Biofuels, tax policies and oil prices in France: Insights from a dynamic CGE model

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ABSTRACT: The 2009 Renewable Energies Directive (RED) has set up ambitious targets concerning biofuel consumption in the European Union by 2020. Nevertheless, budgetary constraints and growing concerns about the environmental integrity of first-generation biofuels have imposed a phasing out of the fiscal instruments to promote them. Focusing on France, this paper combines an exogenous increase in oil prices and tax policies on fossil fuels. The objective is to determine the efficiency of an alternative incentive scheme for biodiesel consumption based on a higher price of the fossil fuel substitute. Policy simulations are implemented through a dynamic computable general equilibrium (CGE) model calibrated on 2009 French data. The results show that the 10% biodiesel mandate set by the RED would not be achieved even if the fixed taxes on diesel reach the same level as those on gasoline. Although integrating the rise in oil prices into the fiscal framework improves the biodiesel penetration rate, it remains slightly below the target. Moreover, we find that the effects of biofuel consumption are limited to the biofuel chain sectors. In other agricultural sectors, the substitution effect of biodiesel with diesel is partially offset by the pricing effect induced by higher energy production costs.

KEY WORDS: biodiesel, oil price, computable general equilibrium

JEL classification: C61, C68, H23, Q16

1. Introduction

Climate change and long-term energy security are among the greatest challenges the global community faces today. Over the last few years, biofuels have attracted the attention of policymakers as they have been seen as instruments to address these concerns (e.g., Farrell et al., 2006). As a consequence, most of the major energy-consuming nations have set mandates to promote biofuels. In the European Union (EU), according to the 2009 Renewable Energies Directive (2009/28/EC) (called RED), the biofuel penetration target in the energy supply mix for road transportation has to be around 10% by 2020 in each member state. However, the huge increase in world agricultural prices in 2008 dampened the enthusiasm for biofuels, which were blamed as a major factor behind the crisis, due to their potential harm to food security. In addition, the net greenhouse gas (GHG) emission reduction potential of biofuels is questionable when the induced direct and indirect land use changes are taken into consideration (Fargione et al., 2008; Searchinger et al., 2008). Following those results, a large number of studies were completed to assess the economy-wide impacts of biofuels (see Banse et al., 2008; Birur et al., 2008; Ogg, 2009; Rosegrant et al., 2008; Timilsina and Shrestha, 2010, for recent analyses discussing the impacts of biofuels). This literature and the increasing tax burden of biofuels led policymakers to distinguish the current biofuels from the new biofuel generations and to redefine the support policies towards cellulosic biofuels. Some EU member states, such as France, thus decided to remove the main support instrument granted until now to first-generation biofuels, namely the partial exemption from the excise tax on fuels. Indeed, new proposals contemplate amending the 2020 target to accelerate the transition towards new-generation biofuels, limiting to 5% the share of first-generation biofuels in fossil fuels to reach the overall 10% (European Commission, 2012). However, France has to increase its current level of biofuel consumption in order to reach the 2020 objective, and the use of second-generation biofuels is not likely to be expanded widely before several years have passed. Waiting for an agreement concerning the new proposal, time flies. However, for the moment, the EU mandate is expected to be fulfilled mainly with the current commercialized biofuels. In the absence of new incentives to develop the consumption of biofuels, it could be challenging for France to comply with its supra-national target.

At the same time, France is currently facing a debate about the taxation on conventional fossil fuels. The French Cour des Comptes has recently reported that the Government should apply the same tax levels to both diesel and gasoline (Cour des Comptes, 2012a). Indeed, diesel in France benefits from a reduced excise tax rate that improves its competitiveness and explains the predominance of diesel over gasoline engines in the national car fleet. However, growing concerns about the adverse impacts of diesel emissions on pollution and health suggest revising fiscality towards internalization of its external effects. The question of the optimal taxation of fuels in order to reflect transportation externalities correctly has already been addressed in the economic literature (see for example Parry and Small, 2005, for a study on fuel taxation in the United States and the United Kingdom). As excise taxes on fuels represent the fourth most important revenue stream for the Government, the removal of the differential excise tax rate between diesel and gasoline could also contribute to lightening its budgetary constraint.

In this context, we consider the following questions: to what extent could higher taxes on diesel be helpful in achieving the 10% biofuel mandate by 2020? How efficient can this policy be in replacing the former support scheme? This paper tackles this issue, investigating how this alternative support policy could contribute to improving the biofuels penetration[1] in France. Our main objective is to determine whether the 2020 mandate is likely to be achieved by taxing diesel at the same rate as gasoline. In the economic literature, it is a common response to impose a supplementary tax on fossil fuels in order to enhance the price competitiveness of their renewable substitutes on the fuel market. A plethora of research on fossil fuel taxation has been produced during the last two decades. Part of this literature investigates whether a carbon tax can be designed in such a way that it also helps to promote renewable energy (Schneider and McCarl, 2005; Timilsina et al., 2011a).

In this study, we also take into account the context of rising oil prices. Few studies underline the role of oil prices in the expansion of biofuels. These analyses are, though, meaningful as they suggest that the linkage between the oil price and the market penetration of biofuels is quite strong (Banse et al., 2008; Timilsina et al., 2011b). Taking into account the evolution of oil prices could thus be helpful in achieving the 2020 biofuel mandate.

We thus combine the two features, fossil fuel taxes and rising oil prices, in the same empirical model. The objective is to measure their contribution to the 2020 binding mandate on biofuels, when the tax exemption on first-generation biofuels is removed, in line with the current discussion to support new-generation biofuels and to avoid conflicts with agriculture.

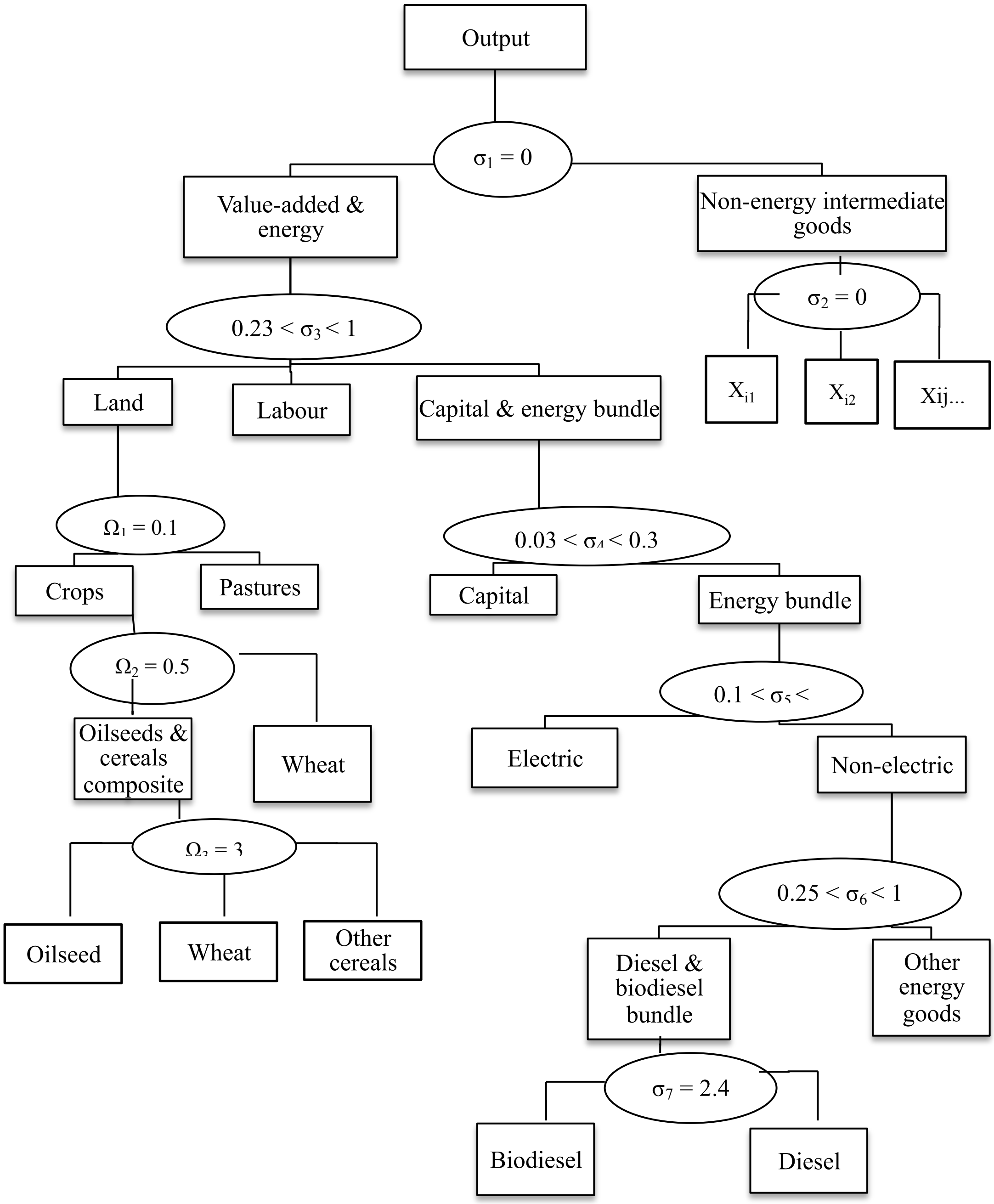
This research is implemented through a multi-sector, recursive dynamic computable general equilibrium (CGE) model calibrated on 2009 French data. CGE models take into account the various inter-linkages between economic sectors and are particularly useful for the evaluation of tax policies. The key feature of the model is that it explicitly models the trade-off between fossil fuels and biofuels. We focus on the diesel and biodiesel sectors, as 80% of the French car fleet relies upon diesel engines. Biodiesel feedstocks and by-products are highly detailed.

The paper is structured as follows. Section 2 provides a brief description of the CGE model developed for the study followed by the presentation of scenarios and key simulation results in Section 3. Section 4 highlights the results of a sensitivity analysis followed by a discussion of policy insights in Section 5. Finally, the conclusions are presented in Section 6.

2. Model and data

We develop a national, multi-sector, recursive dynamic CGE model for the purpose of this study. In this section, we set out an overview of the model. A base scenario is a prerequisite for the application of any CGE model. The main data requirements are a social accounting matrix (SAM) and elasticity parameters. The selection of the elasticity parameters is realized through a review of the literature (Birur et al., 2007; Burniaux and Truong, 2002; Taheripour et al., 2010). The basic data for the calibration of the model are derived from the SAM built upon the 2009 French statistics. This SAM breaks down the economy into 17 sectors. In line with the objective of this study, we take a special interest in farming sectors, which are disaggregated into five sectors: oilseed crops, wheat, other cereals, livestock and other agricultural activities. The agribusiness industry is also broken down into five sectors: biodiesel, vegetal oils, oil meals, processed feed and human food. This high level of disaggregation focusing on sectors linked to biodiesel allows us to consider specific production structures according to some substitution assumptions. The representation of the production sector in the model is illustrated in Figure 1.

Figure 1. Structure of the model



Each sector is depicted by a set of nested CES production functions. On the top level of the production structure, firms minimize their costs by choosing an optimal combination of the non-energy aggregate intermediate input and the composite of value-added and energy input (VAE). This specification follows a production structure similar to the GTAP-E model (Burniaux and Truong, 2002). Value-added contains land, labour and capital. Land is only used in agricultural sectors. On the bottom right side of the second level of the nested production structure, the capital and energy bundle is aggregated through a CES combination of the capital factor and the energy composite. The process continues as illustrated in Figure 1. Furthermore, two additional assumptions are included on the top level of the production structure. First, joint production is introduced into the biodiesel sector to take into account the production of by-products. Second, these oil meal inputs and the rest of the processed feed inputs are combined under a feed composite in the case of the livestock sector. These features highlight the strong capacity of biodiesel by-products to substitute for traditional processed feed, following recent studies such as the one by Taheripour et al. (2010).

Since the study focuses on analysing energy consumption issues, it pays special attention to the energy sector modelling. As Figure 1 illustrates, the total demand for energy is a CES composite of alternative fuels (inter-fuel substitution) and non-fuel energy commodities. The inter-fuel substitution is a CES composite of diesel and biodiesel. Indeed, since the study aims to assess the competitiveness of biodiesel and diesel when a tax is imposed on the latter, we need an explicit representation of both the diesel and the biodiesel sector. This allows us to measure the impacts of increased oil prices and diesel taxes on the production of various agricultural commodities.

In line with Banse et al. (2008), Birur et al. (2008), and Yang et al. (2009), changes in the use of land are incorporated into the model via a three-level constant elasticity of transformation (CET) representation of land supply. Indeed, first-generation biofuels increase the demand for energy crops. However, the feasibility of changing the land use from one crop to another may differ significantly according to the type of land. A three-level nested CET structure allows us to capture the different degrees of substitutability between agricultural land uses. This approach assumes imperfect substitutability between different types of land use, while all similar uses have the same degree of substitutability. As shown in Figure 2, land for pastures is differentiated from land for crops at the top level of the structure. Then, on the second level, crops are partitioned on the one hand into an 'oilseeds–cereals' category and on the other hand into an 'other crops' category. The oilseeds–cereals composite is finally divided with a higher value of elasticity of transformation. This reflects that it is easier to transform cereal land into oilseed land as both types of crops are grown on the same type of land. Land use change is induced by changes in the relative returns to the land. For each of the CET nests of the land module, agents maximize the pay-offs by optimally allocating the fixed land area for this nest to the alternative competing uses.

There are two consumer groups: a representative agent and the government. The representative agent maximizes the total utility subject to the budget constraint. His income comes from the sale of his factor endowments and direct transfers from the Government and the foreign sector. This income is spent on consumption, tax payments, savings and transfers to the rest of the world. A representative agent savings rate determines the fraction of disposable income that is saved, and thus is available for investments. The Government obtains its revenue from a number of indirect taxes, tariffs and a direct tax on households, and spends it on consumption, savings and transfers to the representative agent. The lump-sum transfers between the Government and the representative agent are endogenously adjusted to ensure a budget balance for the Government.

International trade is modelled by a system of Armington demands that give rise to flows of goods and services between France and the rest of the world. On the national level, the import demand is driven by CES functions of domestic and imported components of demand for Armington commodities. The export supply is depicted by a constant elasticity of transformation (CET) function in which the total output of a sector is designated either to total exports or to domestic supply.

In line with the general equilibrium framework, only relative prices are relevant to the specification of the quantities of goods supplied and demanded. The index price for the representative agent is used as the numéraire price level against which all the relative prices in the model are measured. Finally, concerning the dynamic part of the model, the values of the main parameters are obtained from the average values observed in the 1997–2010 period. The level of the annual interest rate is 4.34% and the growth rate is 1.71%. The model is programmed as a mixed complementarity problem (MCP) using GAMS/MPSGE (Rutherford, 1999), and is solved with the PATH algorithm.

3. Scenarios and results

3.1. Description of scenarios

We consider different simulations for this analysis. In each one, we determine the biodiesel penetration rate induced by the implemented policy by 2020. Since the biofuels mandate imposed by the RED directive applies to each part of the fuel market (the diesel–biodiesel market and the gasoline–ethanol market), our reference value to assess the efficiency of these alternative incentive schemes is the 10% penetration rate by 2020. Tax policies are applied on the level of the excise tax on fossil and renewable fuels, in line with the current debate in France[2]. The taxation on road transport fuels in France consists of an excise tax rate (the interior consumption tax) plus a value-added tax (VAT) on both the excise tax value and the wholesale price. As a consequence, the taxation scheme includes a fixed share of taxes (the excise tax and the VAT on the excise tax) and a variable share (the VAT on the wholesale price). As shown in Table 1, the reduced excise tax rate granted to biodiesel in 2009 allows a global reduced rate of fixed taxes of €0.18/litre in comparison with diesel. Similarly, the differential rate of fixed taxes between diesel and gasoline is €0.213/litre.[3]

Table 1. Decomposition and share of taxes in 2009 average fossil and renewable fuel prices (€/l)

	Biodiesel	Diesel	Gasoline
Average production cost (wholesale price) (A)	0.650	0.411	0.406
Interior consumption tax (ICT) (excise tax) (B)	0.278	0.428	0.606
VAT on ICT (C)	0.054	0.084	0.119
ICT + VAT on ICT (total fixed taxes) (D = B + C)	0.332	0.512	0.725
% of fixed taxes in the wholesale price	*51.08*	*124.57*	*178.57*
VAT on wholesale price (E)	0.127	0.080	0.080
Total taxes (F = D + E)	0.459	0.592	0.805
Final price (G = A + F)	**1.110**	**1.003**	**1.211**
% taxes in the final price	*41.35*	*59.02*	*66.47*

Source: UFIP

In the following simulations, additional taxes on diesel should thus not be considered as carbon taxes since it would be difficult to justify imposing such a tax only on diesel while exempting gasoline and more carbon-intensive fuels such as coal. Next, additional taxes only have to be interpreted as an increase in the share of fixed taxes on diesel in order to reduce the price competitiveness of diesel relative to gasoline. Up to now, the higher production costs of diesel have been offset by lower fixed taxes that imply a reduced global tax share of 59.02% of the final price against 66.47% for the final gasoline price (UFIP).

The simulations are divided into two blocks of scenarios.[4] The first one aims to investigate the efficiency of an alternative incentive scheme based on higher taxes on diesel to increase the biodiesel penetration rate. In this regard, we consider the effects of removing the tax exemption on first-generation biofuels while taxing diesel at the same level as gasoline. In order to isolate the impacts of the current incentive scheme based on a reduced excise tax on biodiesel, and those of the incentive scheme based on the increase in taxes on its fossil substitute, this first block consists of three policy scenarios as follows:

I. Scenario 1: removal of the reduced excise tax rate on biodiesel. This scenario assesses the evolution of the biodiesel penetration rate by 2020 if the current incentive scheme for first-generation biofuels disappears.

II. Scenario 2: we increase the fixed taxes on diesel until reaching the same level as the fixed taxes on gasoline, while maintaining the reduced excise tax rate on biodiesel.

III. Scenario 3: we combine Scenario 1 and Scenario 2 in order to replace the current incentive scheme with the new one. As a consequence, the fixed taxes increase on both diesel and biodiesel.

Then, in a second block of scenarios, we wonder what the biodiesel penetration rate would become when we take into account the evolution of oil prices. To obtain a clear picture of their impacts on biofuels' expansion, this block is also divided into three parts:

IV. Scenario 4: we maintain the reduced excise tax rate on biodiesel and introduce an exogenous increase in oil prices. To achieve this, we make a forecast in which we assume that the future evolution of oil prices will follow the trend observed in the past period.

V. Scenario 5: we remove the reduced excise tax rate on biodiesel while maintaining the exogenous increase in oil prices.

VI. Scenario 6: we combine Scenario 5 with Scenario 3. As a consequence, this scenario combines the higher taxes on diesel and biodiesel and the exogenous increase in oil prices.

3.2. Impacts on the biodiesel penetration rate

Tables 2 and 3 show the biodiesel penetration rate[5] induced by, respectively, the first block and the second block of simulations.

The decrease in the penetration rate from the baseline in Scenario 1 underlines the strong dependency of the biodiesel consumption on the reduced excise tax rate. It confirms that the substitutability of biodiesel to diesel depends on the price competitiveness of biodiesel. On the contrary, a low excise tax rate on biofuels combined with higher taxes on diesel leads to a significant increase in the biodiesel penetration rate, as we expected (Scenario 2).

Table 2. Biodiesel penetration in 2020 induced by a change in the fixed taxes on diesel and biodiesel

	Baseline	**Scenario 1**	**Scenario 2**	**Scenario 3**
Fixed taxes on diesel (€/l)	0.512	0.512	0.725	0.725
Fixed taxes on biodiesel (€/l)	0.332	0.512	0.332	0.512
Biodiesel penetration (%)	5.642	4.914	8.460	7.316

Source: Own simulations

More interestingly, Scenario 3 brings out that even removing the excise tax rate on biodiesel and taxing diesel as much as gasoline would enhance biodiesel use compared with the baseline. Note that this system would be more efficient than

Scenario 1 based on taxing biodiesel as diesel, since the market share is higher than in the base scenario.

To sum up, removing the fiscal advantage of biodiesel reduces the biodiesel penetration rate, as we expected. Indeed, this measure requires higher taxes on diesel to avoid a fall in the biodiesel penetration rate. However, even taxing diesel as much as gasoline would be not enough to satisfy the 2020 EU mandate.

On the other hand, we should not forget the context of oil prices. Table 3 shows the results in Scenarios 4 to 6 that investigate whether taking into account the evolution of oil prices could improve the biodiesel consumption.

Scenario 4 clearly shows the effects of rising oil prices. Considering the tax exemption on first-generation biofuels, a rise in oil prices increases the penetration rate of biofuels substantially. This insight confirms the results found by Timilsina et al. (2011b). Indeed, the latter study shows that an increase of 1% in oil prices results in an increase in biofuels penetration of 0.068%. Our results suggest larger elasticity of the French biodiesel consumption to oil prices, with a ratio of a 0.302% increase in the penetration rate to a 1% increase in oil prices.

Table 3. Biodiesel penetration in 2020 with an oil price increase and a change in the fixed taxes on diesel and biodiesel

	Baseline	**Scenario 4**	**Scenario 5**	**Scenario 6**
Fixed taxes on diesel (€/l)	0.512	0.512	0.512	0.725
Fixed taxes on biodiesel (€/l)	0.332	0.332	0.512	0.512
Oil price increase (%)	0.00	5.90	5.90	5.90
Biodiesel penetration (%)	5.642	7.424	6.434	9.986

Source: Own simulations

This strong sensibility to oil prices is also reflected in Scenario 5. Indeed, it suggests that the variation in oil prices allows a higher market share of biodiesel than in the baseline scenario, even in the absence of a differential rate in fixed taxes between diesel and its renewable counterpart.

Finally, Scenario 6 shows the effects of higher taxes on diesel combined with increasing oil prices, taking into account the removal of the tax exemption on first-generation biofuels. In this case, the penetration rate achieves 9.986%, which is almost 10%.

To sum up, the 10% target would only be almost reached in a context of rising oil prices and higher taxes on diesel. In other words, removing the tax exemption on biofuels necessitates higher taxes on diesel and a rise in oil prices.

The previous results lead us to wonder what the optimal excise tax rate on diesel would be to allow the achievement of the 2020 biodiesel mandate. In this regard, we thus propose a third block of simulations aimed at assessing the optimal excise tax rate on diesel. This block is divided into two scenarios (Scenarios 7 and 8) depending on the inclusion of the exogenous increase in oil prices in the simulation. Specifically, Scenario 7 does not include the exogenous increase in oil prices, while Scenario 8 does take it into account. Both scenarios consider the removal of the tax exemption on biofuels. The results are shown in Table 4.

Table 4. The optimal fixed tax rate on diesel needed to achieve the 10% biodiesel mandate by 2020

	Baseline	**Scenario 7**	**Scenario 8**
Fixed taxes on diesel (€/l)	0.512	0.924	0.726
Fixed taxes on biodiesel (€/l)	0.332	0.512	0.512
Oil price increase (%)	0.00	0.00	5.90
Biodiesel penetration (%)	5.642	10.001	10.001

Source: Own simulations

A comparison of Scenario 7 and Scenario 8 highlights that taking into account oil prices in the analysis allows a significant reduction in the additional level of taxes on diesel needed to achieve the target. According to Scenario 8, the mandate could be fulfilled with a fixed tax share of €0.726/litre on diesel, corresponding to a €0.607/litre level of the interior consumption tax, which is slightly higher than the gasoline tax rate.

Table 5. Decomposition and comparison of taxes with the ICT rate of €0.607/litre on diesel

	Diesel	**Gasoline**
Average production cost (wholesale price) (A)	0.411	0.406
Interior consumption tax (excise tax) (B)	**0.607**	0.606
VAT on ICT (C)	0.119	0.119
ICT + VAT on ICT (total fixed taxes) (D = B + C)	0.726	0.725
% of fixed taxes in the wholesale price	*176.64*	*178.57*
VAT on the wholesale price (E)	0.081	0.080
Total taxes (F = D + E)	0.807	0.805
Final price (G = A + F)	1.218	1.211
% taxes in the final price	*66.26*	*66.47*

Source: Own calculus

Using the data of Table 1, we deduce that this excise tax rate would raise the share of total taxes from 59.02% to 66.26% of the final diesel price (Table 5), a level still lower than that of gasoline. A level of total taxes of €0.807/litre on diesel could thus achieve the target by taxing diesel only 0.25% more than gasoline.

These results prove the efficiency of a support scheme for biodiesel consumption based on an increase in taxes on diesel to a level at least as high as that of gasoline. Nevertheless, the implementation of this policy may incur several consequences for other economic variables. Facing multiple results provided by the model, we propose to focus first on the biodiesel and diesel sectors, before exploring the effects on the rest of the linked sectors.

3.3. Impacts on the biodiesel and diesel sectors

Changes in the biodiesel and diesel sectors are shown in, respectively, Tables 6 and 7. The analysis of these results leads to different conclusions. In the biodiesel sector, Scenario 1 shows that the elimination of the fiscal advantage of biofuels would induce a substantial decrease in the domestic supply of around 15%. However, this contraction could also affect France's commercial partners, through a one-third decrease in imports due to the fall in consumption and a fall in disposable income after increasing taxes. In this case, low biodiesel prices lead producers to export to make profits abroad.

Conversely, higher taxes on diesel stimulate the production of biodiesel, even when the fiscal advantage of biofuels is removed (Scenario 3). This endogenous increase in biofuel production is due to the fact that the ratio between the diesel price and the biodiesel price changes in favour of the latter. The increasing demand for biodiesel leads to higher prices and lower exports, as the domestic market becomes more profitable than the foreign one. Note that Scenario 5 also reveals that the effects of rising oil prices in isolation are not sufficiently stimulating to incur an expansion of the biodiesel sector when the fiscal advantage disappears.

The strong variation in imports highlighted in Scenario 6 suggests that the additional biodiesel demand would not be satisfied by domestic production. This insight confirms the projections of various studies on the EU biofuel industry (Banse et al., 2008). Scenarios 7 and 8 show that reaching the 2020 mandate involves an expansion of both biofuel production and biofuel consumption. As prices increase, profit opportunities emerge and the domestic market becomes a more profitable outlet for French industrialists. As a consequence, exports decrease. Nevertheless, we should take into account that commercial partners could impose similar measures to reach the same target.

Table 6. Percentage change (%) in the biodiesel sector in 2020

	Sce1	Sce2	Sce3	Sce4	Sce5	Sce6	Sce7	Sce8
Biodiesel penetration (%)	4.914	8.460	7.316	7.424	6.434	9.986	10.001	10.001
% change compared with baseline								
production	-14.94	21.95	3.08	13.88	-3.57	22.81	22.92	22.92
consumption	-14.65	21.42	3.06	13.54	-3.46	22.32	22.43	22.43
imports	-31.68	56.69	7.48	34.45	-7.91	59.55	59.87	59.87
exports	24.64	-21.54	-4.20	-14.95	4.54	-22.52	-22.60	-22.60
price	7.58	10.45	19.34	6.85	15.29	29.97	30.03	30.03

Source: Own simulations

Table 7 presents the results for the diesel sector. The comparison of Scenarios 1 and 3 underlines the sensitivity of oil refiners to the fiscal burden. While the removal of the fiscal advantage of biodiesel does not influence the refining sector (Scenario 1), the increase in the ICT on diesel to €0.725/litre deeply affects the activity level, the production falling by more than 30% (Scenarios 2 and 3). This situation worsens in a context of rising oil prices (Scenarios 6 and 8) since the production costs increase.

Table 7. Results in the diesel sector in 2020

% change compared with baseline	Sce1	Sce2	Sce3	Sce4	Sce5	Sce6	Sce7	Sce8
production	0.94	-32.13	-31.18	-23.14	-22.19	-48.95	-49.02	-49.02
consumption	0.77	-22.49	-21.62	-16.10	-15.26	-34.65	-34.71	-34.71
imports	0.97	-21.18	-20.02	-15.33	-14.24	-31.54	-31.59	-31.59
exports	0.89	-44.64	-43.93	-32.54	-31.76	-66.16	-66.25	-66.25
price	0.06	27.78	27.92	17.59	17.69	58.14	58.31	58.31

Source: Own simulations

Tables 6 and 7 also suggest that the progression of the biodiesel market share under scenarios 2 and 3 is explained by the fact that the decrease in the diesel consumption is larger than the increase in the biodiesel consumption.

As a consequence, the recessive impacts occurring in the diesel sector could be stronger than the positive effects in the biodiesel sector, and this asymmetry is amplified by the fluctuations in oil prices. Since the diesel sector's economic size is much larger, we focus on macroeconomic variables to determine whether these effects may spread to and affect the rest of the French economy.

3.4. Impacts on macroeconomic indicators

The study of the macroeconomic impacts confirms the above assumptions. Table 8 shows that taxing diesel as much as gasoline could slightly affect the total production (Scenarios 2 and 3). The combination of this policy with rising oil prices strengthens this recessive effect, with a 1.07% fall in the total output relative to the baseline (Scenario 6).

Investment and private consumption are particularly reactive to the negative impacts of oil prices and taxes on diesel. Indeed, these variables decrease in the presence of one of these elements (Scenarios 2, 3, 4, 5 and 7), and the impact is stronger when the two are combined (Scenarios 6 and 8).

Table 8. Results for key macroeconomic variables in 2020

% change compared with baseline	**Sce1**	**Sce2**	**Sce3**	**Sce4**	**Sce5**	**Sce6**	**Sce7**	**Sce8**
Total production	-0.02	-0.66	-0.68	-0.48	-0.50	-1.07	-1.07	-1.07
Investment	0.00	-0.49	-0.49	-0.33	-0.33	-0.85	-0.85	-0.85
Private consumption	0.00	-0.68	-0.68	-0.47	-0.47	-1.19	-1.19	-1.19

Source: Results of simulations

The lower profitability of diesel incurred by higher production costs and/or higher taxes is thus likely to slow down the global activity level. However, economic sectors can be affected differently. We thus adopt a sector approach now.

3.5. Impacts on the agricultural sector

Table 8. Results for agricultural variables in 2020

% change compared with baseline	**Sce1**	**Sce2**	**Sce3**	**Sce4**	**Sce5**	**Sce6**	**Sce7**	**Sce8**
Total farm production	0.00	0.52	0.50	0.38	0.37	0.78	0.78	0.78
				Oilseeds				
Production	-8.04	11.48	1.60	7.27	-1.96	12.01	12.07	12.07
Imports	-8.82	14.19	2.73	9.05	-1.45	14.97	15.04	15.04
Exports	-7.54	9.74	0.87	6.13	-2.29	10.12	10.17	10.17
Price	-1.12	1.74	0.46	1.18	-0.04	1.69	1.70	1.70
				Wheat				
Production	1.69	-1.62	0.36	-0.95	0.93	-1.47	-1.48	-1.48
Imports	1.52	-1.00	0.69	-0.53	1.11	-0.73	-0.74	-0.74
Exports	2.03	-2.83	-0.29	-1.78	0.58	-2.91	-2.92	-2.92
Price	0.09	0.16	0.22	0.16	0.23	0.09	0.09	0.09
				Other cereals				
Production	4.21	-4.50	0.59	-2.70	2.09	-4.17	-4.20	-4.20
Imports	3.88	-4.49	-0.06	-2.80	1.45	-4.48	-4.50	-4.50
Exports	4.34	-4.50	0.85	-2.66	2.34	-4.05	-4.08	-4.08
Price	0.57	-0.66	-0.01	-0.38	0.24	-0.83	-0.83	-0.83
				Livestock				
Production	-0.23	0.55	0.24	0.37	0.09	0.61	0.61	0.61
Imports	0.72	-1.38	-0.48	-0.89	-0.05	-1.70	-1.70	-1.70
Exports	-2.06	4.41	1.66	2.86	0.37	5.25	5.27	5.27
Price	0.34	-0.63	-0.21	-0.38	0.02	-0.91	-0.92	-0.92
				Other agricultural activities				
Production	-0.06	0.69	0.60	0.49	0.41	1.03	1.03	1.03
Imports	0.02	-0.69	-0.67	-0.47	-0.45	-1.18	-1.19	-1.19
Exports	-0.14	2.07	1.88	1.44	1.28	3.27	3.28	3.28
Price	0.00	-0.19	-0.20	-0.10	-0.11	-0.50	-0.51	-0.51

Source: Own simulations

Table 8 reveals a small expansion in the whole agricultural output consecutive to the increasing use of biofuels in the economy. A detailed analysis reveals that this expansion is spread upstream to the production chain, with an increase in the oilseed crops output. In the cereals sector, the competition with oilseed crops for land leads to a fall in the production of wheat and other cereals, but does not involve a rise in prices. This confirms the growing concern about the influence of the first-generation biofuels on the main crops.

Nevertheless, in the rest of the agricultural sectors, the situation is more mitigated. The output of livestock and other activities progresses slowly, suggesting that the biodiesel sector generates positive but limited spillover effects. The negative variation in livestock prices could lie in the decrease in feed costs due to the availability of biodiesel by-products.

To shed light on the above results, we analyse the changes in the land allocation through the study of land use changes and the evolution of land prices.

Table 9. Changes in land allocation in 2020 relative to the baseline

% Land area change compared with baseline	**Sce1**	**Sce2**	**Sce3**	**Sce4**	**Sce5**	**Sce6**	**Sce7**	**Sce8**
				Land use changes				
Oilseed area	-7.96	10.71	1.05	6.74	-2.31	10.97	11.03	11.03
Wheat area	1.79	-2.29	-0.18	-1.44	0.57	-2.36	-2.37	-2.37
Other cereals area	4.32	-5.24	-0.01	-3.24	1.68	-5.14	-5.17	-5.17
Livestock area	-0.03	-0.06	-0.10	-0.05	-0.08	-0.12	-0.12	-0.12
Other agricultural activities area	0.04	-0.12	-0.06	-0.09	-0.03	-0.12	-0.12	-0.12
				Arable land price changes				
Oilseeds and cereals	-0.55	3.92	2.96	2.79	1.99	5.08	5.09	5.09
Livestock	-1.00	2.57	1.18	1.77	0.53	2.75	2.76	2.76
Other agricultural activities	-0.46	3.24	2.49	2.30	1.66	4.27	4.28	4.28

Source: Own simulations

Table 9 clearly shows the trade-off between the allocation of land to oilseeds and cereals, as reflected in the variations in the respective output levels observed previously (Table 8). If the increasing biodiesel demand also diverts areas dedicated to livestock and other agricultural activities, this land use change remains marginal due to different agronomic conditions. It is more complicated to transform pastures –

rather than wheat areas – into areas of oilseed crops. In all cases, the rising land demand is traduced by higher land prices.

Including the ethanol sector and its agricultural feedstocks in the model would probably display different results. Indeed, as the domestic production of ethanol partly relies upon wheat and corn, the possibility to convert wheat and corn areas into oilseed areas would be more limited. As a consequence, the adjustment could result in a slight fall in the production of other agricultural crops and higher pressure on land prices. Nevertheless, since ethanol accounts for less than 20% of the total French biofuel production, these changes are likely to remain marginal.[6]

3.6. Impacts on the agribusiness sector

As expected in the vegetal oil sector, the replacement of diesel with biodiesel leads to a significant increase in domestic production and imports of biodiesel. The adjustment of the supply to the rising demand limits the variation of prices.

In the feed sector, oilmeals resulting from biodiesel production are substituted with traditional processed feed. The abundance of cheap by-products allows a decline in prices and strengthens the competitiveness of oilmeal exports, which increase by around 45% in Scenario 6. This result confirms the potential role played by these by-products with lower production costs encountered in the livestock sector. Consequently, the domestic and foreign demands fall in the other processed feed sector.

Despite the increasing costs of vegetal oils induced by the biodiesel demand, human food prices decrease slightly, probably due to the decline in the price of some raw materials, such as cereals or livestock products.

Table 10. Results for the agribusiness sector variables in 2020

% change compared with baseline	**Sce1**	**Sce2**	**Sce3**	**Sce4**	**Sce5**	**Sce6**	**Sce7**	**Sce8**
				Vegetal oils				
Production	-9.05	13.66	2.29	8.69	-1.84	14.38	14.45	14.45
Imports	-12.34	19.39	3.13	12.22	-2.59	20.39	20.49	20.49
Exports	-6.36	9.25	1.63	5.94	-1.24	9.77	9.81	9.81
Prices	-1.44	1.94	0.38	1.30	-0.22	1.88	1.89	1.89
				Oilmeals				
Production	-14.94	21.95	3.08	13.88	-3.57	22.81	22.92	22.92
Imports	-5.65	6.50	0.68	4.27	-1.55	6.51	6.54	6.54
Exports	-24.79	43.02	5.99	26.34	-5.91	45.20	45.44	45.44
Prices	0.89	-1.29	-0.21	-0.79	0.22	-1.52	-1.53	-1.53
				Other processed feed				
Production	6.64	-8.51	-0.66	-5.35	2.08	-8.67	-8.71	-8.71
Imports	7.12	-9.60	-1.35	-6.14	1.72	-10.02	-10.07	-10.07
Exports	6.15	-7.38	0.06	-4.54	2.45	-7.26	-7.31	-7.31
Prices	0.61	-0.94	-0.16	-0.56	0.15	-1.16	-1.16	-1.16
				Human food and other products of agribusiness				
Production	-0.06	0.69	0.60	0.49	0.41	1.03	1.03	1.03
Imports	0.10	-2.26	-2.13	-1.59	-1.47	-3.59	-3.59	-3.59
Exports	-0.18	2.93	2.68	2.05	1.83	4.58	4.59	4.59
Prices	0.01	-0.42	-0.41	-0.26	-0.26	-0.84	-0.84	-0.84

Source: Own simulations

3.7. Impacts on the other economic sectors

First, several comments can be formulated in the energy sector. The lower diesel consumption enhances electric energy only marginally. However, it affects the other energy production due to the share of diesel in the production costs. This recessive effect is stronger when considering oil price fluctuations and leads to the output level being halved (Scenarios 6, 7 and 8). Increasing production costs have partial repercussions for the final price of non-electric energies, penalizing exports.

In the other industries, the commerce and transport sectors, the impacts are more mitigated. In a general way, these activities are sensitive to energy price fluctuations and tend to reduce the output levels when the prices rise. Thus, these effects are more visible in Scenarios 6, 7 and 8, reporting both higher taxes on diesel and rising oil prices.

On the other hand, non-energy-intensive activities, such as service sectors, are not affected by these policies. The output variation remains small but positive.

Table 11. Percentage change (%) in other economic sectors from the baseline level (2020)

% change compared with baseline	**Sce1**	**Sce2**	**Sce3**	**Sce4**	**Sce5**	**Sce6**	**Sce7**	**Sce8**
				Electricity				
Production	-0.03	0.04	0.01	0.01	-0.01	0.06	0.06	0.06
Imports	-0.04	-0.19	-0.25	-0.18	-0.23	-0.25	-0.25	-0.25
Exports	0.00	0.43	0.44	0.34	0.35	0.59	0.59	0.59
Prices	-0.02	-0.02	-0.05	0.01	-0.02	-0.18	-0.18	-0.18
				Other non-electric energies				
Production	-0.23	-40.67	-40.84	-30.54	-30.71	-58.14	-58.20	-58.20
Imports	0.00	-0.04	-0.04	-0.33	-0.33	1.30	1.31	1.31
Exports	-0.32	-55.54	-55.75	-42.34	-42.57	-76.39	-76.46	-76.46
Prices	-0.01	2.28	2.26	1.58	1.57	3.79	3.79	3.79
				Other industries				
Production	-0.03	0.11	0.07	0.17	0.13	-0.33	-0.33	-0.33
Imports	-0.01	-1.84	-1.85	-1.35	-1.35	-2.80	-2.80	-2.80
Exports	-0.04	1.25	1.19	1.06	1.00	1.12	1.12	1.12
Prices	-0.01	-0.20	-0.22	-0.13	-0.15	-0.44	-0.44	-0.44
				Commerce				
Production	0.02	-0.14	-0.10	-0.11	-0.08	-0.12	-0.12	-0.12
Imports	-0.02	-2.12	-2.13	-1.55	-1.56	-3.25	-3.26	-3.26
Exports	0.06	2.26	2.35	1.62	1.69	3.71	3.72	3.72
Prices	-0.02	-0.42	-0.45	-0.28	-0.30	-0.83	-0.84	-0.84
				Transport				
Production	0.02	-0.29	-0.27	-0.19	-0.17	-0.53	-0.53	-0.53
Imports	-0.02	-1.26	-1.27	-0.97	-0.98	-1.70	-1.71	-1.71
Exports	0.05	0.66	0.73	0.57	0.64	0.64	0.64	0.64
Prices	-0.02	-0.12	-0.15	-0.08	-0.10	-0.30	-0.30	-0.30
				Services				
Production	0.01	0.03	0.04	0.02	0.03	0.05	0.05	0.05
Imports	-0.03	-2.94	-2.98	-2.08	-2.12	-4.86	-4.87	-4.87
Exports	0.05	3.51	3.58	2.46	2.53	5.92	5.93	5.93
Prices	-0.02	-0.63	-0.66	-0.42	-0.45	-1.22	-1.23	-1.23

Source: Own simulations

4. Sensitivity analysis

In the model, we assume the elasticity of substitution between diesel and biodiesel to be 2.4. This value influences the strength of the substitution effect due to changes in the relative prices of the two fuels. Based on the literature (Banse et al., 2008;

Timilsina et al., 2011a, 2011b), we check the robustness of our results by running scenarios after decreasing then increasing the elasticity of substitution between biodiesel and diesel.

Table A1 in Appendix A shows the results when halving and doubling the initial value. In both cases, the variation in the penetration rate shows the sensitivity of the model to this parameter. Doubling the value of the elasticity of substitution between biodiesel and its fossil counterpart (diesel) increases the penetration of biofuels, specifically in a context of rising oil prices (Scenarios 4, 6 and 8). The opposite result is obtained in the case of low substitution elasticity. A high elasticity value has a relatively large impact on variables directly involved in biofuel use, such as oilseed and vegetal oil production, prices and imports. However, biodiesel imports seem to be the most sensitive variable, as illustrated by Scenarios 6 and 8.

Our estimate of the biodiesel penetration rate and of the necessary excise tax rate on diesel to achieve the 10% target could be inaccurate. However, the analysis of the overall impacts of the alternative policy scenarios remains relevant since they provide the general trend of the potential effects. The sensitivity analysis shows that the qualitative results are not fundamentally different, but the size of the effects can change substantially.

This finding is crucial from a policy perspective. Indeed, the sensitivity of the penetration rate to this parameter suggests that a policy designed to increase the substitution possibility between biofuels and fossil fuels may significantly contribute to enhancing the consumption of biofuels. For instance, a higher use of flex-fuel vehicles in the vehicle fleet would increase the value of the elasticity of substitution. In this context, a combination of rising oil prices and lower additional taxes on diesel would result in a greater expansion of biofuels. Similarly, if the substitution possibility between biofuels and fossil fuels is limited, the impacts of fossil fuel taxes and oil price changes on the biofuel penetration rate would be moderate.

5. Policy insights

In a partial equilibrium setting, the introduction of a higher tax on fossil fuels could make biofuels economically attractive, thereby causing a significant substitution of fossil fuels with biofuels depending upon the substitution of elasticity. Such a finding would be intuitive since a partial equilibrium analysis assumes ceteris paribus. However, in a general equilibrium framework, this does not necessarily hold true, as a tax would have economy-wide repercussions. Indeed, it would slow down economic activities and reduce the demand for energy. Models lacking such a feature do not capture these feedback effects of fossil fuel taxes and oil prices. Thus, the net increase in the biofuel demand in a general equilibrium setting would be smaller than that in a partial equilibrium setting.

In this study, we have demonstrated the efficiency of a support scheme for biodiesel consumption based on lowering the competitiveness of its fossil substitute using higher taxes. This impact is strengthened when it is analysed in the context of rising oil prices. Indeed, we find that the increased demand for biofuels caused by the substitution effect enhances the expansion of the whole biodiesel chain, through an increase in inputs, notably in the oilseed crops and vegetal oils sectors.

However, in the other agricultural and agribusiness sectors, the spillover effects are limited, except in the livestock sector in which the abundance of cheap biofuel by-products mitigates the rise in production costs due to increased energy prices. This insight is particularly important since biofuels' expansion is often expected to improve agribusiness profitability and rural development. A policy aimed at enhancing rural development through an increasing demand for energy crops would thus be relatively inefficient since only the sectors directly related to the biofuel industry would benefit from it.

In the rest of the economy, higher taxes on diesel may even cause recessive impacts due to the pricing effect. Indeed, all energy-intensive industries are affected by rising energy prices, through changes in production costs. As a consequence, a general equilibrium analysis, contrary to the partial equilibrium approach, raises the possibility that the spillover effects of the biofuel sector, especially in agricultural activities, could be partially offset by the reduction in the global energy demand in the whole national economy. The implementation of such an alternative support scheme would thus reflect the priority given by public decision makers to enhance renewable energies instead of farm income.

6. Concluding remarks

The French biodiesel industry is strongly dependent on the presence of a support scheme improving its price competitiveness regarding its fossil fuel counterpart. Facing the removal of the fiscal advantage of biodiesel, we have explored the efficiency of variations in oil prices and taxes on diesel as alternative support schemes to improve biodiesel consumption. Both schemes contribute to enhancing the biodiesel market share. The results suggest that higher taxes on diesel are efficient, although substantial additional taxes are required to achieve the 10% mandate by 2020.

On the other hand, the economy-wide impacts suggest potential counterproductive effects of such a tax policy. Except for sectors directly linked to the biodiesel production chain, or benefiting from its by-products, the economy suffers from higher energy production costs induced by the additional taxes on diesel. These depressive effects are accentuated when oil prices are taken into account.

To conclude, these considerations show how difficult it is to find a new incentive scheme to increase the consumption of biofuels. In France, but also in other developed countries, they may constitute an argument to postpone the removal of the excise tax rate on first-generation biofuels. The fiscal rebate could indeed be extended until the commercialization of new-generation biofuels takes place. This question will be addressed in future research.

The choice of a support scheme is thus contingent on the overall objective of biofuels: if public decision makers want to promote renewable energies, increasing the taxation on fossil fuels may help to achieve the EU target; however, if the priority is given to rural development, this policy could be partially ineffective, since only directly linked sectors would gain from biofuels' expansion. Nevertheless, greater efforts to launch new generations of biofuels could shed light on the solution to this trade-off: on the one hand, avoiding the conflict between bioenergy and food security, and on the other hand, reducing environmental impacts and oil dependence.

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[1] Biodiesel penetration is defined in this study as the ratio of biodiesel to the total diesel–biodiesel bundle consumption in road transportation, on an energy equivalence basis.

[2] Indeed, a tax on all fossil energies could have been considered but it may be less appropriate since the purpose of the tax is to increase the penetration of biofuels.

[3] We obtain these figures simply from: 0.512-0.332 = €0.18/l; and 0.725-0.512 = €0.213/l.

[4] Note that, under all the scenarios, the tax policies and exogenous shocks are introduced in 2009. Indeed, the French Government has not yet scheduled the removal of the partial exemption from the excise tax on both biodiesel and diesel, though the fiscal advantage was expected to disappear by 1 January 2013. Concerning the reduced excise tax rate on diesel, the discussion process on its potential removal has just begun and will probably not end before several months' time. As a consequence, we place ourselves in a hypothetical situation in which such changes are implemented since 2009.

[5] The calculus of the penetration rate takes into account the lower energy content of biodiesel in comparison with diesel. We use data from the French Cour des Comptes (2012b), i.e. energy content of 35.952 kJ/litre for diesel against 33.024 kJ/litre for biodiesel.

[6] Indeed, ethanol is also affected by the 10% mandate by 2020. Biofuels' expansion in the EU is thus expected to lead to higher production in both the oilseed and the cereal sectors. However, the impacts on land use change are likely to be larger for oilseeds than for cereals. At the level of total agricultural production, wheat and corn represent more areas in France than oilseed crops, but the share of wheat and corn areas dedicated to ethanol remains marginal, around 3.48%. Conversely, 64.05% of oilseed areas are dedicated to biodiesel (Cour des Comptes, 2012b).

Appendix A.

Table A1. Sensitivity analysis (*% change compared with baseline)*

	Low value					High value				
	Sce1	**Sce3**	**Sce4**	**Sce6**	**Sce8**	**Sce1**	**Sce3**	**Sce4**	**Sce6**	**Sce8**
Biodiesel penetration rate (%)	5.13	7.02	7.00	8.85	8.86	4.72	7.63	7.88	11.31	11.33
					Production results in 2020					
Biodiesel	-10.70	-1.67	6.62	7.43	7.48	-18.70	7.94	21.55	40.44	40.63
Oilseeds	-5.74	-0.93	3.46	3.98	4.01	-10.09	4.17	11.27	20.97	21.07
Vegetal oils	-6.47	-0.58	4.31	5.11	5.14	-11.33	5.23	13.31	24.95	25.06
					Price results in 2020					
Biodiesel	10.50	16.50	3.44	21.84	21.86	4.88	22.13	10.25	38.25	38.33
Oilseeds	-0.80	0.12	0.69	0.68	0.68	-1.40	0.79	1.69	2.79	2.80
Vegetal oils	-1.02	-0.05	0.70	0.65	0.66	-1.82	0.79	1.91	3.15	3.16
					Import results in 2020					
Biodiesel	-23.26	-3.53	15.94	18.45	18.58	-38.76	19.32	55.43	113.66	114.29
Oilseeds	-6.34	-0.12	4.66	5.59	5.62	-11.01	5.65	13.74	25.94	26.06
Vegetal oils	-8.89	-0.85	6.01	7.09	7.13	-15.37	7.25	18.89	36.10	36.28

Source: Own simulations