The French Biodiesel Production: An Assessment of the Impacts and Interaction Effects of Policy Instruments

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Abstract: This paper proposes to explore the welfare impacts of the French biodiesel policies on the consumer fuel prices. We use a theoretical model to determine under which conditions a binding mandate may lead to an increase in fuel prices. We distinguish between two cases, i.e. when the mandate is used alone and when it is implemented alongside a tax credit on biodiesel. The mandate is defined as a minimum percent requirement. Then we use historical data to make an empirical assessment of the effects of these policies. We derive from the observed quantities and prices of diesel and biodiesel in France over the past the value of the price elasticities of the diesel supply, the biodiesel supply and the fuel demand. This allows us to determine the sign of the fuel price change and thus the impact on consumers' welfare. Results show that the marginal effect of the mandate alone has been until now a decline of the fuel prices. But as the incorporation rates still grow, the situation is likely to reverse in the coming years. Hence the consumers' welfare would be negatively affected. But this policy may be efficient to reduce GHG emissions as the rise of fuel prices could lower fuel consumption and thus fossil fuel use. A tax credit allows a mitigation of the increase in the biodiesel price. However, this absorbing effect may disappear as the rate of the tax credit is decreasing.

Key words: biofuels, blend mandate, subsidy, social costs.

JEL classification: H23, Q41, Q42, Q48.

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1. **Introduction**

The European Union, like many countries worldwide, is implementing large scale biofuel programmes. If the United States focus on ethanol production, the EU enhances biodiesel, mainly through rapeseed vegetable oil (fatty-acid-methyl-esther, called FAME). With near six billion liters produced in 2008, the EU provides half the global volume and is still the first biodiesel producing region (UNEP 2009). Since the EU is a net importer of diesel, the expansion of rapeseed-based fuel should contribute to improve its energy independency. On the contrary, ethanol doesn't participate in this goal as gasoline surplus are exported[2]. That's the reason why governments favor biodiesel that represents more than 80% of total biofuels produced in the EU.

This article focuses on the French case. It aims at assessing the impacts of the biodiesel support policies implemented in this country. Indeed, in order to reach the indicative targets set by the 2003 and the 2009 European Commission's Directives, member states rely on several incentive tools. Among these policies, the most commonly used are tax credits, mandates and import tariffs. The first ones can be defined as a reduction of the excise tax charged on consumer fuel sales. Mandates work as an obligation to incorporate a minimum percentage of biofuels in transportation fuels. The latter policy aims at protecting domestic biofuel producers from competitive imports. The rationale of these policies is multiple. Generally, governments invoke the necessity to promote a sustainable development by enhancing the use of renewable energies, to reduce GHG emissions, to increase energy

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[2] The EU has known an increasing disequilibrium between the different road transport fuels. Indeed, diesel represents in average more than three quarters of the consumed fuels (in some member states the part of diesel exceeds 80%, as in Belgium or Luxemburg). The reason of this disequilibrium lies on the tax differential between diesel and gasoline. This taxation gap destabilizes the refining sector. Originally, the EU aimed at preserving its energy independency by enhancing the use of diesel engines, more economical in fuel consumption. But this strategy is no longer efficient as it has led to a sharp rise in diesel imports.

independency and to improve farm incomes. But the level of production and consumption of each member state varies a lot. If some countries such as Germany and France have already reached the indicative target set in the 2003 Directive, other countries are still far from it. In the same way, the systems of support measures lie on very different schemes. Nonetheless, these differences could no longer last. Indeed, concerns about the impacts of biofuels on food prices and the environment have put into question the mass production of this renewable energy. The respect of sustainability criteria and certification schemes has been considered by the new 2009 Directive as a necessary condition to the future biofuel expansion. As a consequence, some countries such as the United Kingdom have reduced their incorporation objectives to limit their imports from areas that don't respect sustainable criteria. The cost-effectiveness of biofuel support policies is also a currently discussed issue in the EU. The idea that tax exemption levels could be adjusted downwards without affecting the viability of the biofuel industry has been often uphold (see for e.g. Rozakis and Sourie 2005). Finally, Germany, first European biodiesel producer, decided in 2008 to increase the taxation rate on this product and to reduce the amount of quotas allocated to operators. The resulting decreasing German consumption has led to a lesser increase in the European biofuel use of 28.5% on the 2007-2008 period (the growth rate was 45.7% and 70.9% over, respectively, the 2006-2007 and the 2005-2006 periods, according to EurObserv'ER (2009)). This position has been adopted by other member states such as Luxemburg.

But, interestingly, France, the second European biodiesel producer, chose not to follow this tendency. Its production is continuously growing. The incorporation rates fixed by the government are the most ambitious of the whole area and anticipate by two years the European targets. In order to reach its objectives, France has implemented an original incentive system combining several measures. In spite of a non-officially binding mandate, distributors are required since 2005 to pay a supplementary tax if they fail to supply the

transport market with the level of biofuels desired by the government. Next, a tax credit on low and high blends gives them incentives to incorporate biofuels in fossil fuels. But this advantage is reserved to operators that have received a production quota by the government following an invitation to tender.

The purpose of this article is to explore the welfare economics of the combination of policies implemented by France. If it seems efficient to reach the desired level of consumption, the question of its social costs and of its ability to reduce fossil fuel use remains open. The economic literature provides many examples of analyses on the welfare impacts of the various measures supporting biofuels. Most of them focus on the US ethanol policies and study their isolated effects. Gardner (2003), Gardner (2007), Taheripour and Tyner (2007), Lapan and Moschini (2009) study the effects of the mandate and of the tax credit implemented by the US federal government. Martinez-Gonzalez et al. (2007) assess the consequences of the import tariff on ethanol. Some attention has also been given to the Brazilian case. Schmitz et al. (2003) study the Brazil's ethanol mandate, while Althoff et al. (2003) focus on the Brazilian biodiesel mandate. More recently, researchers have begun to explore the combined effects of the US biofuel policies. They study their impacts simultaneously, to underline their interactions. The understanding of such combined effects has been improved notably thanks to studies by Harry de Gorter and David Just. In three articles published in 2009, these authors have examined firstly the interactions between mandate and tax credit (De Gorter and Just 2009a), then the interactions between tax credits and price contingent farm subsidies (De Gorter and Just 2009b), and finally the interactions of the latter measures with import tariffs (De Gorter et al. 2009). Their works provide interesting findings on the efficiency of such policies. For example, De Gorter and Just (2009a) show that under some conditions the use of a tax credit alongside a blend mandate may act as a fuel consumption subsidy and thus subsidize both the use of renewable and fossil fuels. As a consequence, the combination of

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both tools has counter-productive effects that are at odds with the initial objectives of reduction of GHG emissions. Following these authors, this article aims at identifying the impacts of the French biodiesel policies on the final fuel prices. Using the theoretical model developed by De Gorter and Just (2009a), we find that the marginal effect of the French mandate has been a decline of the fuel price on the 2003-2008 period. But projections for 2010 and 2015 show that this situation is likely to reverse in the coming years as the incorporation targets are more ambitious. Those results put into question the efficiency of the French biodiesel policies. Indeed, as the tax burden and the welfare losses on taxpayers and consumers respectively are expected to grow, the increasing use of biofuels can only be justified on the basis of significant environmental benefits.

The article is organized as follows. The next section shows that the multiple measures used by the French government can be summed up as a binding mandate and a tax credit, and then exposes the conceptual model developed by de Gorter and Just (2009a). In the third section, we use historical data to determine the empirical impacts of the French mandate on the consumer fuel prices. We distinguish between two cases. We first assess the effects of the mandate alone, then the effects of the mandate in the presence of tax credit. We'll discuss in section 4 the results of our assessment. The last section provides some concluding remarks.

2. <u>A theoretical representation of the French biodiesel policies</u>

Despite its apparent complexity, we argue that the French biodiesel support scheme can be represented as a combination of a binding mandate and a tax credit. Indeed, even if there is not a legal obligation to incorporate biodiesel in conventional fuels, the introduction through

the article 32 of the 2005 Finance Law of a supplement[3] of the General Tax on Polluting Activities makes it binding. This supplement must be paid by fuel distributors that supply fuels with a biofuel content lesser than the incorporation national objectives. Hence, each operator has to make a tradeoff between the incorporation of the required level of biofuels and the payment of the GTPA supplement. This decision lies on the relative costs of biofuels and of the GTPA. From an economic perspective, incorporating biofuels is profitable only if the buying price of biofuels is inferior to the amount of GTPA that would have to be paid otherwise. As underlined by Guindé et al. (2008), Kutas et al. (2007) and EurObserv'ER (2009), the return of this tax is quite limited, and thus demonstrates that this financial penalty provides a strong incentive. Indeed, the rate of the supplementary GTPA is very high. The calculus of the tax depends on the difference between the required quantities imposed by the government and the current quantities supplied. So the amount of the tax increases with each non incorporated percent of biofuels. Alternatively, if the objective is reached, no tax is due the following year[4] (since the tax is based on the quantities supplied on the precedent year) . This argument seems to be verified. If the 2003, 2004 and 2005 French targets were not reached, the following objectives were respected. Since 2006 (first year of the GTPA payment), the targets were exceeded, traducing the will to avoid this supplementary tax. Consequently, the implementation of the GTPA led to a sharp increase in the domestic biofuel consumption.

Concerning the tax credit, it is only granted to a certain amount of quotas. The quotas allocated to operators are based on the needed volumes to reach the annual incorporation rates fixed by public deciders. In other words, the allocated production quotas match the biofuel

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[3] The initial GTPA has been implemented since 1999 and is supported by each firm whose economic activity causes environmental damages, including sectors of waste disposal and of washing powders.
[4] This supplementary tax is based on the fuel retail price excluding VAT. Its rate increases every year: from 1.2% in 2005, it was 1.75% in 2006, 3.5% in 2007, 5.75% in 2008, 6.25% in 2009 and 7% in 2010. It is reduced by the biofuel part in energy content. Thus, to avoid paying the GTPA, the biofuel incorporation rate had to be since 2005, respectively, 1.2%, 1.75%, 3.5%, 5.75%, 6.25% and 7%.

quantities that distributors have to buy to avoid to paying the GTPA supplement. From the government side, this system allows to limit the loss of tax revenue for the government, to control the expansion of the biofuel production and to avoid to resorting to non-European imports. For the authorized operators, it is a means to be protected from international competition[5] (particularly from the US biodiesel imports) and to significantly reduce investment risks. As a matter of fact, it seems that the French support scheme combining indicative incorporation target, financial penalty, tax credit and production quotas, could be represented as a system with binding mandate and tax credit in a framework without imports. For this reason, we use the partial equilibrium approach developed by De Gorter and Just (2009a) in order to represent the French biodiesel market. They build a theoretical framework without imports to analyze the US mandate and tax credit on ethanol. Following these authors, we first examine the theoretical implications of the mandate before exploring the combined effects of both mandate and tax credit.

2.1. The modeling of the binding blend mandate alone

Consider a competitive market where S_D is the domestic supply for diesel, S_B the domestic supply for biodiesel and D_F the domestic demand for fuel. Fuel represents the diesel-biodiesel mixture. We make the assumption that diesel and biodiesel are perfect substitutes in consumption. This is the case in France for the low blends used with conventional motors. Indeed, since the 1990s, the use of biodiesel up to a 5% volume in gasoil, and a 7% volume

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[5] Indeed, the EU import tariffs on biodiesel are very low (unlike tariffs on ethanol), in the range of 6.5% according to Kutas et al. (2007). Hence these tariffs don't protect against more competitive imports from other countries, notably from the United States. On April 2008, the European Biodiesel Board (organism defending the economic interests of the European biodiesel industry) lodged a complaint to the European Commission to denounce the high level of subsidies granted by the US government (in the range of $300/ton). These subsidies would have generated a sharp increase of the EU biodiesel imports between 2007 and 2008, and this fact would explain a large part of the slowdown of the EU production. The European Commission held this competition unfair and decided to authorize the temporary use of import tariffs on the US biodiesel, in the range of €213-409/ton (EurObserv'ER 2009). On July 7th 2009, the European Council extended this decision to five years.

since January 1st of 2008 has been unmarked. This means that distributors don't distinguish the products and sell the B5 or B7[6] diesel-biodiesel mixture as diesel. From a technical perspective, the energy content of biodiesel is 8% less than diesel, and hence the use of biodiesel with diesel should lead to an increase in fuel consumption[7]. But a 5 or 7% incorporation rate only leads to a theoretical increase in consumption in the range of 0.44-0.62%[8]. This difference is too weak to be easily perceived by consumers. Alternatively, high blends containing up to 30% of biodiesel for flex-fuel vehicles are clearly sold as distinct products. Nevertheless, B30 use is limited in France to captive fleets[9]. As a consequence, most of fuel users are not aware of the energy content difference and don't adjust their consumption behavior[10]. We also assume in this model that there is no distinction between domestic and foreign diesel supply and that there are no biodiesel imports. As explained previously, this latter assumption seems plausible since production quotas are sufficient to fill the incorporation objectives.

Consider a binding blend mandate requiring that a minimum share of biodiesel α has to be incorporated in all fuel sold, with α ∈ (0, 1). In equilibrium, biodiesel price and diesel price are equal to their respective marginal cost to blenders. In the same way, consumer fuel price is equal to its marginal cost. So the price of the diesel-biodiesel mixture can be calculated as the weighted average of diesel and biodiesel. The weights are given by the share of biodiesel required by the mandate, i.e. α.

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[6] The number indicates the percentage of biofuel incorporated into conventional fuels. Indeed, mixed fuels are commonly named by their biofuel part (B7, B30, B100, E10, E85…).

[7] Indeed, the FAME has an energy content of 33 024 kJ/l, against 35 952 kJ/l for diesel. All other things being equal, this means that the consumption in liters per 100 km is exactly 8.87% more with FAME than with diesel.

[8] The lower and upper limits are given by the following calculus, respectively (5x8.87)/100 and (7x8.87)/100.

[9] The term « captive fleets » refers here to firms' and local authorities' vehicles.

[10] Because of the lower energy content of biodiesel, the quantity consumed is expected to increase in order to keep the same mileage than with conventional diesel. As the marginal cost of biodiesel is higher, a larger consumption implies a more expensive fuel bill. If fuel is a normal good, a rational consumer will decrease its consumption as price rises.

The price relationship between biodiesel, diesel and fuel mixture is thus given by the following equation:

(1) $P_F = \alpha P_B + (1 - \alpha)P_D$

where P_F is the weighted average consumer fuel price, P_B is the market price of biodiesel and P_D is the market price of diesel.

The market-clearing condition on the fuel market is the equalization of the demand of fuel to the sum of both the biodiesel and diesel supplies:

(2) $D_F(P_F) = S_D(P_D) + S_B(P_B)$

Equation (3) describes the constraint imposed by the mandate:

(3) $\alpha D_F(P_F) = S_B(P_B)$

The mandate also requires the entire biodiesel supply to be used into fuel production:

(4) $\alpha S_F(P_F) = S_B(P_B)$

and

(5) $(1 - \alpha)S_F(P_F) = S_D$

The total differentiation of equations (1) to (3) allows us to derive the comparative static changes in prices resulting from variations in the mandate.

The change in the price of fuel for a change in the mandate can be written as

(6) $\dfrac{dP_F}{d\alpha} = \dfrac{(P_D - P_B) - \left(\dfrac{P_B}{\eta_B^S} - \dfrac{P_D}{\eta_D^S}\right)}{\dfrac{P_B}{\eta_B^S}\left[\alpha\dfrac{\eta_F^D}{P_F} - \dfrac{\eta_B^S}{P_B}\right] + (1-\alpha)\dfrac{P_D\eta_F^D}{\eta_D^S P_F}}$

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where η_F^D is the price elasticity of the fuel demand, η_B^S is the price elasticity of the biodiesel supply and η_D^S is the price elasticity of the diesel supply.

As the price elasticity of the fuel demand is negative, the denominator is negative. Thus a change in the mandate causes an increase of P_F if $(P_D - P_B) - \left(\frac{P_B}{\eta_B^S} - \frac{P_D}{\eta_D^S} \right) < 0$

or

$$(7) \left(1 + \frac{1}{\eta_D^S} \right) P_D < \left(1 + \frac{1}{\eta_B^S} \right) P_B$$

Thus the implementation of a mandate, with endogenous diesel price, doesn't necessary result in higher fuel price. The direction of the change in the final fuel price depends on the relative weighted supply elasticities of diesel and biodiesel. If the diesel supply is more elastic than the biodiesel supply, the fuel price is likely to increase. Indeed, an increase in the mandate leads to a rise in biodiesel consumption and hence in biodiesel price. On the contrary, as biodiesel substitutes for diesel, the drop in the demand for diesel causes a downward pressure on diesel price. As a consequence, the price of the fuel mixture will increase if the rise of biodiesel price is stronger than the decrease of diesel price. It will decrease otherwise.

2.2. The impacts of the mandate in the presence of a tax credit

Governments generally set tax exemptions along mandates. As biofuel production costs are higher than fossil fuel costs, tax credits aim at mitigating the adding costs for refiners. In the EU, France has been a pioneer by granting a tax credit on biofuels since 1992 through a partial exemption of the excise duty charged on all fossil fuels. Thanks to this policy, France rapidly became leader of the European production of biodiesel until 2001 (Ballerini et al. 2006).

In the presence of a tax credit, the price relationship between biodiesel, diesel and fuel is now:

(1′) $P_F = \alpha(P_B + t - t_c) + (1 - \alpha)(P_D + t)$

where t is the excise tax applied on the fossil fuel part and t_c is the tax credit on the renewable fuel part.

By differentiating equations (1′) to (3), the change in the final fuel price induced by a change in the mandate results in

$$(6') \quad \frac{dP_F}{d\alpha} = \frac{(P_D - P_B + t_c) - \left(\frac{P_B}{\eta_B^S} - \frac{P_D}{\eta_D^S}\right)}{\frac{P_B}{\eta_B^S}\left[\alpha\frac{\eta_F^D}{P_F} - \frac{\eta_B^S}{P_B}\right] + (1-\alpha)\frac{P_D\eta_F^D}{\eta_D^S P_F}}$$

The fuel price increases with the mandate if

$$(7') \quad \left(1 + \frac{1}{\eta_D^S}\right)P_D < \left(1 + \frac{1}{\eta_B^S}\right)P_B - t_c$$

Equation (7′) indicates that the impact of a mandate alongside a tax credit depends on the weighted supply elasticities of diesel and biodiesel, as in the case with mandate alone. But the level of the tax credit has a direct influence on the relative values of both elasticities. Indeed, the more it decreases, the more the weighted price elasticity of biodiesel increases.

3. An empirical assessment

Kutas et al. (2007) assert that the impact of mandates cannot be generalized as it varies following regions and periods. Moreover, few studies assess the effects of these policies on prices. The exogenous fixation of a market share on a good likely leads to an increase of its

price. Indeed, the mandate causes an upward pressure on demand resulting in a higher price than the one that would have occurred without mandate. Since biofuel production costs in EU are much higher than those of fossil fuels, the obligation to incorporate biodiesel into conventional diesel may increase final fuel price to consumers. But De Gorter and Just (2009a) have shown that the annual marginal effect of the US ethanol mandate on the 2001-2007 time period was to reduce fuel prices except for 2003-2004 and 2006-2007. This result confirms that a biofuel mandate doesn't lead necessary to higher fuel prices. This section provides such an investigation for France. Indeed, it seems useful to determine if the interesting findings of de Gorter and Just (2009a) may be verified for a smaller country. As oil consumption is less intensive in France than in the United States, the replacement of fossil fuels by the required part of biofuels doesn't represent a very important volume compared to the total transport fuel consumption. As a consequence, the mandate may not lead to a decline of fuel prices. Besides, it is likely that the magnitude of the change is smaller in France than in the United States. Another intuition is that the introduction of the GTPA in 2005 affects the results.

To determine the direction and the magnitude of the French mandate on fuel prices, we calculate the price elasticities of biodiesel and diesel supplies and the price elasticity of the fuel demand as they are key variables according to equations (6) and (6'). We use historical data on the 1994-2008 period to derive the values of these elasticities for different years. Concerning the price elasticity of fuel demand, we find an average value of -0.235, in the range of Clerc and Marcus (2009), Graham and Gleister (2002), Goodwin, Dargay and Hanly (2004). These three studies estimate that the short run price elasticity is in the range of -0.3 and -0.2. As explained by Clerc and Marcus (2009), individuals may adapt their fuel consumption in the short run by reducing the use of particular vehicles and by reducing mileage. The possibilities of adjustment are larger in the long run as households are able to do

more significant changes, for e.g. buying a more fuel economical vehicle. Hence the value of the long run elasticity is larger (-0.4 according to Clerc and Marcus, 2009).

Concerning the diesel supply, we find a relative price inelasticity with an average value of 0.81(but the diesel supply tends to be more elastic in time, exceeding 1.0 since 2007). The structure of consumer fuel prices in France may explain this feature. About 60% of the final fuel prices are taxes, and more than 80% of these taxes are fixed. Indeed, the excise duty on conventional fuels has a constant rate and thus the part of the VAT on this excise tax is constant too. As a consequence, fluctuations in both crude oil and diesel prices have relatively few repercussions on final fuel prices. Thus, refiners can transfer an eventual increase in the production costs into fuel prices without affect demand. The taxation weight masks and absorbs the downward and upward variations of energy prices. If the diesel retail price has increased by 110% on the 1994-2008 period, crude oil price and diesel price have risen, respectively, by 393% and 397%[11].

The biodiesel supply is assumed to be more elastic, with an average value of 2.15. But this elasticity is not homogeneous on the 2000-2008 period. If the biodiesel supply is quite inelastic or slightly elastic until 2006, there is a sharp increase of the elasticity value during the following years, with 4.56 and 4.04 estimates in 2006 and 2007 respectively. This traduces the introduction of the GTPA in France and the transition from non binding to binding mandate. Nevertheless, we find a decrease of the elasticity value in 2008, probably due to the rise in the incorporation rate. Indeed, the price of rapeseed oil is between 50% and 90% of the biodiesel price. As biodiesel becomes a growing share of rapeseed production, the price of rapeseed oil increases because of the competition between food and energy uses.

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[11] The average diesel price for consumer was 0.59€/l in 1994 and 1.24€ in 2008. The average crude oil price in € per ton was 100.42 in 1994 and 494.65 in 2008. The average diesel price in € per ton was 126.98 in 1994 and 630.87 in 2008 (data collected from French Ministries of Ecology, of Economy, Industry and Employment, INSEE, Reuters).

Thus, the price elasticity of biodiesel supply is likely to decline in the future, as it is underlined in De Gorter and Just (2009a) for corn-based ethanol.

Table 1 provides estimates of the variations of the fuel price induced by the implementation in France of a blend mandate alone and alongside a tax credit. Columns 2 and 3 indicate the incorporation rate that has to be reached and the level of the tax credit for the corresponding years.

Table 1. Estimated impact of the French mandate on fuel prices

	Incorporation rate α	Tax credit t_c	Variation of fuel price P_F induced by a change in α	
			With mandate alone	With mandate + tax credit
2003	0.98%	0.33€/l	-0.1307	-0.3922
2004	1.12%	0.33€/l	-0.1452	-0.4191
2005	1.2%	0.33€/l	-0.5809	-0.8575
2006	1.75%	0.25€/l	-0.7251	-0.9193
2007	3.5%	0.25€/l	-0.0943	-0.3299
2008	5.75%	0.22€/l	0.0701	-0.1355
2010*	7%	0.11€/l	0.0775	-0.0216
2015*	10%	0.08€/l *	0.0934	0.0062

Asterisk (*) denotes forecast

Source: calculated.

4. <u>Interpretation of results</u>

The above table reveals some useful insights. It shows that in the absence of a tax credit, the blend mandate always reduces fuel price on the 2003-2007 period. This means that the weighted price elasticity of diesel supply is larger than the weighted price elasticity of biodiesel supply. In other words, the substitution of diesel by biodiesel induces a reduction of the demand of diesel, leading to a decline of its price. On the contrary, the larger demand for biodiesel exerts an upward pressure on its price. Finally, the overall effect is a decline of the fuel prices because the decrease of the diesel price is larger than the increase of the biodiesel price. Concerning the magnitude of this fall, it is quite small in 2003 and 2004 but becomes

more significant in 2005 and mostly in 2006, as expected. Indeed, distributors face incorporation objectives that are increasingly ambitious, and have to comply with them to avoid to paying the supplementary GTPA. Nevertheless, we find that the decline of the fuel price becomes weaker in 2007 and gives way to a small increase of the price in 2008. This evolution may be explained by the constraint imposed by the energetic feedstocks of the biofuel industry. Indeed, as blending objectives are growing, the food-processing industry diverts an increasing share of the rapeseed production to produce biodiesel (at least 50% of the French rapeseed production is already used for energetic purposes). The competition between food and energy uses is intensified and leads to an upward pressure on rapeseed prices, because farm supply is limited by the amount of arable land. Hence the biodiesel supply becomes less elastic, as evoked previously. Besides, results show that the implementation of a tax credit alongside a mandate mitigates the rise of the biodiesel price. From 2003 to 2007, the fall of the diesel price in comparison of the increase in the biodiesel price is larger than in the absence of the tax credit. Thus there is a net reduction of final fuel prices. In 2008, if the mandate alone leads to a small increase of the fuel price, the combined use of the mandate and the tax credit allows the price change to remain negative. But this impact of the tax credit is likely to weaken in the future. Indeed, the exemption rate from the excise duty is decreasing, contrary to the incorporation rate of biodiesel. This means the upward pressure exerted by the mandate will be less and less softened by the tax credit. This is confirmed by the projections for 2010 and 2015.

Concerning the welfare impacts of the French biodiesel policies, the above results show an improvement of the consumer's welfare over the past period through the reduction of the fuel price. This positive impact is intensified by the use of the tax credit. But this may change in the future as the upward pressure of the mandate is stronger than the mitigating effect of the tax credit. Thus we expect a deterioration of the consumer's welfare in the coming years. But

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for consumers that pay taxes, it could be relevant to compare the variations of the fuel price with the changes in the amount of tax credit. The decrease of the tax credit acts as a welfare improvement for taxpayers. As the price of biodiesel increases with the demand, rapeseed producers get higher income. But for the refining sector the situation seems more uncertain. Indeed, as the level of the tax credit is decreasing, the profitability of the biodiesel will be more tightly linked to the price of crude oil. The higher the crude oil will be, the more profitable the biodiesel will become.

The efficiency of the French biodiesel policies has also to be assessed from an environmental perspective. Indeed, the European directive on fuels requires a 10% reduction of GES emissions by 2020, including a 6% biofuel contribution to this purpose. But the decline of the final fuel price on the 2003-2008 may lead to an increase in fuel consumption. If the fossil fuel content per liter of fuel tends to decrease, a rise in the consumed quantity of fuel also generates a global increase of the consumed quantity of fossil fuels. As a consequence, biodiesel policies lead to an increase in GHG emissions, that is at odds with the initial objectives. It also has to be noticed that the global effect on the oil producers' welfare is mitigated since the reduction of the fossil fuel content per unit of fuel (and hence the reduction of demand and price) can be mitigated by the increase in the global volume consumed. Nevertheless, the expected rise of the fuel price in the coming years could reduce fuel consumption and thus improve the environmental balance of biodiesel. But this analysis suggests that the impacts of these policies on consumers' welfare and the environment are opposed. It seems that an improvement of the consumer's welfare means an increase in GHG emissions and vice-versa. But this conclusion might be modified by taking into account the environmental improvement in the assessment of the consumer's welfare. Both the variables could be correlated in a positive way.

5. <u>**Concluding remarks**</u>

The French government is implementing ambitious measures to stimulate the production and the use of biofuels in transport fuels, and particularly of biodiesel. In order to reach the incorporation objectives, different policies are combined: blend mandates, tax credits on biofuels, production quotas and fuel taxes. The model we use in this article shows that until now the marginal effect of these policies has been a decline of the final fuel prices and hence an improvement of the consumers' welfare. But results have also revealed that the situation is likely to reverse in the coming years. As the incorporation rate of biofuels increases, fuel prices may rise. We find that the use of a tax credit alongside a binding mandate allows a mitigation of the rise of the biodiesel price and hence of the fuel price. But granting tax exemptions represents an important tax burden for taxpayers. The total cost of the tax credits applied on biofuels in France is assumed to be € 500 millions in 2007. This amount has almost tripled since 2003 and is expected to follow an exponential rise. This huge cost explains the decision of some European member states to revise their objectives. Indeed, even if the rate of the tax credit is decreasing in France, the total cost will continue to increase as the volume of biofuels will still grow. As a consequence, fuel prices are expected to grow faster as the French targets are higher and the tax credit lower. The environmental benefits of biofuels will have to be very positive to counterbalance those additional costs. Otherwise, the decision of the French government to maintain increasing blend mandates will have no justification.

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We give in the lines below a full derivation of the equations exposed in section 2.2. When there is a mandate in the presence of a tax credit, the three equilibrium conditions are:

(E1) $P_F = \alpha(P_B + t - t_c) + (1 - \alpha)(P_D + t)$

(E2) $D_F(P_F) = S_D(P_D) + S_B(P_B)$

(E3) $\alpha D_F(P_F) = S_B(P_B)$

Equation (E1) traduces the price relationship between biodiesel, diesel and fuel mixture; equation (E2) gives the market-clearing condition on the fuel market, and equation (E3) describes the constraint imposed by the mandate.

By totally differentiating equation (E1) we obtain:

$$dP_F - \alpha dP_B - (1 - \alpha)dP_D + (P_D - P_B + t_c)d\alpha - dt + \alpha dt_c = 0$$

In the same way, the total differentiation of equation (E2) and (E3) gives:

$$D'_F.dP_F - S'_D.dP_D - S'_B.dP_B = 0$$

and

$$\alpha D'_F.dP_F - S'_B.dP_B + D_F.d\alpha = 0$$

This system of differential equations can be described by the following matrix form:

$$\begin{pmatrix} 1 & -\alpha & -(1 - \alpha) \\ D'_F & -S'_B & -S'_D \\ \alpha D'_F & -S'_B & 0 \end{pmatrix} \begin{pmatrix} dP_F \\ dP_B \\ dP_D \end{pmatrix} = - \begin{pmatrix} P_D - P_B + t_c & \alpha & -1 \\ 0 & 0 & 0 \\ D_F & 0 & 0 \end{pmatrix} \begin{pmatrix} d\alpha \\ dt_c \\ dt \end{pmatrix}$$

This being so, the change in the fuel price induced by a change in the mandate can be assessed by solving:

$$\frac{dP_F}{d\alpha} = - \frac{\begin{pmatrix} P_D - P_B + t_c & -\alpha & -(1 - \alpha) \\ 0 & -S'_B & -S'_D \\ D_F & -S'_B & 0 \end{pmatrix}}{|H|}$$

where the numerator has been obtained by substituting the first column of the left-sided squared matrix with the first column of the right-sided squared matrix. $|H|$ represents the determinant of the left-sided matrix.

Hence,

$$\frac{dP_F}{d\alpha} = \frac{(P_D - P_B + t_c)(S'_B.S'_D) - D_F(\alpha S'_D - (1 - \alpha)S'_B)}{S'_D(\alpha^2 D'_F - S'_B) + (\alpha - 1)^2 D'_F.S'_B}$$

or

$$\frac{dP_F}{d\alpha} = \frac{(P_D - P_B + t_c) - \left(\frac{P_B}{\eta_B^S} - \frac{P_D}{\eta_D^S}\right)}{\frac{P_B}{\eta_B^S}\left[\alpha\frac{\eta_F^D}{P_F} - \frac{\eta_B^S}{P_B}\right] + (1-\alpha)\frac{P_D}{\eta_D^S}\frac{\eta_F^D}{P_F}}$$

where η_B^S is the price elasticity of the biodiesel supply, η_D^S is the price elasticity of the diesel supply, and η_F^D is the price elasticity of the fuel demand.

As η_F^D is lesser than zero, the denominator is always negative. Thus a change in the mandate increases the price of fuel if:

$$(P_D - P_B + t_c) - \left(\frac{P_B}{\eta_B^S} - \frac{P_D}{\eta_D^S}\right) < 0$$

i.e. when

$$\left[P_D + \frac{P_D}{\eta_D^S}\right] - \left[(P_B - t_c) - \frac{P_B}{\eta_B^S}\right] < 0$$

or

$$\left(1 + \frac{1}{\eta_D^S}\right)P_D < \left(1 + \frac{1}{\eta_B^S}\right)P_B - t_c$$

This result means that the price of fuel is more likely to increase with a change in the mandate if the price elasticity of the biodiesel supply is lesser than the price elasticity of the diesel supply.