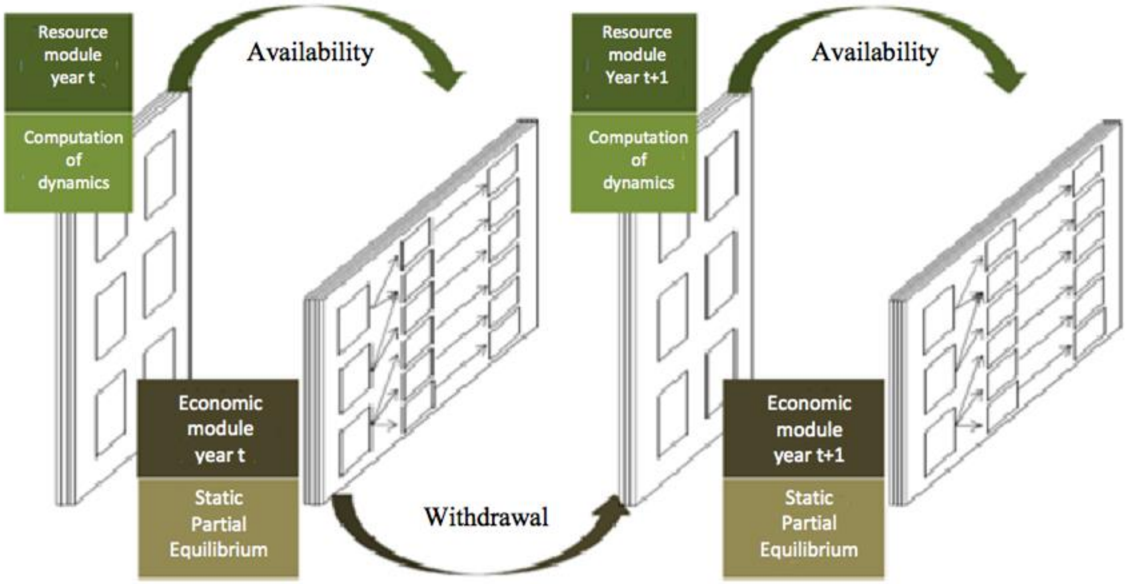


Figure 3 : Modular and Recursive Dynamics



2/ Forests contribution to climate change mitigation: sequester or substitute?

As presented in frame 1, forests contribute to climate change mitigation both from carbon sequestration and substitution. The main purpose of Lecocq et al. (2011) was thus to analyze the mitigation potential of those two levers. More precisely, our aim was to compare the implications of a stock (sequestration) policy and a substitution policy (as well as a combination of both), from an environmental (i.e., carbon balance) and an economic (i.e., price and economic surpluses variations) perspectives. In this paper, a carbon price signal is introduced either on the demand side (substitution policy) or on the supply side (stock policy). We assume a carbon price of 17 euro/tCO2, linearly increasing to 37 euro/tCO2 in 2020, as suggested by Quinet (2009) at that time.

Considering the substitution policy (S1), we simulate a public subsidy to end-use fuelwood consumption. By decreasing the perceived price by consumers, the subsidy increases fuelwood consumption, which favors energy substitution and decreases fossil fuel use. The amount of the subsidy is calculated as the value of emissions that are avoided due to energy substitution. The substitution coefficient given by the French Environment and Energy Management Agency (ADEME, 2005), according to which burning one cubic meter of fuelwood avoids the emissions of approximately 0.625 metric tons of CO2 on average. The consumer subsidy that we introduce is therefore the substitution coefficient times the price of carbon of each ton of fuelwood consumed.

Considering the stock policy (S2), we assume that the policy maker implement a policy to retribute forest manager for their effort to increase the carbon stock in standing forests. The policy thus takes the form of a Payment for Environmental Services to forest manager, so that they increase their carbon stocks compared to a Business-As-Usual scenario. We can note here that the PES implemented consists in giving forest owners incentives to reduce their wood supply compared to the Buisiness-As-Usual.

Scenario S3 is a combination of S1 and S2.

2.1/ Environmental Impacts

The environmental impacts that we assess are composed of the carbon stock in standing forests and the cumulative (over the 2010-2020 period) amount of CO2 that are not emitted due to energy substitution, compared to the BAU reference.

The sequestration policy is unambiguously the one that has the best carbon balance by the 2020 horizon. Indeed, even if it tends to decrease timber supply, and thus to decrease carbon emission reductions due to substitution, the net effect is positive. In contrast, the substitution policy has indeed a positive substitution effect: the increased consumption of fuelwood decreases fossil fuel consumption and thus reduces carbon emissions. However, this positive effect has to be considered in the light of the large decrease in carbon sequestered in standing forests: the subsidy tends to increase timber harvesting, which has a negative impact on the stock, compared to the BAU. Overall, when both the stock and the substitution affects are taken into account, the substitution policy even has a negative carbon outcome. The combination of both policies unsurprisingly brings an intermediate result.

This finding is consistent with previous studies (e.g., Hofer et al., 2007), but contingent on our choice of considering only substitution effects associated with fuelwood; and on the fact that electricity in France has a carbon content approximately one fifth of Germany's or of the US. The ranking between policies is also likely to change if we were to extend the simulation horizon sufficiently, because the drawdown on stock would ultimately level out[1], whereas cumulative emission reductions would keep increasing.

Table 1: carbon balance of the three scenarios

Changes in (i) carbon stock in standing forests, (ii) cumulative substitution effect, and (iii) total carbon stock in 2020 relative to BAU ($MtCO_2$). By convention, (+) signs refer to net absorptions (i.e., less carbon in the atmosphere) and (−) signs refer to net emissions (i.e., more carbon in the atmosphere).

	Substitution policy (S1)	Stock policy (S2)	Combination (S3)
Carbon stock in standing forests in 2020	−7.1	+0.9	−6.1
Cumulative substitution effect 2010–2020	+3.7	−0.05	+3.6
Net carbon balance in 2020	−3.4	+0.85	−2.5

Source: Lecocq et al. (2011)

2.2/ Economic Assessment

The economic assessment made here concerns three types of actors: fuelwood consumers, fuelwood producers and the government. We assess the variation of surplus of those three classes of agents, compared to the reference scenario. The consumer surplus corresponds to the welfare gain of purchasing a good at a lower price than the highest price that consumers would be willing to pay. Equivalently, the producer surplus corresponds to the welfare gain of selling a good at a higher price than the lowest price that producer would be willing to receive.

First, the substitution policy obviously increases the consumer surplus, as consumers are able to consume more wood at a lower perceived price. Moreover, this effect trickles down to forest managers who experience a larger demand. The cost to the policy maker is however quite important, as the windfall effect is important: consumers that would have consumed fuelwood without the policy also experience a lower perceived price. Another effect concerns increased fuelwood import: the subsidy increases fuelwood demand, which tends to increase local prices; French fuelwood becomes less competitive compared to foreign fuelwood (of which the price do not change), which tends to deteriorate the trade balance of the sector.

Second, the stock policy has a positive impact on forest managers (who perceive a payment for increasing their carbon stocks). However, in order to reach this objective, they have to decrease their timber supply; this tends to increase consumer prices, whose surplus thus tends to decrease. It is also important to note that the cost of the policy is smaller than the substitution one: there is no windfall effect of the stock policy, as only additive stock accumulation is taken into account by the policy. The overall surplus analysis indicates clearly that the stock policy dominates the substitution policy, essentially due to its lower impact on public spendings. As for the environmental assessment, the combination of both policies brings an intermediate result.

Overall, this study shows that the policy with the best carbon balance, i.e. the stock policy, is also the one with the lowest cost and the one that brings the best result in terms of economic welfare. However, it might also be the one that creates the largest opposition from the civil society, since it is detrimental to consumer surplus.

[1]Due to increasing risks of windfalls and pathogen invasions when forest density is increasing, amongst others.

Table 2: Surplus variation for the three scenarios

Welfare implications of policy scenarios relative to BAU in 2020 (unit: M€).

	Substitution policy (S1)	Stock policy (S2)	Combination (S3)
Consumers	+41.15	−6.28	+34.87
Of which fuelwood consumers	+40.85	−0.66	+40.16
Producers	+20.85	+7.37	+17.53
Of which fuelwood producers	+20.8	+0.77	+20.19
Government	−79.40	−1.36	−66.18
Net change in social welfare	−17.8	−0.27	−13.97

Source: Lecocq et al. (2011)

3/ Focusing on substitution through the stimulation fuelwood consumption

Of the two channels of climate change mitigation by the forest sector that were identified before, the French government has essentially based its strategy on substitution. Indeed, strong objectives of renewable energy in the French energy mix has been set. The European directive 2009/28/EC has set the objective of increasing the share of renewable energy in French energy mix to 23% by 2020. In France, where forest resources are abundant—France has the fourth largest forest cover among of the EU25 countries—biomass energy is expected to play a major role in achieving this objective. The overall objective of these programs is to increase fuelwood consumption by 6 Mm3/yr by 2020, which represent 1.38 Mtoe/yr.

Caurla et al. (2013a) consider several options to achieve this goal and we assess their implications in terms of tensions over forest resources and in terms of economic welfare for the forest sector. Concretely, the potential impacts of fixed-demand contracts (in which the policy maker commits to purchase a givent amount of fuelwood, at market price, every year), consumer subsidies and producer subsidies are considered. Both policies are set so that they achieve the 6 Mm3/yr objective by 2020.

A crucial issue here is the level of availability of forest resources. By resource availability, we mean the amount of timber that may eventually be harvested by timber suppliers and thus taken into account in their supply function. An additional 12 Mm3/yr harvest seems to be physically and economically possible, according to Colin et al. (2009) and Ginisty et al. (2009). However there is high uncertainty regarding forest-owners' responses to economic incentives. Indeed, in France, 70% of forests owners have a forest less than 1 ha, while almost 70% of the whole forest area is composed of forest properties smaller than 4 ha. Since small forest owners might not react to economic incentives as expected, there is important uncertainty as to how much wood would be available for harvest in forests. In this context of uncertainty about available resources, the sustainability of the programs to stimulate fuelwood consumption must be questioned.

Therefore, we consider an optimistic and a pessimistic case of resource availability. The optimistic level that is based on the estimations of Colin et al. (2009) and Ginisty et al. (2009), while the pessimistic one, of approximately 6Mm3/yr, assumes that small forest owners do not react to economic incentives. Therefore, the 6Mm3/yr objective is achievable also in the most pessimistic scenario, but could only be made at the expense on increasing tensions over forest resources.

3.1/ Environmental Impacts

The 3 policies are set so that they achieve the objective of 6 Mm3/yr by 2020, but they have different impacts in terms of forest resources. Indeed, consumer-sided policies and suppliers-sided policies have diverse impacts on the forest stock. The trade balance of the forest sector explains this effect. Therefore, we concentrate here on the impact of both policies on the forest stock, compared to the no-policy Business-As-Usual scenario.

Policies that focus on consumers tend to increase fuelwood import to achieve the objective: agents balance their consumptions between local and foreign fuelwood. In contrast, in policies focusing on the supply side, the whole additional consumption is provided by local supply. The level of wood extraction from standing forests is larger under supply-sided policies than under consumer-sided policy, for the same level of final consumption. It follows that supply subsidies tend to decrease the forest stock more than consumer subsidies. This can create tensions over forest resources, especially in the case where there is low timber availability. Regional variability can be explained by (i) initial differences in forest stocks, and (ii) the presence of transformation industries in the region.

Table 3: Regional forest stock variation, for the three policies and the two availability scenarios

Rate of increment of available forest stock per French region in 2020 (in %) for each level of availability. "BAU" refers to a scenario in which no policy is implemented during the 2012–2020 period, "fd" refers to a fixed-contract policy, "Sub p" refers to producer subsidies and "Sub c" refers to consumer subsidies.

Regions	Optimistic case (+12 Mm^3)				Pessimistic case (+6 Mm^3)			
	BAU	fd	sub_c	sub_p	BAU	fd	sub_c	sub_p
IF	0.7	0.4	0.2	−0.1	0.2	−0.2	−0.4	−0.9
CA	−1.1	−1.8	−2.1	−3.6	−1.9	−3.0	−3.3	−5.2
PI	−5.8	−8.3	−8.7	−23.3	−9.0	−12.0	−12.5	−35.2
HN	−1.0	−1.8	−1.6	−6.7	−1.9	−2.9	−2.8	−9.4
CE	1.4	1.0	0.9	0.1	1.0	0.5	0.3	−0.7
BN	−1.4	−2.2	−2.2	−6.2	−2.4	−3.5	−3.5	−8.7
BO	1.1	0.6	0.4	0.1	0.6	0.0	−0.2	−0.7
NP	−7.1	−9.2	−9.7	−33.4	−10.5	−13.0	−13.5	−52.9
LO	−0.7	−1.6	−1.7	−1.6	−1.5	−2.7	−2.8	−2.9
AL	−0.2	−0.8	−0.9	−1.1	−1.0	−1.7	−1.9	−2.2
FC	0.5	0.0	−0.1	0.1	0.0	−0.7	−0.8	−0.7
PL	0.9	0.5	0.3	−0.5	0.3	−0.1	−0.4	−1.6
BR	2.2	2.1	2.1	2.0	1.9	1.7	1.7	1.6
PC	2.5	2.0	1.7	1.2	2.0	1.4	1.1	0.5
AQ	−0.3	−1.7	−1.1	−0.1	−1.4	−3.3	−2.5	−1.6
MP	1.6	1.2	1.4	1.0	1.3	0.9	1.0	0.7
LI	−0.3	−1.0	−0.7	−2.3	−1.0	−2.0	−1.5	−3.6
RA	1.9	1.7	1.7	1.5	1.6	1.5	1.5	1.2
AU	1.5	1.3	1.2	1.3	1.2	0.8	0.8	0.9
LR	1.2	0.9	0.8	0.6	0.9	0.5	0.3	0.2
PA	0.5	0.2	0.1	−0.7	0.1	−0.3	−0.4	−1.4
CO	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8
France	0.72	0.21	0.21	−0.14	0.5	−0.41	−0.41	−0.85

Source: Caurla et al. (2013a)

3.2/ Economic Assessment

Both types of subsidies tend to increase the fuelwood consumer surplus, as they decrease the perceived price to consumers. The effect is either direct, when demand subsidies are implemented, or indirect, when supply subsidies are set. However, since policies are calibrated so that the increase in consumption is whatever the same, the increase in consumer surplus is comparable.

In contrast, fuelwood consumer surplus decreases under fixed-demand contracts due to the price increase and the crowding-out effect of non-contracting agents. Indeed, the additional fuelwood is consumed by agents involved in the fixed-demand contracts. This has the effect of increasing market prices for non-contracting agents, who then tend to decrease their consumption. This crowding-out effect has to be taken into account when calibrating the fixed-demand policy, in order to avoid under-shooting the target.

On the supply side, both subsidies and the fixed-demand contracts tend to increase the surplus of the industrial wood producers (which feeds both fuelwood and pulpwood sectors). The increase in surplus is larger under a supply-sided policy. Indeed, in that case, the full increase in fuelwood consumption is captured by local supplier. In contrast, the consumption subsidy increases local supply, but also imports.

The 3 policies have different effects on the trade balance, however. Indeed, while the consumer subsidies tend to increase import and thus deteriorate the french trade balance, the producer subsidy, by increasing supply and decreasing market prices, tend to increase exports (which become more competitive), which has the advantage of ameliorating the trade balance.

Finally, it is interesting to note that those policies create economic tensions of other industrial wood sector, such as the pulpwood industry. Indeed, those industries use the same type of wood than the fuelwood industry. The increased fuelwood consumption increases the wood use competition, “dries out the pipeline”, which tend to increase pulp prices, especially when resources have low levels of availability.

Overall, the producer subsidy is the policy that appear to have the best total welfare outcome, and even the only one with a total positive economic welfare impact. This is due to the boost in exports that it provokes.

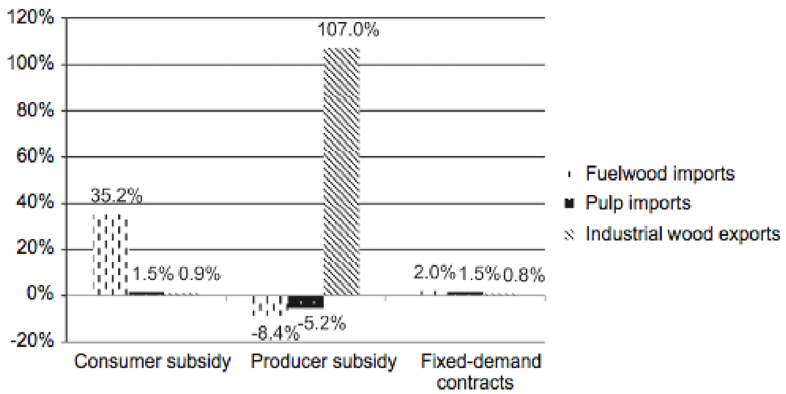
Table 4: Welfare implications of the three policies

Welfare implications of policy scenarios relative to the BAU scenario in 2020 (unit: M€) for all consumers and producers in FFSM.

	Consumer subsidy	Producer subsidy	Fixed-demand contracts
Fuelwood consumers	+596	+577	−7
Pulp consumers	−22	+95	−28
Panels consumers	−23	+61	−22
Plywood consumers	+4	+2	+1
Sawnwood consumers	+22	+25	+10
Industrial wood producers	+210	+540	+183
Roundwood producers	+10	+29	+12
Government	−818	−1211	−481

Source: Caurla et al. (2013a)

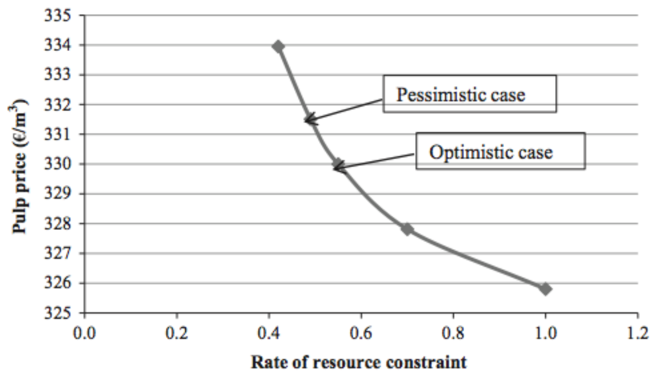
Figure 4: Trade impacts of the three policies



Source: Caurla et al. (2013a)

Figure 5: Impacts of the three policies on the pulpwood price

Pulp prices for different resource availability levels in 2020 in a scenario without fuelwood policy. These levels encompass what we defined as the optimistic and the pessimistic cases, as well as other unrealistic cases.



Source: Caurla et al. (2013a)

All in all, those results underline an interesting trade off when choosing a policy option to increase the consumption of fuelwood. Supply-sided policies tend to favors the forest sector trade balance, at the expense of increasing tensions over forest resources; in contrast, consumer-sided subsidies deteriorate the trade balance, but allow less pressure on the forest stock.

4/ Potential impacts of a carbon tax on the French forest sector

FFSM being a sectoral model, feedback effects with the rest of the economy are not consider in its initial version. However, in reality, there are links existing for instance between the fuelwood sector and the energy sector. Moreover, inter-sectoral policies may have an impact on the forest sector through those feedback effects.[2]

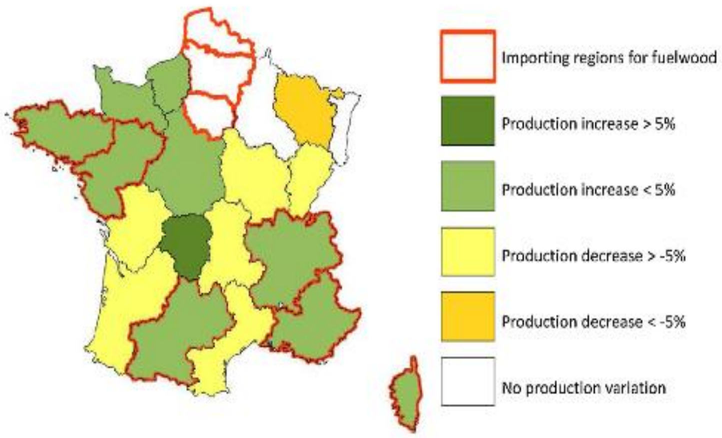
Focusing on fuelwood, Caurla et al. (2013b) take the hypothetical case of an economy-wide carbon tax, and the way it could impact the forest sector. Our simulations are therefore based on this value of Euro 17/tCO2 in 2010 +Euro 2/tCO2/yr. The basic idea is that several wood product have a lower carbon content than their non-wood substitutes (coal, fuel, oil, electricity, gas). It naturally follows that a carbon tax does not impact wood products to the same extend than non-wood products, as long as their carbon contents differ. Therefore, a carbon tax may have two effects on the forest sector: a direct income effect tends to reduce consumption, because of the price increase due to the tax; while a substitution effect tend to increase it for products with a comparative advantage in terms of carbon, as their price increase less than their more carbon-intensive substitutes. This study finds that, for fuelwood, the substitution effect dominates the income effect. If the substitution effect is not taken into account in the model, fuelwood production decreases by approximately 0.5% at the national level. Once competition between wood and non-wood products, and hereby the substitution effect, are introduced, fuelwood production increases by 1.8% at the national level.

However, a carbon tax on the whole economy also has the impact of increasing transport costs. In our case, one can notice that regions exporting fuelwood tend to decrease their production, while regions importing fuelwood tend to increase it. This is especially true for regions that tend to export to/import from regions that are further away, since the burden of the tax is then more important.

An economy-wide carbon tax may thus have a general effect of increasing wood consumption and production. However, this increase hides regional disparities that are mainly due to transport costs.

Figure 6: Impacts of the three policies on the pulpwood price

Regional variations in 2020 fuelwood production after a D17/tCO2 +D2/tCO2/yr carbon tax is implemented with regard to a scenario without tax.



Source: Caurla et al. (2013b)

[2]The work on feedback effects between the energy sector and the French forest sector is actually the topic of a research project of coupling FFSM with the Green Electric System model (Bertrand, 2014).

5/ Conclusion

Forests have an important role to play to mitigate climate change, both from a sequestration and an energy perspective. There is therefore an essential need to have a good understanding of the implications of implementing policies to enhance those two channels, as they are likely to provide synergies and trade offs both on the environmental side (resource use, climate change mitigation) and on the economic side (impact on consumers, producers, trade balance, government budget).

The French Forest Sector Model (FFSM, Caurla et al., 2010) is a bio-economic simulation model that was created with the view to assess potential impacts of public policies on the forest sector. In this paper, we synthesized major results that have been published so far using this model, and assess their main implications.

The work stemming so far from the French Forest Sector Model exhibits three main messages:

1/ When applying the same consistent carbon price on both substitution and sequestration policies, the latter tends to have better carbon balance over a short time (2020) horizon. Moreover, this policy option tends to have the best outcome in terms of global welfare (but not for the consumers only).

2/ When focusing on substitution policy, an implicit trade off between tensions over forest resources and trade balance determines the choice between a producer-sided (enhancing harvest intensity and increasing exports) and consumer-sided policy (increasing imports with lower harvest intensity).

3/ A carbon tax may be beneficial to the forest sector, as long as forest products have better carbon performance than their non-wood substitutes. This is done however at the expense of having heterogenous regional effects, that are due to increased transport costs.

More work can be done with FFSM and define our future research program. First, having a better understanding of fuelwood consumption behaviors would help to get a more precise view of the fuelwood sector. Moreover, a better description of the use of the by-products of the timber-processing industry is required, as it can be a source for fuelwood provision. Second, integrating a forest management module in FFSM will allow to run longer term simulations (over the century), that are necessary in order to assess the forest sector potential for adaptation to climate change, as well as the long term capacity of the French forests to represent an efficient carbon sink (Lobianco et al. 2014a, Lobianco et al. 2014b).

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