Fuelwood Consumption, Uncertainty over Resources and Public Policies: What Impacts on the French Forest Sector?

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Abstract

In the context of climate change and expected rise of energy prices, fuelwood may become an important source of energy, especially for countries with large forest stocks. However, an important increase in fuelwood consumption may have non-negligible impacts on other parts of forestry sectors. Using a new national forest sector model, this paper aims at assessing those potential impacts on the French forestry sector. We compare three different policy options to boost fuelwood demand. Overall it appears that increasing forest resources availability is critical to avoid competition and eviction effects on other timber uses.

Keywords: forestry sector modeling, fuelwood, bioenergy, supply contracts.

JEL classification:

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1 Introduction

As part of its climate change and energy package, the European Union aims at increasing the share of renewables in its overall energy mix to 20% by 2020. Biomass energy is expected to play a major role in meeting this objective, most notably in countries such as France, where wood resources are both abundant (France has the fourth largest forest cover among EU25 countries) and under-exploited, in the sense that only an estimated 60% of the total annual increment in wood resources is harvested, leaving room for an additional annual harvest of some 30 to $40Mm3$ without decreasing total stock (IFN, 2008).

On this basis, French forest sector development plans call for an increase in timber and fuelwood consumption, and the Government has encouraged the construction of new medium- to large-scale combined heat and power biomass plants. Yet there is considerable uncertainty as to how much of this physical volume is in fact commercially available. High exploitation costs in mountainous areas make part of this stock commercially unnattractive anyway. In addition, more than one third of French forest properties are below 25ha, and small-scale forest owners do not necessarily react to price signals as large-scale forest owners do. Thus, concerns have also been raised that an increase in fuelwood consumption might actually restrict supply of raw material for other parts of the French forestry sector, notably for the pulpwood industry (Chasset, 2007).

The objective of this paper is to assess the economic implications of an increase in biomass energy demand on the French forest sector, in a context of uncertainty about the commercially available stock of wood, and the rate at which this stock increases over time. To do so, we develop a partial equilibrium model of the French forest sector, and examine how it reacts to a gradual increase in biomass energy demand from now on to 2020, under various assumptions about commercially available stock and about forest dynamics.

Three potential public policies to boost fuelwood consumption are considered. First, we model an exogenous increase in demand, which mimics the current policy of encouraging medium- to large-scale biomass energy plant development. We also consider two alternatives to reach the *same* total increase in demand: a consumer and a producer subsidy. For each policy, we assess raw materials price dynamics and potential tensions between fuelwood and pulpwood. On the consumer side, we assess how increases in public demand influence market prices and private demand. We also look closely at the implications of the various policies for imports and exports, which play a significant role in assessing whether increases in the demand for biomass energy can be met while preserving sustainable management of the French forest. Section 2 describes the model. Section 3 presents simulation results, and Section 4 concludes.

2 A Model of the French Forest Sector

There exist several partial equilibrium models of the international forest sector, such as the Global Forest Sector Model (Buongiorno et al. 2003) or the EFI-GTM (Kallio et al. 2004). These models, however, have a very aggregate representation of individual countries such as France. In addition, these models either do not have a detailed representation of forest dynamics, or are based on monospecific, even-aged forests, which are not as dominant in France as they are in other countries. It is thus useful to develop a model that be more detailed, and that be specific to French forest conditions.

2.1 Specific Features of the French Forest Sector

First, most existing forest sector models only consider even-aged monospecies forests. Yet a larger variety of forest management must be considered in the French case. Uneven-aged forests are indeed an important forest management practice. Moreover coppices and coppices under standard are also frequently used. Those practices have an impact both on the growth dynamics of the forest stock and on the behavior of the forest owners. Basically, uneven-aged forests imply no clear-cutting of the forests stands, and selected harvest. Timber supply is thus potentially affected. Moreover, a large variety of timber species with different quality, growth and management patterns are to be distinguished.

Second, the French forest is characterized by over-capitalization. Indeed the state of the French forests is not consistent with industrial long-term management. Basically, French forests are considered to be under-harvested (Ballu et al., 2007). An intuitive explanation for this fact is that many forest owners do not behave as industrial forest owners and respond to other incentives than prices and costs. Another potential cause of under-harvesting is the important extraction costs of timber in certain regions. If prices do not match those extraction costs, it may be rational not to supply timber since timber harvesting is simply not profitable.

2.2 A sectorial bio-economic model

We consider a simulation model, with a succession of identical periods. Equilibria are computed sequentially, one period after another, and periods are linked by key dynamic equations, such as timber growth, and supply and demand evolution.

Our model is composed of two inter-related parts. Dynamics of the forest stock is contained in a biological module which forms the backbone of the model. This biological module is linked to an economical module through the inventory volume and the price of raw materials. The economic module describes the French forest sector dynamics with a static simulation mechanism, in a partial equilibrium framework.

2.3 Biological forest dynamics

Growth of timber stocks is evaluated taking into account different potential influencing factors. We distinguish: diameter classes d, type of management m, property rights pr, national regions i and species s. In this sense, we are able to cope with the large variety of the French forests.

Basically, timber growth dynamics are defined as follows :

$$F_{d,m,pr,i,s,t} = F_{d,m,pr,i,s,t-1}(1 + r_{d,m,pr,i,s} - d_{d,m,pr,i,s} - h_{d,m,pr,i,s}) \tag{1}$$

Forest stock F depends on the stock one period before, plus the natural increment r, minus natural mortality d and harvest rate h.

Our forest stock can be divided in two components, depending on the final use of timber. This division follows the assumption that different types of goods imply different types of good. Namely we distinguish timber that is sold for lumber from the one sold for fuelwood and pulpwood.

2.4 Economic interactions

The economic part models the whole sector, from timber suppliers to final consumers. Specification for the supply and demand functions is quite close to the one of GFPM (Buongiorno et al., 2003). Forest owners supply timber w which is transformed by the timber processing industry. Processed goods p are sold to final consumers. Our main theoretical contribution concerns foreign trade.

Trade: First, consistently with the GFPM, inter-regional trade (i.e among national regions) is considered through Samuelson theory (1952): trade between regions is only determined by relative prices and transport costs. Trades between region i and j are noted $e_{i,j,p,t}$ and $e_{i,j,w,t}$. Transport costs are $C_{i,j,p}$ and $C_{i,j,w}$, p refers to final products, w to primary ones and t to time.

Second, following Armington (1969), international and domestic goods are considered to be imperfect substitutes in consumption. Armington theory proceeds sequentially. First, consumers D determine their demand considering a composite price $\tilde{P}_{D,i,v,t}$ of good p:

$$\tilde{P}_{D,i,p,t} = [P_{i,p,t}^{1-\phi_{D,i,p}} (1 - b_{D,i,p})^{\phi_{D,i,p}} + P*_{p,t}^{1-\phi_{D,i,p}} b_{D,i,p}^{\phi_{D,i,p}}]^{1-\frac{1}{\phi}_{D,i,p}} \tag{2}$$

with $P_{i,p,t}$ the local price of good p and $P*_{i,p,t}$ its international price. $\phi_{D,i,p}$ is the elasticity of substitution of good p and $b_{D,i,p}$ is the initial share of the good that is imported.

Then, once the composite good demand is determined, agents share it between importations and local demand. We assume that local and international goods are imperfect substitutes. More precisely, production preferences have the form of a CES function. Thus local demand $LD_{i,p,t}$ and importations $M_{i,p,t}$ of good p are respectively:

$$LD_{i,p,t} = (1 - b_{D,i,p})^{\phi_{D,i,p}} D_{i,p,t} (\frac{P*_{p,t}}{\tilde{P}_{D,i,p,t}})^{-\phi_{D,i,p}} \tag{3}$$

$$M_{i,p,t} = b_{D,i,p}^{\phi_{D,i,p}} D_{i,p,t} (\frac{P*_{p,t}}{\tilde{P}_{D,i,p,t}})^{-\phi_{D,i,p}} \tag{4}$$

with $D_{i,p,t}$ the demand of the composite good.

Third, concerning the transformation industry, we assume that the share of exports and imports are fixed: $X_{i,p,t} = xS_{i,p,t}$ and $M_{i,w,t} = mD_{i,w,t}$, with $x < 1$ and $m < 1$. Finally, concerning timber suppliers, we assume that they face an external demand implying an export function of the type: $X_{i,w,t} = b_{S,i,w}^{\phi_{S,i,w}} D_{A,p,t}(\frac{\tilde{P}_{i,p,t}}{P*_{S,w,t}})^{-\phi_{S,i,w}}$. Where $D_{A,p,t}$ is the demand for p for the whole rest of the world.

We can now focus more precisely on the behavior of the three classes of agent: timber suppliers, final consumers and the transformation industry.

Timber Supply: Suppliers of good w have the following supply function:

$$S_{i,w,t} = S_{i,w,t-1}(\frac{P_{S,i,w,t}}{P_{S,i,w,t-1}})^{\epsilon}(\frac{F_{i,k,t}}{F_{i,k,t-1}})^{\gamma}(\frac{F'_{i,k,t}}{F'_{i,k,t-1}})^{\psi} \quad (5)$$

with $S_{i,w,t}$ timber supply of type w at time t in region i, and F and F' are the forest stocks of type $k = l, f$. ϵ, γ and ψ are the supply elasticities with respect to prices and stocks, respectively. Three timber supplies are distinguished: fuelwood, pulpwood and lumber.

Those three different supplies are likely not to come from the same timber stock. Lumber stock ($F_{i,l,t}$ and $F'_{i,l,t}$) contains forest inventory which is likely to enter roundwood market. We distinguish two types of lumber stock. $F_{i,l,t}$ is the stock of timber with increasing value, while $F'_{i,l,t}$ represents the stock of timber with decreasing value. The implicit idea is that forest owners do not have the same supply behavior with those two types of timber. Indeed, an important challenge of the model is to understand causes and patterns of forest under-harvesting. In this perspective, it is crucial to distinguish the stock of timber which has achieved its optimal cutting diameter (or age).

Stocks for pulpwood and fuelwood markets are represented by $F_{i,f,t}$ and $F'_{i,f,t}$. Fuelwood and pulpwood are thus directly competing for the same raw materials. $F_{i,f,t}$ represents living stock, typically wood coming from coppices or thinning, and $F'_{i,f,t}$ contains by-products, waste paper and logging residues.

Depending on the assumption made on the supplier's behavior, the patterns of timber supply (mainly elasticities) may be distinguished according to region, forest management type, property rights (private or public), timber species or accessibility.

Timber Processing Industry: As in many forestry sector models, the processing industry is represented by an input-output matrix. Transformation is made with fixed coefficient. Technologies are thus assumed constant in time, with no technical progress nor scale effects. Moreover the industry is assumed to have no market power, and only works as a transformation filter:

$$S_{i,p,t} = \sum_{i,p} a_{p,w} D_{i,w,t} \tag{6}$$

a is the quantity of raw material w used to create a unit of final product p. We have six different final products p: sawnwood, plywood, pulp, fuelwood, fiber and particle board and other industrial roundwood. The unit cost of product p is $c_{i,p,t}$.

Final Goods Composite Demand: Demand of timber processed goods p in region i at time t takes the form:

$$D_{i,p,t} = D_{i,p,t-1}(1 + \alpha_p g)(\frac{\tilde{P}_{D,i,p,t}}{\tilde{P}_{D,i,p,t-1}})^{\sigma_p} \tag{7}$$

Links between $M_{i,p,t}$,$LD_{i,p,t}$ and $D_{i,p,t}$ are given by the Armington equation below:

$$D_{i,p,t} = [(1 - b_{D,i,p})LD_{i,p,t}^{\frac{\phi_{D,i,p}-1}{\phi_{D,i,p}}} + b_{D,i,p}M_{i,p,t}^{\frac{\phi_{D,i,p}-1}{\phi_{D,i,p}}}]^{\frac{\phi_{D,i,p}}{\phi_{D,i,p}-1}} \tag{8}$$

Base-year Data: Economic data used in building the model comes from various sources: SCEES (the French agriculture ministry service for surveys and statistic studies), FAO (Food and Agriculture Organisation UN) and French customs data. The base year chosen to initialize the model and start the projections was 2005. As our modeling is regional, some statistics - essentially for the demand side - are not available at the desired spatial level and was reconstituted using national observed benchmarks and some regional indicators.

National consumption was estimated as production plus imports minus exports. These values were then spatially disaggregated using regional GDP figures as indicators. Regional harvested wood and sawn wood production are available in published statistics. However data for veneer/plywood, panels and pulp was reconstituted from observed national figures and some indicators on factory capacities and number of workers. Quantities and values of foreign trade among the regions was reconstituted using national figures and regional weights furnished by French customs. Finally, inter-region trade was recovered using data on wood transport and region supply/demand balance. Prices are unit prices resulting from the surveys on final values in forest industries.

Table 1: **Comparison of Price and Income Elasticities of Consumption and Production between our Model and Literature**

Product	Buongiorno et al.		Kangas and Baudin		Our Model	
	price	*income*	*price*	*income*	*price*	*income*
Fuel wood			-0.62	-2.26	-0.63	-1.5
Sawn wood			-0.16	0.32		
Coniferous sawn wood	-0.44	0.185			-0.5	0.32
Non-coniferous sawn wood	-0.24	0.44			-0.5	0.32
Plywood	-0.53	0.92				
Veneer and plywood			-0.13	0.73	-0.5	0.73
Particleboard	-0.15	1.09	-0.24	1.15	-0.4	1
Printing and writing paper	-0.25	1.35	-0.15	1.66		
Pulpwood					-0.5	1.2

Model Parameters: Parameters of demand functions used in the model come from early published studies and estimations. There is an important variation in the values of these estimates because of the differences in methods and countries and years covered. Our parameters were chosen so as to be consistent with recent estimates and studies for countries comparable with France (Buongiorno and al. 2003 ; Kangas and Baudin 2003). Table 1 summarizes elasticities in these studies and those selected in the French model.

Supply function parameters of primary product are based on short-term estimations of timber supply function. As for demand function large differences exist in the published estimates of price and inventory elasticities depending on countries, years and methods. Buongiorno and al. (2003) used a 0.8 price elasticity for all countries. Barkaoui (2007) estimated price elasticities to 0.5 for broadleaved timber and 0.1 for conifer timber. In the present model price elasticities are set at 0.5 for non-coniferous sawlogs and 0.2 for coniferous sawlogs. Two inventory elasticities are used in the model depending of the size of trees. These elasticities are equal to 0.1 for large size trees and 0.3 for small size trees.

Equilibrium: At every period, the market equilibrium is given by the maximization of sum of all individual surpluses:

$$\begin{aligned}
\max_{D_{i,p,t},S_{i,p,t},D_{i,w,t},S_{i,w,t}} \quad &= \sum_{i,p}(\int_0^{D_{i,p,t}} \tilde{P}_{D,i,p,t}(D_{i,p,t})dD_{i,p,t} - \tilde{P}_{D,i,p,t}D_{i,p,t}) \qquad (9)\\
&+ \sum_{i,w}(P_{i,w,t}S_{i,w,t} - \int_0^{S_{i,w,t}} P_{i,w,t}(S_{i,w,t})dS_{i,w,t})\\
&+ \sum_{i,w,p}(P_{i,p,t}(1-x-c_{i,p,t})S_{i,p,t} + P^*_{i,p,t}xS_{i,p,t} - P_{i,w,t}(1-m)D_{i,w,t} - P^*_{i,w,t}mD_{i,w,t})\\
&+ \sum_{i,j,p}((P_{j,p,t} - P_{i,p,t} - C_{i,j,p})e_{i,j,p,t})\\
&+ \sum_{i,j,w}((P_{j,w,t} - P_{i,w,t} - C_{i,j,w})e_{i,j,w,t})
\end{aligned}$$

s.t.

$$LD_{i,p,t} + \sum_j e_{i,j,p,t} + xS_{i,p,t} = S_{i,p,t} + \sum_i e_{i,j,p,t} \qquad (10)$$

$$(1-m)D_{i,w,t} + \sum_j e_{i,j,w,t} + X_{i,w,t} = S_{i,w,t} + \sum_i e_{i,j,w,t} \qquad (11)$$

$$S_{i,p,t} \leq K_t \qquad (12)$$

$$S_{i,w,t} \leq F_{i,t} + F'_{i,t} \qquad (13)$$

$$X_{i,w,t} \leq S_{i,w,t} \qquad (14)$$

$$S_{i,w,t}, X_{i,w,t}, S_{i,p,t}, LD_{i,p,t}, M_{i,p,t}, e_{i,j,p,t}, e_{i,j,w,t}, P_{i,p,t}, P_{i,w,t} \geq 0 \qquad (15)$$

Equation (10) and (11) represent material balance for products w and p. $F_{i,t}$ and $F'_{i,t}$ refer to either f or l stock depending on which product w is considered. Periods are related *via* the growth of the timber stock (1), changes in supply (5) and changes in demand (7).

3 Fuelwood consumption and public policy

3.1 Policies calibration

First, we consider a policy in which the increase in demand in biomass energy is guaranteed by the Government. This can either be done directly (e.g., the public sector purchasing more biomass energy) or via fixed-supply arrangements whereby the Government generates the required increase in biomass demand from the private sector (e.g., as in the current CRE tenders). The impact of such a policy on the biomass energy market depends on the new plants supply themselves. A first possibility is that the new plants establish *fixed supply contracts* with domestic producer. This can be modelled by entering the additional demand directly into the domestic supply function (5). A second possibility is for the new plants to acquire biomass directly on the market, an option we denote by *fixed demand* here. Technically, the supplementary demand is then introduced directly in the material balance equation (left side of equation 10).

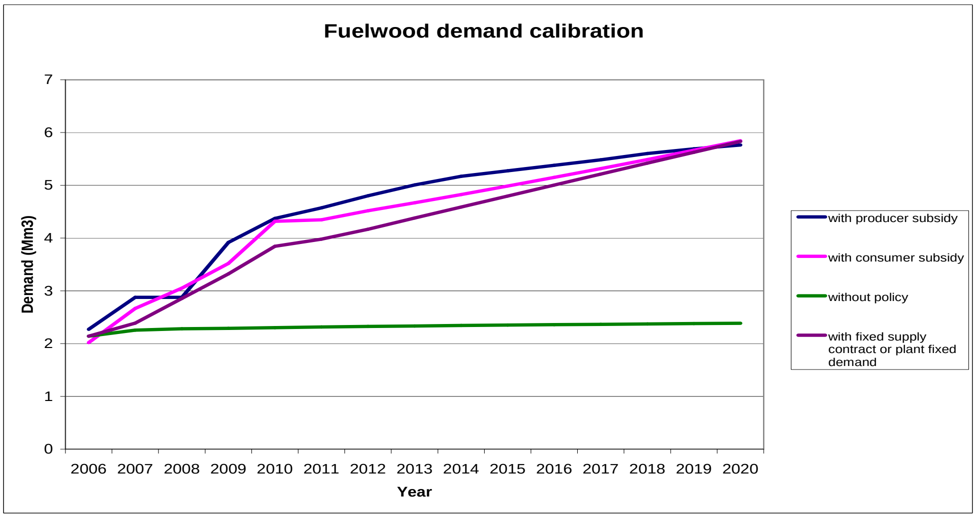
Second, we consider two alternative price instruments, namely a *supply-side subsidy* for fuelwood production and a *demand-side subsidy* for fuelwood consumption.

The aim of this section is to compare these four options on the basis of: (1) their impacts on fuelwood price, (2) their impacts on harvested volumes and international trade, (3) their sustainability and their implications for the tensions over wood inventory. For the comparison to be meaningful, all four policies are introduced in the same year (2007). In addition, all four policies are calibrated in such a way that the increase in demand follow the *same* path:

- Increase in demand from 2006 to 2010 is consistent with the expectations of the French Environment and Energy Management Agency (ADEME), i.e. +1.5 Mm3 in 2010 relative to 2006 level (ADEME, 2006; Chasset, 2007).
- From 2011 to 2020, we assume an annual increase in fuelwood demand of 0.2 Mm3 per year.

In this scenario, fuelwood demand has thus more than doubled in 2020 relative to 2006 (+3.32 Mm3). This is also twice the level of fuelwood demand in 2020 in our business-as-usual scenario.

Figure 1: **Policies are calibrated so as to match the same rising path**



In the remainder of this section, we compare the four policies in terms of their impacts on the market for fuelwood (3.2), total budgetary costs (3.3), sustainability of wood supply (3.4), and national carbon inventory (3.5).

3.2 Impacts on prices and volumes

3.2.1 Consumer side effects

First, the market price of fuelwood unsurprisingly increases relative to business-as-usual (BAU) when a consumer-side subsidy is implemented (Figure 2). Yet demand also increases relative to business-as-usual, because the price perceived by consumers (i.e., the market price minus the subsidy) is lower than the price perceived by consumers in the BAU.

The market price of fuelwood decreases when a producer-side subsidy is implemented. This is because suppliers are now able to simultaneously sell more than in BAU (Figure 6) (thus experiencing a higher marginal cost of production – see Figure 3) and sell at lower price, thanks to the subsidy they receive.

The market price of fuelwood decreases in the exact same way for the fixed supply contract policy (Figure 2). In fact fixed supply contracts and producer subsidies are perfectly equivalent in the sense <that a supplementary volume supplied is the corrollary of a supplementary amount of money received and leads to a decrease in supplier price (see following section), which leads to a decrease in consumer price> (*pas clair pour moi.*

Under the 'plant fixed demand' policy, the consumer price of fuelwood does not decrease. In fact, this policy is implemented so that a given volume of fuelwood is sold to public plants every year no matter what happens on the rest of economy. In particular, private demand functions remain unchanged in this policy. In the first four years consumer price even increases with plants fixed demand, which can be explained by an eviction effect coming from the competition between new public demand (contracts) and private demand. We will get to this idea more precisely later.

3.2.2 Producer side effects

Consumer subsidy leads to a rise in supply (figure 6) and thus to a rise in producer price (figure 3). Meanwhile, producer price decrease with both the producer subsidy and the fixed-supply contracts. This is due to the supplementary amount of money brung by producer subsidy. Producer price remains stable with plants fixed demand (figure 3), which has to be linked to the lack of supply stimulation with this policy.

3.2.3 Effects on trade

To get a similar rise in demand volumes, domestic supply intensity is different with the two subsidies, that comes from the model architecture concerning foreign trade. By implementing a consumer side subsidy domestic consumer price increases thanks to the subsidy (figure 2) and we are presently convinced that it leads to the visible rise in imports (figure 4). On the producer side, when implementing a producer subsidy supply and exports soar (figure 5 and 6) owing to the decrease in supplier price (figure 3). Exports pump out a high amount of domestic products and force supply to increase so as to match the rising path in demand.

3.2.4 Eviction effect with fixed-supply contracts

We can see fixed-supply contracts as competitors of private demand. This competition is obvious when looking at figure 7 which shows the eviction effect of contracts on fuelwood

Figure 2:

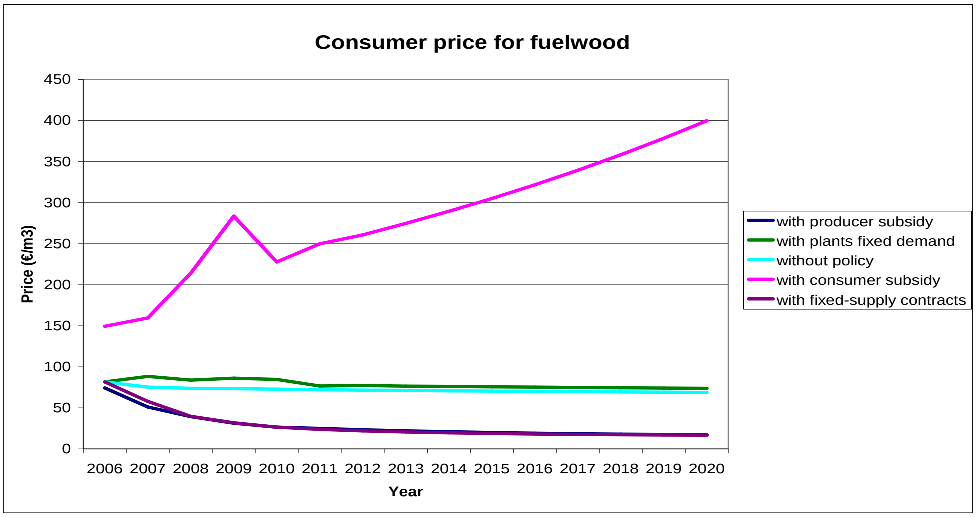


Figure 3:

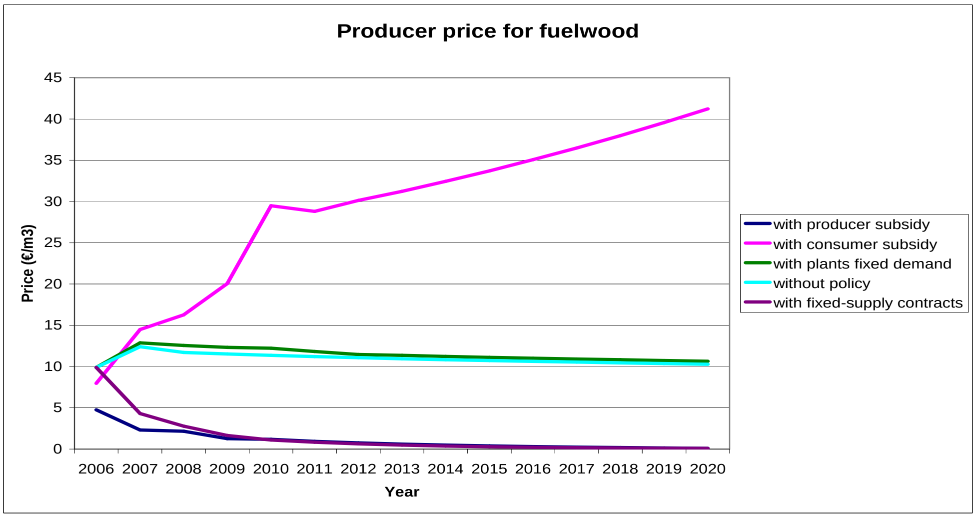


Figure 4:

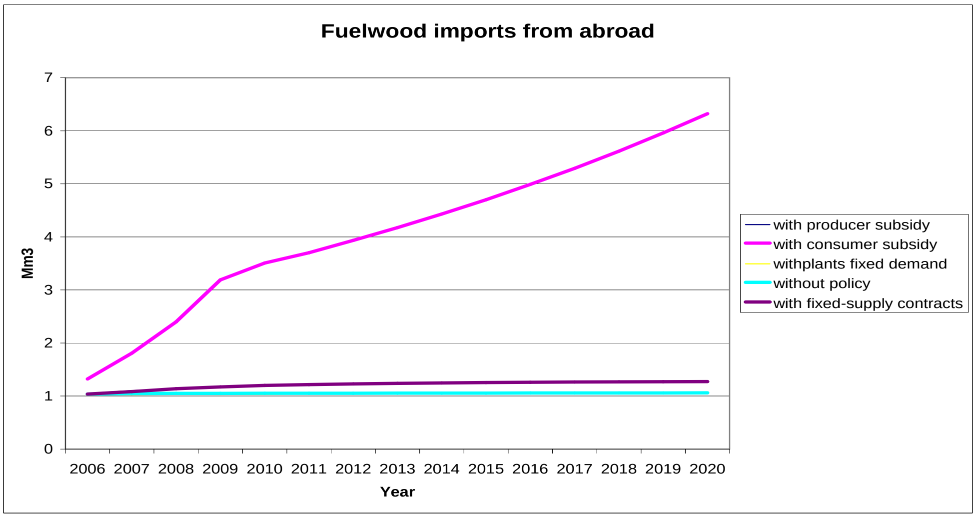


Figure 5:

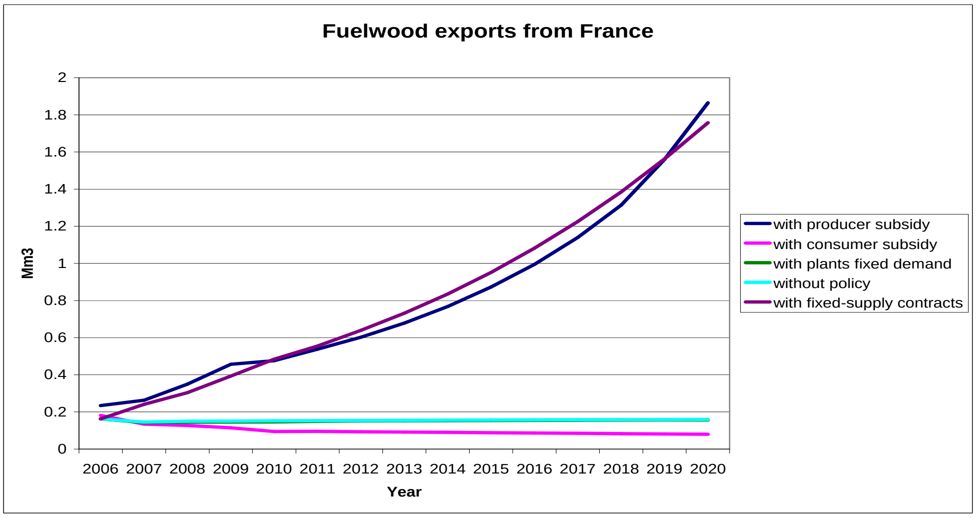
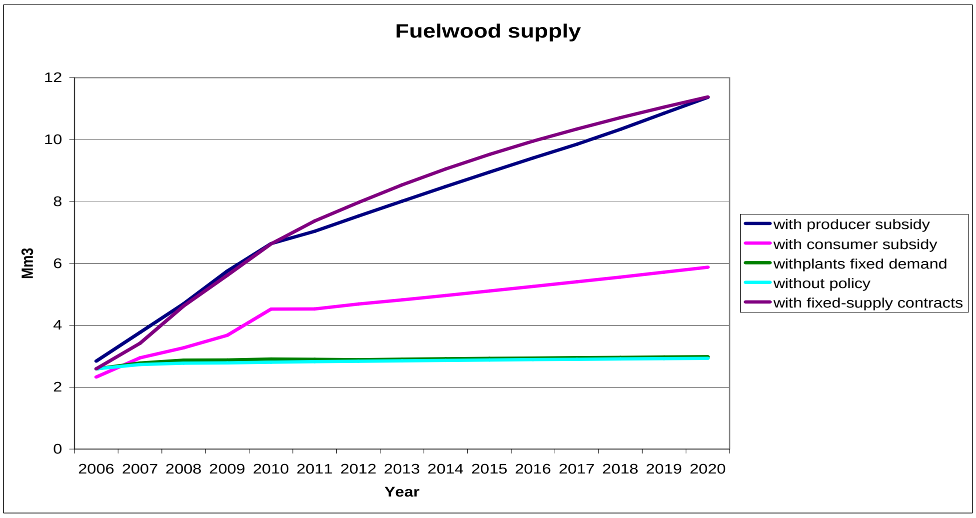


Figure 6:



private demand. This eviction effect leads to a tension on the price side (figure 8). This result clearly suggests that public contracts compete directly with private demand. However not all the amount of contracts come from eviction, indeed figure 7 clearly shows that domestic supply increases when policy is implemented but this increase is lower than with subsidies (figure 6).

3.3 Budgetary costs comparison

Having obtained a precise picture of the way the four policies impact on prices, quantities, and international trade, we now assess their budgetary costs. Subsidies cost is already given by the amount of subsidy (see Table **??**). Plant fixed demand costs and fixed-supply contracts are easy to calculate with the rise in demand ou supply volume that results from the policy and the price of the products.

On the basis of these results, it appears likely that implementation costs are different for the three policies. Nevertheless these figures must be considered cautiously. Indeed the high costs for consumer and producer subsidies partly result from the price elasticities we chose. Indeed a lower absolute value for price elasticity in demand would lead to a softer response in demand. We would obtain the same conclusions on the producer side.

Figure 7:

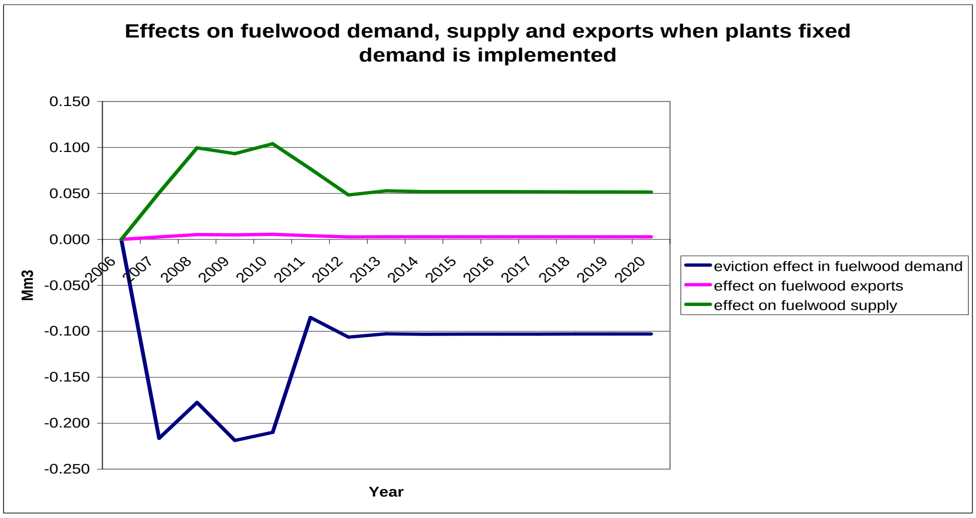


Figure 8:

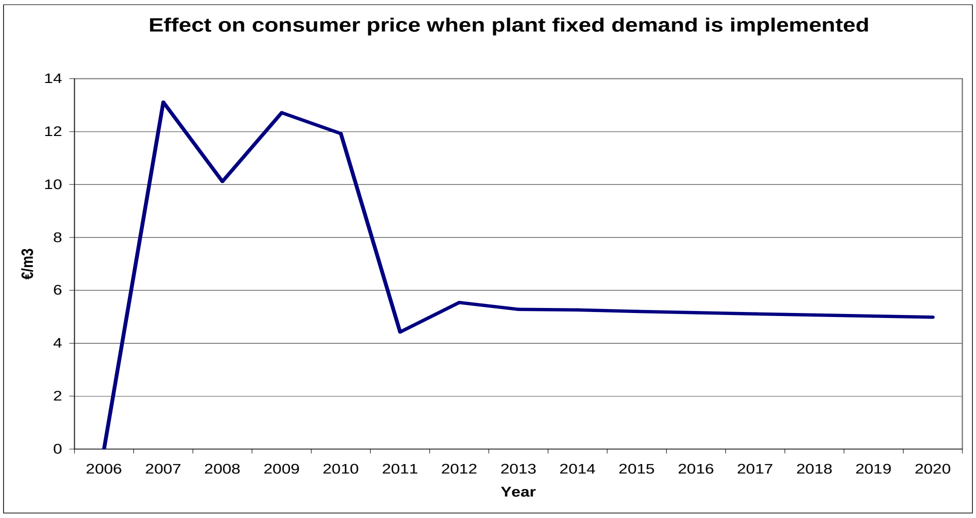


Table 2: **Policies costs**

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Producer subsidy(€/m3)	7.1	21.4	31.5	48.4	63.6	70.6	80	90	????
Consumer subsidy(€/m3)	59.7	102	167.5	246.6	201	223.2	235.8	251.1	????
Plant fixed demand(€/m3)	81.6	75.2	73.7	73.4	72.7	72.1	71.6	71.2	70.8
Fixed-supply contracts(€/m3)	81.6	57.8	39.6	31.8	26.5	23.7	22	20.6	19.5
Year	2015	2016	2017	2018	2019	2020			
Producer subsidy(€/m3)	100.2	111.8	123.7	136.3	150.4	155.7			
Consumer subsidy(€/m3)	266.9	283.7	301.5	320.2	340.1	361.1			
Plant fixed demand(€/m3)	75.6	75.2	74.8	74.4	74.1	73.7			
Fixed-supply contracts(€/m3)	18.7	18.1	17.6	17.3	17	16.7			

Besides, producer subsidy and fixed-supply contracts lead to a rise in domestic supply and thus in exports, which is profitable for the French economy. Meanwhile consumer subsidy decreases exports and increase imports.

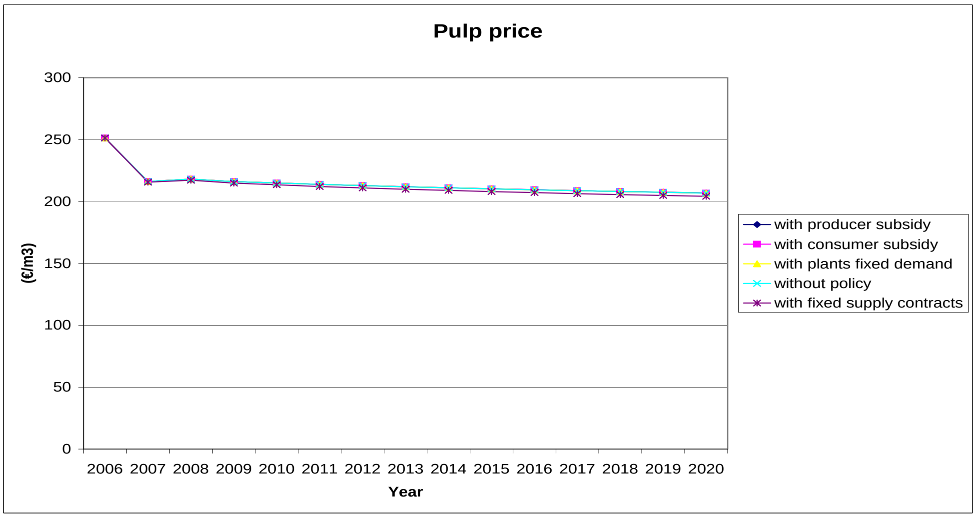
While policies clearly affect the fuelwood sector they do not impact the pulpwood sector. Pulpwood price and pulp price follow exactly the same trend with or without any of the three policies (figure 9). The stock available is rising no matter which policy is implemented. It would appear likely that the rise in harvesting rate due to policies is not strong enough to create tensions and there is every reason to believe that pulpwood sector is not affected owing to the lack of competition for the same raw materials.

To confirm this assumption we propose in the next section to test assumptions on stock and their effects on competition between fuelwood and pulpwood markets.

3.4 Sustainability

A policy will be sustainable if the stock is not reduced by the harvests. Thus sustainability depends on two parameters: (1) the rate of increment of the stock and (2) the initial volume of the stock. The rate of increment ($r_{d,m,pr,i,s}$ in equation (1)) can only be measured for one tree, in one region and for a specific type of forest. Growth rate for a stock composed of trees of different species, different diameters and from different region must then aggregate infor-

Figure 9:



mation of all individual trees. We made it possible by calculating a growth rate which take into account all this information. Nevertheless we consider this value as a first assessment that must be improved. We then take a range of three value for our further simulations: our value will be the medium one, we also test a ”fast” and a ”slow” scenario, fast scenario corresponds to a growth rate equal to twice our value while slow consists in a growth rate equal to half the medium rate (figure 10).

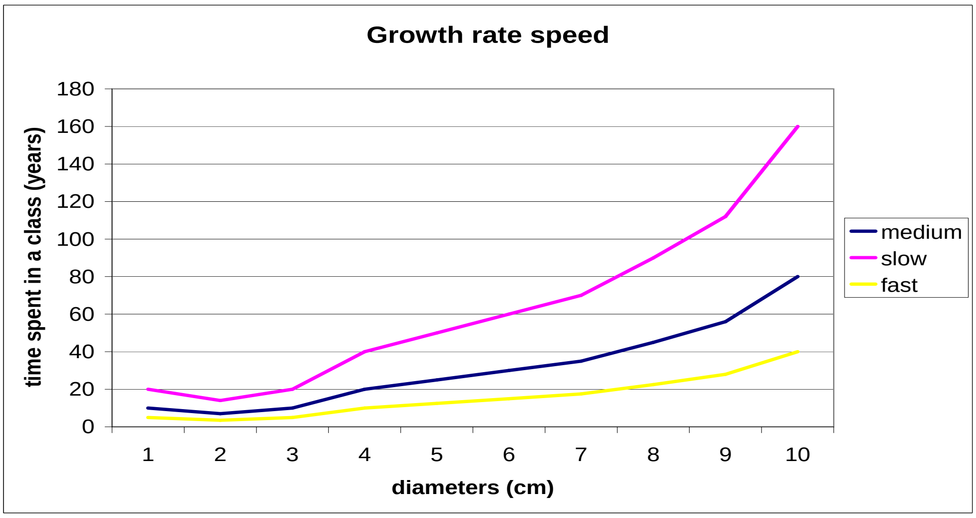
The assessment of volume available in 2006 is based on three criteria: first a raw stock is calculated through physical parameters such as the species, the diameter or the type of forest management. Then it is assumed that only a part of this raw stock is harvestable owing to economical considerations. Finally, the real harvestable stock depends on the forest owner supply behaviour. In general the harvestable stock is assumed to range between 10 and 30 % of the raw stock (Vallet et al., 2009) thus we test three cases: the low stock value consists in 10% of the raw stock, the medium one consists in 20% of the raw stock while the high value corresponds to 50%.

Besides, the level of restriction depends on the harvesting cost and on the raw products price trend. If prices increase it could become cost-efficient to harvest parts of the stock which were initially considered as inaccessible and then harvestable stock definition can

Table 3: **Cases**

Stock in 2006 (in % of the raw stock) growth rate	10%	20%	50%
slow	case A	case B	case C
medium	case D	case E	case F
fast	case G	case H	case I

Figure 10:



change, thanks to these three cases we can make different assumptions on the harvesting cost.

Finally we need to test effects of our three policies for nine cases corresponding to table 2. Those nine cases deal with uncertainty by representing a wide spectrum of biological stock behaviour.

Those nine scenarios allow to test potential tensions on the supply side, and potential eviction effects if the resource is poorly available or slowly renewable. We choose pulp price as a tension indicator, since pulp compete with fuelwood for the same raw material.

First we notice that pulp price increases when the stock is constrained. This result supports the conclusion that competition increases when the stock is constrained. Given our

Table 4: **Sustainability and tensions**

	Cases	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
without policy	sustainability	yes	yes	yes	yes	yes	yes	yes	yes	yes
	pulp price in 2020(€)	271	217	213	216	208	205	204	197	197
Consumer subsidy	sustainability	no	yes	yes	yes	yes	yes	yes	yes	yes
	pulp price in 2020(€)	281	217	213	217	208	205	204	197	197
Producer subsidy	sustainability	no	yes	yes	yes	yes	yes	yes	yes	yes
	pulp price in2020 (€)	298	217	213	219	208	205	204	197	197

assumptions only the case A is not sustainable, this case corresponds to the highest restrictive stock assumption (10%, which corresponds to about 50 Mm3 available for fuelwood and pulpwood sector in 2006) and the slowest rate of increment. Latest assessments of available stock is around 60 Mm3 (Vallet et al., 2009) which is slightly more than stock in case A.

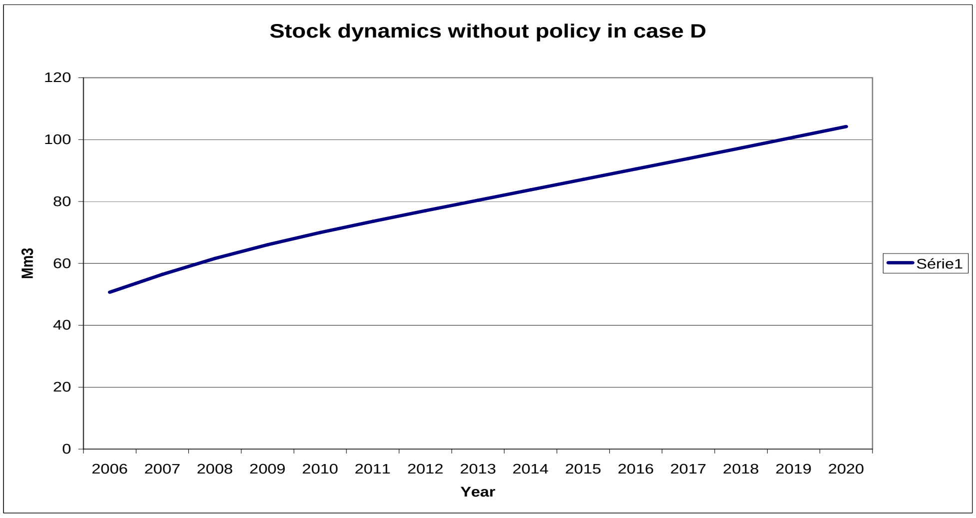
Besides, rate of increment and initial stock, sustanaibility depend highly on policy intensity. We have considered here a demand increase of 3.5 Mm3 in 2020 relative to 2006 level which seems to be a low rise. What happens if we need a rise of 21 Mm3 in 2020 regarding 2006 level? Considering a 10% stock assumption can we achieve these objectives? From a mathematical point of view the objectives are feasible (figure 11) but the main question remains what is the best way to make it possible? On the one hand, producer subsidy and fixed-supply contracts have the advantage to increase exports which is profitable from an economical point of view. On the other hand implementing a producer subsidy so as to obtain a 21 Mm3 rise in fuelwood demand could fast lead to an unstainable level owing to exports which pump out a part of the domestic supply.

A last question would be about effects of policies on carbon stock, this is what we propose to do in the next section.

3.5 Effects of policies on carbon stock and flows

As noted in the introduction, one of the overarching goal of increasing biomass energy consumption is to reduce greenhouse gases emissions. However, this increase in consumption has

Figure 11:



two different impacts on the national carbon balance. First, as long as biomass is replanted in a sustainable manner, fuelwood consumption is virtually carbon-neutral. Replacing fossil-fuel by biomass energy thus creates a positive substitution effect. Second, however, increase in biomass consumption may lead to a decrease in total standing stock, and thus on the total amount of carbon sequestered in national forests.

We notice plant fixed demand balance for stock is equal to zero, which means that this policy does not modify trade in any way. This is consistent with how the policy works: increase demand for plant is possible thanks to, first an eviction in private demand and second a very low rise in domestic supply. By demand we mean total demand (private +public) which, in this case, increases by about only 0.1 Mm3 for every cases because of eviction effect.

Second, we can notice that producer subsidy or fixed-supply contracts, which work the same way, have a higher negative impact on balance stock than consumer subsidy. We find every reason to believe that this is due to a higher supply level and a trade balance in favour of exports. However in case A, this balance is less negative: as shown in figure 12 , exports

Table 5: **Timber flows**

	Producer subsidy		Consumer subsidy		Plant fixed demand	
(Mm3)	*substitution*	*stock*	*substitution*	*stock*	*substitution*	*stock*
Case A	+3.7	-9	+3.7	-3.3	+0.1	-0.1
Case B	+3.7	-13.8	+3.7	-4.9	+0.1	-0.1
Case C	+3.7	-13.8	+3.7	-4.8	+0.1	-0.1
Case D	+3.7	-13.8	+3.7	-5	+0.1	-0.1
Case E	+3.7	-14.4	+3.7	-5.1	+0.1	-0.1
Case F	+3.7	-14	+3.7	-5.1	+0.1	-0.1
Case G	+3.7	-13.9	+3.7	-5	+0.1	-0.1
Case H	+3.7	-13.9	+3.7	-5.2	+0.1	-0.1
Case I	+3.7	-14.2	+3.7	-5.1	+0.1	-0.1

Figure 12:

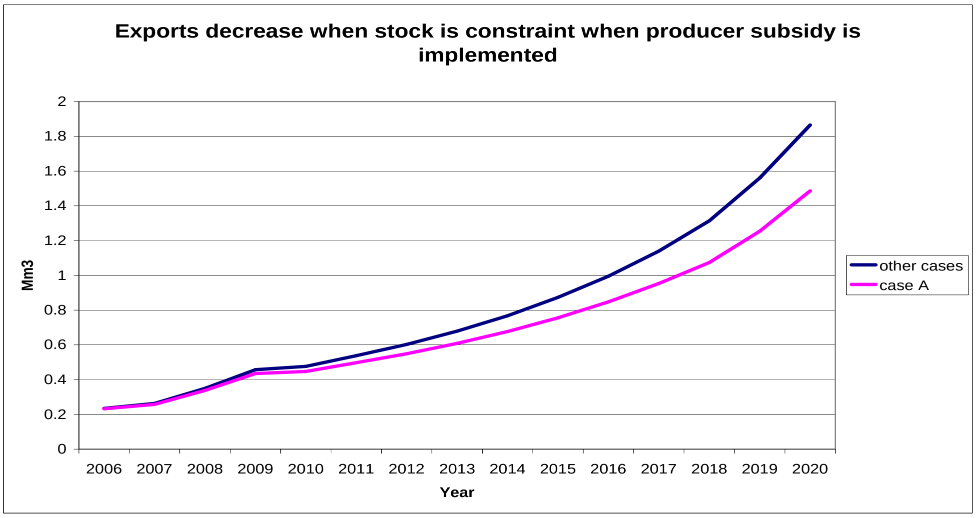


Table 6: **Carbon flows**

	Producer subsidy		Consumer subsidy		Plant fixed demand	
(teqCO2)	*substitution*	*stock*	*substitution*	*stock*	*substitution*	*stock*
Case A	+2.3	-9	+2.3	-8.1	+0.06	-0.24
Case B	+2.3	-33.7	+2.3	-12	+0.06	-0.24
Case C	+2.3	-33.7	+2.3	-11.7	+0.06	-0.24
Case D	+2.3	-33.7	+2.3	-12.2	+0.06	-0.24
Case E	+2.3	-35.2	+2.3	-12.4	+0.06	-0.24
Case F	+2.3	-34.2	+2.3	-12.4	+0.06	-0.24
Case G	+2.3	-33.9	+2.3	-12.2	+0.06	-0.24
Case H	+2.3	-33.9	+2.3	-12.5	+0.06	-0.24
Case I	+2.3	-34.7	+2.3	-12.2	+0.06	-0.24

decrease regarding other cases, constraint on stock results in a decrease of all "“leakages"’from France to abroad.

4 Conclusion

It has often been suggested that a policy increasing fuelwood demand would affect sectors in competition with fuelwood, such as pulpwood. Our goal was thus to understand the potential impacts of a rise in fuelwood consumption on both the fuelwood sector and the pulpwood sector. We made it possible by implementing a new French forest sector model that takes into account French particularities. We then considered three different policy options and nine potential cases of stock behaviour.

On the first hand, our results clearly show that, when implemented, the two types of subsidies lead to different trend in supply, exports and imports. Moreover the fixed-supply contracts led to an eviction effect in private fuelwood demand that does not appear with both consumer subsidy and consumer subsidy.

On the other hand, our results support the conclusion that the competition between fuelwood and pulpwood sectors depends on two parameters: timber availability and biological dynamics. Being a first approximation, this starting point is thus highly perfectible and points out future improvements. On the biological part, it is essential to strengthen the stock dynamics, by getting a more precise and accurate idea of timber growth. In this context, a research agenda has been set with a French specialized research center on forest resources (LERFOB) in order to get an accurate estimation of timber dynamics

On the economic side, implementing imperfect substitution concerning timber and the transformation sector using Armington theory (1969) seems a natural extension. Second, it is important to refine suppliers behavior in order to better describe the patterns that may lead to under-harvesting of the forest resources. In order to better understand long-term patterns, the land-use choice of land-owners has to be considered. Indeed, we consider here that forest management and replanting practices are constant in time. However, it is likely that those patterns respond to long-term price variation. Finally, we consider here that fuelwood consumption is as flexible as any good. However, it is likely that energy consumption presents some inertia, which would have to be considered to get a more precise idea of long-term evolution.

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