Biofuel Sustainability Requirements – The Case of Rapeseed Biodiesel

Nachhaltigkeitsanforderungen für Biotreibstoffe – der Fall von Biodiesel aus Rapsöl

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Abstract

Biodiesel production in Europe and Germany relies heavily on rapeseed oil. Thus, the biodiesel industry has become the most important outlet for rapeseed oil. In light of the increasing greenhouse gas (GHG) saving requirements at the European level, this situation may change: according to the default values specified in the current legislation, biodiesel produced from rapeseed oil will not meet GHG saving requirements as of 2017.

In this article, we assess the market impacts of the withdrawal of rapeseed oil from the biodiesel industry in Germany and Europe. Simulations with the MAGNET and CAPRI modelling systems indicate a decline in producer prices for rapeseed of approximately 17% in the EU. The area dedicated to rapeseed production will decline by 6%. Rapeseed oil is primarily substituted by imported vegetable oils. Simultaneously, imports of biodiesel from North America, Argentina and Asia are projected to increase.

We investigate options to improve the GHG balance of rapeseed biodiesel. We conclude that only a combination of climate-friendly produced fertiliser and efficient conversion processes can provide the necessary GHG emission-savings to meet the EU's sustainability goals after 2017.

Key Words

rapeseed; biodiesel; sustainability; greenhouse gas emissions; biofuel policies

Zusammenfassung

Rapsöl ist in der Europäischen Union und besonders in Deutschland der wichtigste Rohstoff für Biodiesel, und dadurch ist die Biodieselindustrie zum wichtigsten Abnehmer von Rapsöl geworden. Es ist fraglich, ob dies angesichts der steigenden Anforderungen an die Reduktion der Treibhausgas(THG)-Emissionen, die ab 2017 in der EU gelten, Bestand haben wird. Nach den gegenwärtig gültigen Standardwerten erreicht Biodiesel aus Rapsöl ab 2017 nicht die geforderten THG-Emissionseinsparungen.

Um die Marktwirkungen eines Ausschlusses von Rapsöl vom Biodieselmarkt abzuschätzen, simulieren wir diesen mit den Modellsystemen MAGNET und CAPRI. Den Simulationsergebnissen zufolge würde der Rapspreis in der EU um 17% zurückgehen, die für den Rapsanbau genutzte Fläche um 6%. Rapsöl wird durch andere importierte Pflanzenöle ersetzt. Gleichzeitig steigen die Einfuhren von Biodiesel aus Nordamerika, Argentinien und Asien.

Wir prüfen, durch welche Anpassungen die geforderten Emissionseinsparungen erreicht werden können. Unsere Analyse hat ergeben, dass nur durch das Zusammenwirken mehrerer Akteure der Wertschöpfungskette (Düngemittelproduzenten, Landwirte und Biodieselanlagenbetreiber) das THG-Reduktionsziel von 50% oder mehr erreicht werden kann.

Schlüsselwörter

Raps; Biodiesel; Nachhaltigkeit; Treibhausgasemissionen; Biokraftstoffpolitik

1 Introduction and Motivation

Biofuel policies in Europe started with great expectations: emissions reductions, reduced reliance on energy imports, and farm income improvements, as well as rural development and job creation ranked highly among policy-makers' priorities (OECD, 2008; EUROPEAN PARLIAMENT AND COUNCIL, 2009). The corresponding implementation of biofuel policies induced the rapid development of the biofuel industry in Europe: between 2000 and 2012, biodiesel production expanded by a factor greater than ten and the production of bioethanol by a factor greater than 25 (LAMERS, 2011; IEA, 2015).

Consequently, in 2012, the EU became the most important producer of biodiesel worldwide. The EU produced over 10 million tons of biodiesel that year, with Germany accounting for over 25%, as shown in Table 1. Germany has a history of being a key producer of biodiesel within the EU. This history is partially explained by particularly favourable political conditions (e.g., tax exemptions) in the past and partially by geographical and historical economic patterns (LAMERS, 2011). As can be deduced from Table 1, Germany imported and exported approximately 30% and 40%, respectively, of its domestic production in 2012, with its main trading partners being within the Union´s territory. Extra-EU trade of biodiesel played virtually no role for Germany. However, the EU as a whole has been a net importer of biodiesel since 2005 (LAMERS, 2011). Apart from Germany, other Member States imported some 3 million tons (equivalent to approximately 20% of the Union´s domestic use) of biodiesel from third countries, predominantly from Argentina, Indonesia and Malaysia (EUROSTAT, 2015b; IEA, 2015).[1]

Table 1. Market overview for biodiesel, rapeseed oil, rapeseed and rape cake in 2012

	Germany	European Union*
Biodiesel (million t)		
Production	2.73	10.21
Imports	0.82	2.80
Exports	1.08	0.08
Rapeseed oil (million t)		
Production	2.96	8.90
Imports	0.22	0.61
Exports	0.80	0.23
Rapeseed (million t)		
Production	4.82	19.25
Imports	4.11	2.75
Exports	0.16	0.08
Rape cake (million t)		
Production	3.96	12.37
Imports	0.33	0.24
Exports	1.48	0.28

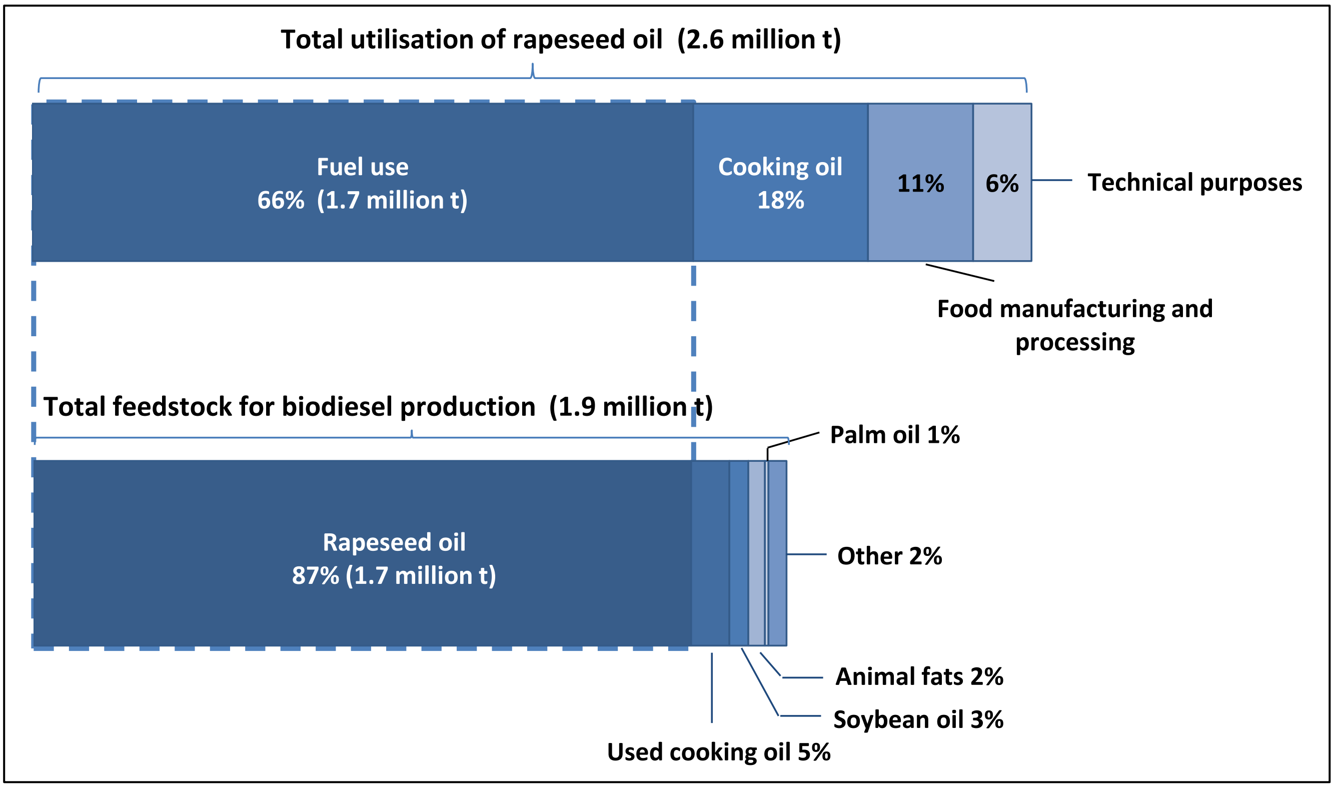
* Imports and exports of the EU refer to trade with third countries, i.e., intra-EU trade is excluded.
Sources: AMI (2014), EUROPEAN COMMISSION (2015a), EUROSTAT (2015b), FAO (2015), IEA (2015)

The main feedstock for biodiesel production in Europe is rapeseed oil. Although its share has decreased slightly in recent years, it still accounted for over 65% of the total feedstock used for biodiesel in 2012 (ECOFYS, 2014). This situation is even more pronounced in Germany: according to industry data (VDB, 2012), almost 90% of the feedstock used in 2011 was rapeseed oil (see Figure 1).[2] Other inputs for biodiesel production in Germany were used cooking oil, soybean oil, palm oil and animal fats with shares

[1] As shown by LAMERS et al. (2011), bilateral international trade of biodiesel may be underestimated: Biodiesel trade may take place under different codes of the Combined Nomenclature. Here, bilateral biodiesel trade data refers to trade of products that are described under Code 3826 of the Combined Nomenclature: "Biodiesel and mixtures thereof, not containing or containing less than 70 % by weight of petroleum oils or oils obtained from bituminous minerals" (EUROPEAN COMMISSION, 2015b). It may well be that international trade of biodiesel occurs in lower blends than 30 %. These blends correspond to the Code 271020 ("Petroleum oils and oils obtained from bituminous minerals (other than crude) and preparations not elsewhere specified or included, containing by weight 70% or more of petroleum oils or of oils obtained from bituminous minerals, these oils being the basic constituents of the preparations, containing biodiesel, other than waste oils of the Combined Nomenclature"). Comparison with IEA data on aggregated biodiesel trade shows that whereas exports seem to take place predominantly as pure biodiesel or blends with a high concentration of biodiesel, imports of biodiesel may be underestimated by factor of two when low blends are not considered. However, because the IEA does not provide data on bilateral trade flows, data from EUROSTAT were the only feasible option to estimate bilateral trade flows.

[2] No information on the composition of feedstock for biodiesel production is available from official statistics. To gain insight into the role of different feedstock, it was necessary to refer to industry and agency data. However, these data are sampled only in selected years, and the latest comprehensive evaluation was conducted for 2011.

Figure 1. Utilisation of rapeseed oil and feedstock composition for biodiesel production in Germany, 2011



Source: authors' representation based on VDB (2012)

between 0.5 and 5% in 2011. These figures imply that almost two-thirds of total domestic demand (2.6 million tons) for rapeseed oil, or some 1.7 million tons of rapeseed oil, was used for biodiesel production in Germany in 2011 (VDB, 2012). There is a price wedge between rapeseed oil for biodiesel and other purposes. In 2012, reflecting the cost of biofuel sustainability certification, rapeseed oil for biofuel production was more than 20% more expensive than oil used for food purposes (AMI, 2014).

Similar to biodiesel, rapeseed oil is predominantly produced, traded and consumed within the EU (see Table 1). Imports and exports accounted for less than 7% of the 8.9 million tons of domestic production in 2012 (EUROPEAN COMMISSION, 2015a). Germany accounts for approximately one-third of the total production in the EU and imports approximately 9% of its domestic use, with its main trading partners being the Netherlands and France (AMI, 2014; EUROSTAT, 2015b).

A similar pattern is observed for rapeseed. As indicated in Table 1, approximately 14% of the total European supply was imported from non-EU countries in 2012, of which approximately half originated from Australia, and another third, from the Ukraine. Shipments to outside the EU were negligible (EUROSTAT, 2015a, 2015b). Germany, in contrast, sourced approximately half of its domestic supply from abroad in 2012. Its main trading partners were France, the Netherlands and the United Kingdom.

Despite the predominance of rapeseed oil in German biodiesel production, the composition of inputs is somewhat flexible. In 2013, the share of rapeseed oil dropped to 64%, it was predominantly substituted by palm oil, soybean oil and used cooking oil, with each accounting for fractions of approximately 10% (VDB, 2014).

Crushing rapeseed necessarily leads to the joint production of both oil and rape cake. In 2012, the production of rape cake in the EU amounted to over 12 million tons, of which approximately one-third was produced in Germany (see Table 1). The co-production of rape cake infers that changes to rapeseed oil demand will be buffered to some degree by the rape cake market. The research of TAHERIPOUR et al. (2010) underlines the importance of taking these effects into account in quantitative biofuel policy analysis.

To ensure the sustainability of biofuel production pathways, the current policy of the EU as laid out in the Renewable Energy Directive (RED) requires that sustainability criteria be fulfilled in order for biofuels to be counted towards the blending obligation of at least 10% renewable fuel in total fuel use in the transport sector (EUROPEAN PARLIAMENT AND COUNCIL, 2009). To date, these criteria have been mainly related to characteristics of the cropland on which the biomass was cultivated, biodiversity and carbon stock. Now, GHG emission-saving requirements are becoming increasingly relevant: whereas currently savings must reach 35% compared with those from fossil fuels, this target rises to 50% by 2017. For biofuels produced in new installations, a 60% reduction must be reached by 2018 (EUROPEAN PARLIAMENT AND COUNCIL, 2009).

To help individuals or organizations that have ownership or control of one or more parts of the bioenergy supply chain to assess the potential emission savings of different feedstocks, the RED defines default emission values. According to these default values, the emission savings from rapeseed biodiesel amount to 38 % and thus lie far below the foreseen threshold value for 2017 (EUROPEAN PARLIAMENT AND COUNCIL, 2009). The RED allows GHG emission values to be used for cultivation at the regional level (NUTS 2) if these can be expected to be more favourable than the default values specified in the RED (EUROPEAN PARLIAMENT AND COUNCIL, 2009). In the case of Germany, the emission values for the respective NUTS 2 regions were approximately 24 g CO_{2eq}/MJ and thus well below the default values of 29 g CO_{2eq}/MJ specified in the RED (FEDERAL REPUBLIC OF GERMANY, 2010). However, even when using specific NUTS 2 values for rapeseed cultivation, the GHG emission savings are, at 40%, not sufficient to meet the criteria after 2017 (authors' calculations with BIOGRACE (2013)). Therefore, biodiesel produced from rapeseed would no longer qualify for certification under the RED.

The analysis carried out in this section underlines the relevance of rapeseed biodiesel for German and European rapeseed markets. This analysis leads us to ask the following questions: what would it mean for the European and German biodiesel and rapeseed markets if rapeseed oil were no longer attractive as an input for biodiesel production? What would be the effects on prices and farmers´ incomes? Which feedstocks would be used as substitutes? How would trade flows change?

In this paper, we conduct a quantitative impact assessment to explore the consequences of an exclusion of rapeseed oil from the biodiesel market using the computable general equilibrium model MAGNET and the partial equilibrium model CAPRI. Changes in production and income are assessed with the CAPRI model. CAPRI has a detailed representation of agricultural supply and can account for regionalised rapeseed production (yields and fertiliser levels), the rape cake market for feeding and crop rotation effects in the EU. In addition, and because the scenario also impacts other sectors in a complementary way via the energy market, the MAGNET model was used to assess trade and cross-sectoral effects. With the application of both models, we gain insights into the robustness of our scenario results, particularly results based on similar aggregation levels and similar methodological approaches. Both models have a biodiesel and bioethanol module (BLANCO et al., 2013; SMEETS et al., 2014), including information on various feedstocks. Differences exist with respect to the way certain variables are treated exogenously or endogenously (e.g., energy prices), as well as the aggregation level of the feedstocks. To align the models, exogenous drivers are harmonised and, in the case of deviations, adjusted accordingly.

The remainder of this paper is structured as follows: we present the models and discuss the baseline and applied scenario. Subsequently, the results of the impact assessment are presented. Finally, we investigate the extent to which fertilising practices and other adjustment options along the biodiesel production chain can contribute to allowing rapeseed biodiesel to be counted towards the quantitative targets after 2017.

2 Models and Scenarios

2.1 Models

For our analysis, we applied the computable general equilibrium model MAGNET and the partial equilibrium model CAPRI (for model documentations, see BRITZ (2012), WOLTJER et al. (2014)). MAGNET models biofuel production at the national level and distinguishes between domestic and imported sources of feedstock. Thus, it enables a closer investigation of the implications for bilateral trade flows following a scenario shock at the crop level as well as at the intermediate input level (see SMEETS et al. (2014) for a detailed description of the modelling of biofuels in MAGNET). Furthermore, MAGNET allows for a more inclusive assessment of cross-sectoral implications outside of agriculture. CAPRI in contrast, is able to provide a more in-depth look at implications at the sub-national level. This model provides insights into implications for income and producer prices as well as a more differentiated look at changes in feed use and other consumption dynamics. Additionally, CAPRI is able to provide a comprehensive assessment within the agricultural sector due, for example, to its more detailed incorporation of farm level cost structures and feedbacks.

Biofuel policies and production activities involve and affect actors at different levels, ranging from farm-level decisions in Germany to the international trade of feedstock, vegetable oils and biodiesel. Therefore, we saw the necessity of running both models using an aligned scenario specification to account for the complexity of the issue at hand. MAGNET is used in this sense to examine general economic implications, as well as trade dynamics, whereas CAPRI allows for a more in-depth assessment of impacts at the national and regional levels, with a particular focus on farm-level effects. To ensure the consistency of the results, we compared key general macroeconomic parameters such as GDP development as well as the correct specification of the scenario shock.

2.2 Baseline and Scenario

The baseline defines the comparison point for the counterfactual scenario analysis in the year 2020. To this end, we assume a continuation of biofuel policies as defined in the RED. Notwithstanding the target of 10% biofuels in the transport sector as defined in the legislation, a share of 7.6% of first-generation biofuels in 2020 is implemented in this study[3]. Additionally, the biofuel blending target of the United States is assumed to be enforced as described by OECD and FAO (2012). For Brazil, no blending mandate is implemented because the actual blending rate exceeds the minimum policy requirement. Furthermore, macroeconomic specifications such as GDP and population growth rates are based on projections by the USDA's Economic Research Service (USDA, 2012). For MAGNET, underlying assumptions on the development of agricultural yields are derived from estimations by the FAO (see BRUINSMA (2003)).

The necessity for biofuel pathways to comply with a 50% GHG reduction compared to fossil fuels will have a major effect on the use of rapeseed oil for biodiesel production.[4] Based on current default values, most rapeseed production systems will not comply with the new reduction targets, although the exact share is difficult to determine. We, therefore, defined two views to cover the possible range of implications. The baseline depicts the view that all of the produced rapeseed oil qualifies for biodiesel production under the RED, whereas the scenario depicts the view that the threshold cannot be met and rapeseed oil is no longer a possible biofuel feedstock to meet EU targets. The scenario view is a rather conservative assumption concerning the emission-saving potential of rapeseed, as the potential for GHG-saving strategies is neglected. For the scenario, we further assume that vegetable oil from oil palms, soybeans and sunflowers continues to be used for the European biodiesel production target based on a presumed compliance with the 50% GHG emission reduction threshold.

2.3 Results

The baseline projections show that economic and population growth in the EU result in an increase in total transport fuel consumption of 14% between 2010 and 2020. The binding EU biofuel mandates expressed as shares will thus require higher biofuel blending quantities. With average EU biofuel shares in transport fuel set to increase from 5% in 2010 to the mandated 7.6% in 2020, EU biofuel quantities are almost doubled. For Germany, the mandated biofuel share increases from the relatively high value of 6% to 7.6%, with a more moderate associated increase in biodiesel consumption of 42% and an increase in bioethanol consumption of 30%. As European, and particularly German biodiesel is primarily produced from rapeseed oil (see Section 1), the mandate-driven increase in biodiesel demand also affects its main feedstock, rapeseed. Thus, the demand for rapeseed as an input for biodiesel production is projected to increase

[3] In April 2015, the European Council and the Parliament decided to cap the use of first-generation biofuels at 7% (EUROPEAN PARLIAMENT, 2015b). At the time of the writing of this article, the cap was still under negotiation; thus, the authors decided to implement a baseline share of 7.6% first-generation biofuels to ensure consistency with other scientific analyses. Furthermore, as analysed by JUNKER et al. (2015), the implementation of a 7% share versus a 7.6% share only yields implications for European oilseed and vegetable oil producers that range in the single digits.

[4] In 2018, this threshold would increase to a 60% reduction requirement for installations that started production as of 2017 (EUROPEAN PARLIAMENT AND COUNCIL, 2009).

Table 2. EU market balance in 2020 for vegetable oils, cakes and oilseeds as well as absolute and percentage deviation compared with the baseline

	Production	Biofuel processing	Consumption*	Feed use	EU imports without intra trade	EU exports without intra trade
	in million t					
Rapeseed oil	8.35 *-1.24 [-15%]*	6.72 *-6.68 [-99%]*	3.28 *0.96 [29%]*	0.32 *1.82 [569%]*	2.02 *-1.79 [-89%]*	0.05 *0.87 [1 798%]*
Sunflower oil	3.97 *0.28 [7%]*	1.44 *0.99 [69%]*	2.83 *-0.17 [-6%]*	0.07 *-0.02 [-26%]*	0.79 *0.42 [53%]*	0.47 *-0.11 [-23%]*
Soybean oil	2.72 *0.21 [8%]*	0.99 *0.79 [79%]*	2.73 *-0.13 [-5%]*	0.32 *-0.04 [-11%]*	1.78 *0.31 [17%]*	0.41 *-0.10 [-24%]*
Palm oil		1.09 *1.57 [144%]*	6.44 *-0.17 [-3%]*		7.53 *1.40 [19%]*	
Rape cake	12.54 *-1.87 [-15%]*		0.01	9.18 *-1.43 [-16%]*	0.19 *-0.05 [-28%]*	3.55 *-0.49 [-14%]*
Sunflower cake	4.85 *0.34 [7%]*		0.03	4.84 *0.27 [6%]*	1.89 *-0.01 [0%]*	1.86 *0.07 [4%]*
Oilseeds	32.08 *-0.59 [-2%]*		43.72 *-1.19 [-3%]*	2.05 *0.05 [3%]*	16.79 *0.61 [4%]*	3.09 *1.15 [37%]*
Rapeseed	20.44 *-1.15 [-6%]*		20.37 *-2.97 [-15%]*	0.69 *0.07 [9%]*	2.06 *-0.53 [-26%]*	1.43 *1.22 [85%]*
Sunflower seed	10.38 *0.54 [5%]*		8.78 *0.60 [7%]*	0.28 *-0.01 [-3%]*	0.004 *0.002 [50%]*	1.33 *-0.05 [-4%]*
Soy seed	1.26 *0.02 [1%]*		14.57 *1.18 [8%]*	1.07	14.72 *1.14 [8%]*	0.34 *-0.02 [-5%]*

Note: Scenario deviation is depicted in italics. * Consumption refers to the sum of human consumption plus losses and processing. The base year used for the projection is a three-year average centred on 2008.
Source: authors' results

on average by 43% in the EU and by 45% in Germany between 2010 and 2020.

In our scenario, if rapeseed is no longer available as a biodiesel feedstock, the total biofuel production in the EU will decline by 19%. The large share of rapeseed oil used for biodiesel in Germany results in a more profound reduction of 33%. An endpoint comparison between the baseline and the scenario for the EU in 2020 indicates that the scenario results in, ceteris paribus, a welfare increase in the agricultural sector of 1.7 billion euros. This increase is a consequence of lower prices for vegetable oils from rapeseed[5], which decline by almost 65%.

As indicated in Table 2, the net production of rapeseed oil in the EU declines by 15% (i.e., 1.2 million tons). This decline is a direct result of the reduction in the use of rapeseed oil for biodiesel production (i.e., intended scenario shock), which can only be partially offset by other uses. Thus, consumption[6] increases by 0.9 million tons and feed use by 1.8 million tons resulting in an overall remaining gap of 3.9 million tons of vegetable oil. Consequently, EU trade patterns are also affected with the EU going from being a net importer to a net exporter of rapeseed oil. Furthermore, whereas the use of palm oil for biofuel production increases by 1.5 million tons, the use of sunflower and soybean oils for this purpose only increases by approximately 1 million tons and 0.8 million tons, respectively. Taking the modest increase in EU production of sunflower and soybean oil and the considerable increase in imports of palm oil into consideration, it can be concluded that non-EU producers of palm oil are the main benefactors of an EU ban on the use of rapeseed oil for biodiesel production.

[5] These findings indicate that the negative income effect for farmers is smaller than the positive price effect for consumers in the agricultural sector.

[6] Consumption refers to the sum of human consumption plus losses and processing.

The reduced production of rapeseed oil is associated with a reduction in rape cake production of 15%. This decline is translated directly into a reduced availability of rape cake for domestic feed use of 16% and, to a lower extent, a reduction of exports of -14%. Because the EU production of sunflower oil does not receive a considerable boost as a result of these developments, neither does the EU market of sunflower cake.

At the crop level, impacts on EU production are less pronounced compared to those on the vegetable oil and cake markets, with EU rapeseed production only declining by 6%. This difference is associated with a considerable increase in exports and a decrease in imports, with the EU becoming a net exporter of rapeseed. In contrast, implications for sunflower seed production are, with an increase of 5%, of the same order of magnitude as those observed for sunflower oil and cake production. This increase is a result of an increased use for consumption purposes and biofuel production of sunflower seed and oil, respectively.

As a further consequence of banning the use of rapeseed oil for biodiesel production, the producer price for rapeseed declines by approximately 17%, which is responsible for an income loss in the agricultural sector of 0.7% for the EU and 2% for Germany. Overall, the rapeseed area declines by less than 4% (50,000 hectares) in Germany and by less than 6% (252,000 hectares) in the EU. The total area for sunflower increases, and a small increase for cereals, as well as for cattle and pig production, can also be observed. Income losses from oilseeds are partially offset by reduced feeding costs for beef and pig fattening. However, prices for rape cake increase by 6%, whereas the price of cake from other oilseeds declines due to increased crushing.

In light of reduced biofuel production quantities in the EU and Germany accompanied by increasing biofuel blending obligations and a growing general fuel demand for transport, the EU increases its net imports of biodiesel by 18%, with the majority coming from North America, Argentina and Asia. Germany, in contrast, is a net exporter in the baseline, with other EU Member States being its main trading partners. The restriction on the use of rapeseed oil for biodiesel production in the scenario results in a decline of German net exports of biodiesel of 38%.

Our scenario results project that the most pronounced impacts will occur on vegetable oil markets. For the EU, net imports of total vegetable oils in 2020 are projected to be 42% above those in the baseline, and German net imports are projected to triple. On the one hand, this effect is attributed to an increase in the net imports of vegetable oil for biodiesel production. On the other hand, it is attributed to a decline in the net imports of vegetable oil for other purposes such as human consumption.

At the crop level, the results are ambiguous. Whereas EU net imports of total oilseeds in 2020 only decrease by 4%, German net imports decrease by 20%. This discrepancy is related to the unique setting of the EU. As discussed in Section 1, the most relevant feedstock in the EU, rapeseed, is primarily traded between EU Member States. Therefore, a ban on the use of rapeseed oil mainly affects the intra-EU trade of rapeseed (as shown by the aforementioned 20% reduction for Germany). Furthermore, the comparison between the relatively moderate decrease in the net imports of total oilseeds at the EU level and the impacts on EU net imports of vegetables as described above highlights that a ban on the use of rapeseed oil for European biodiesel production does not result in an increase in trade at the feedstock level but, rather, at the more intermediate input level of vegetable oil.

3 Discussion

In the preceding section we analysed the impact of a complete withdrawal of rapeseed oil from the European biodiesel industry. This scenario is realistic when either default emission values as provided by the RED or the emission values provided by the Member States at NUTS 2 level are used. However, with regard to GHG emissions, a wide range of results can be found depending on the allocation approach, co-product treatment, land use effects and carbon stock changes, among others factors (LUO et al., 2011; MALÇA and FREIRE, 2011a, 2011b; GONZÁLEZ-GARCÍA et al., 2013; BOLDRIN and ASTRUP, 2015). Nitrogen fertiliser and subsequent nitrous oxide (N_2O) emissions are identified as being the most important contributors to the GHG emissions of rapeseed (THAMSIRIROJ and MURPHY, 2010). Hence, in reality, one can expect there to be potential for adapting production processes in a way that individual rapeseed biodiesel production pathways remain eligible to count towards mandated blending requirements.

To determine whether the emission-saving requirements of the RED could be met, straightforwardly, by changing cultivation practices, we use the methodology outlined in the RED to compute GHG

Table 3. GHG emissions of rapeseed biodiesel with varying fertiliser strategies and processing technologies

	I	II	III	IV	V
	German values, climate-friendly produced nitrogen fertiliser	German values, organic fertiliser	Updated default values	Updated default values, climate-friendly produced nitrogen fertiliser	Updated default values, organic fertiliser
	g CO_{2eq}/MJ				
Cultivation and drying	22	20	38	29	26
Oil extraction and refining	5		2		
Transesterification	17		7		
Transport and storage	1		1		
Total	45	43	48	39	36
GHG savings [%]	46	48	43	54	57

Source: authors' computations based on European Parliament and Council (2009), Edwards et al. (2013), Brentrup and Pallière (2008), Federal Republic of Germany (2010), BioGrace (2013)

emissions and savings when climate-friendly produced fertiliser with low associated emissions or organic fertiliser is used. [7] The resulting GHG emissions and savings are depicted in Table 3. Columns I and II show that even when using climate-friendly produced nitrogen fertiliser or organic nitrogen fertiliser in Germany, emission savings only amount to between 46% and 48%. These savings are not sufficient to meet the mandatory GHG savings threshold of 50% as of 2017.[8]

In an effort to update the GHG emission values along the entire production chain, EDWARDS et al. (2013) reviewed the underlying data. According to the authors, the values for chemicals increase compared with the values given in the RED. This increase is reflected in higher values for cultivation and drying (38 g CO_{2eq}/MJ) when standard fertiliser is used (see Column III). The values for oil extraction and refining as well as for transesterification, are significantly reduced compared with the values given in the RED decreasing from 5 to 2 g CO_{2eq}/MJ and from 17 to 7 g CO_{2eq}/MJ, respectively. However, even with these updated values for the processing stages, only a 43% GHG emission savings can be achieved. Our computations, as depicted in Columns IV and V of Table 3, show that rapeseed biodiesel can meet the target of 50% GHG savings if, and only if, a combination of both climate-friendly produced fertiliser or organic nitrogen fertiliser *and* low-energy-demanding conversion processes are used. Then, savings of 54% to 57% can be achieved.

However, using emission values for non-standard fertiliser implies a deviation from default values and the values given by Member States at the NUTS 2 level. Any such deviation can only be approved when all actors involved in the cultivation stages, as well as the transesterification process, provide actual input data. This requirement represents an additional administrative effort and is only attractive if associated costs are covered by the price premium for certified vegetable oil that has been described previously.

At present, it seems unlikely that rapeseed biodiesel will meet the emission-saving targets of the RED after 2017 and continue to qualify as a 'sustainable' biofuel in the EU. Even if rapeseed biodiesel would formally qualify as being 'sustainable', considerable uncertainty around its real environmental benefit remains.

One source of uncertainty is found in the assumptions underlying the calculation of GHG emissions. For instance, for the emissions values that the German government provided at the NUTS 2 level, the amount of fertiliser is derived from the nutrient content of the harvested products (FEDERAL REPUBLIC OF GERMANY, 2010). This procedure ignores fertiliser losses and

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7 We assume emissions of 1.6 kg CO_{2eq}/kg N (compared with 5.9 kg CO_{2eq}/kg N for the standard nitrogen fertiliser) as indicated by BRENTRUP and PALLIÈRE (2008) for the low-emission fertiliser system. When organic fertiliser is used, we assume zero upstream GHG emissions but higher ammonia emissions.

8 Our calculations use values for German NUTS 2 regions that can be considered to be representative for other major rapeseed producing regions within the EU (see REPUBLIC OF POLAND (2011), FRENCH REPUBLIC (n.d.), TE BUCK and NEEFT (2010)).

hence tends to underestimate GHG emissions leading to a yield-to-nitrogen fertiliser ratio that seems optimistic in light of the fertiliser recommendations of several German agencies (LMUV, 2007; LWK NIEDERSACHSEN, 2010; LFL, 2012; LTZ, 2013; LWK SCHLESWIG-HOLSTEIN, 2013). In addition, apart from direct land use changes, the expansion of energy crop production can cause the displacement of other land uses leading to the conversion of formerly non-farmed land (SEARCHINGER et al., 2008; LABORDE, 2011). The appropriateness of methodologies for capturing this effect is at the centre of the indirect land use change (iLUC) debate (LAHL, 2013). iLUC impacts of more than 50 g CO_{2eq}/MJ RME are reported for biodiesel from rapeseed oil (COMMISSION OF THE EUROPEAN COMMUNITIES, 2010; LABORDE, 2011; ELBERSEN et al., 2013). According to a political agreement reached in April 2015, iLUC effects shall be reported but not considered for the GHG emission-saving targets (EUROPEAN PARLIAMENT, 2015a). Clearly, including iLUC impacts in a revised emission calculation methodology for political guidelines would result in an exclusion of many first-generation biofuels.

From a modelling perspective, the assumptions on GDP, population growth and the oil price affect the results of the baseline. An alteration of assumptions would change the projected endpoint for the comparison as well as affect scenario results. However, the baseline assumptions are well-grounded and based on official outlooks.

As with any other model analysis, the outcome of our quantitative analysis depends on the elasticities applied in the models. The substitution elasticities between biofuel feedstock and biofuels in the fuel blend, as well as the elasticities between EU-grown feedstocks, play important roles in the magnitude of the simulated effects. The simulated land use is derived from the regional parameterised mathematical programming models, which explicitly account for natural constraints and farm factor endowment, and hence do not depend on elasticities but, rather, on the opportunity costs of other crops. A sensitivity analysis could provide further insights, but the long computational time prevented us from conducting a systematic analysis of different elasticities. In our approach, the baseline and the scenario were implemented in both models, and the comparison of effects already indicated the robustness of the assumptions and model settings.

The agreement that has been achieved between the European Council and the Parliament to cap first-generation biofuels at 7% is a source of uncertainty regarding our baseline specification (EUROPEAN PARLIAMENT, 2015b). For the biofuel industry this cap implies a forced adjustment of the composition of inputs - away from food crops such as rapeseed and corn towards residual products such as used cooking oil, animal manure and sewage. It is unclear which feedstock will be substituted by residual products. If one assumes that rapeseed oil is among them, the impact of our scenario would be somewhat dampened. However, the difference can be expected to be small.

4 Conclusions

Until 2017, biodiesel from rapeseed can be used for blending mandates if 38% GHG emissions are saved compared to fossil fuels. In 2017, higher savings targets of 50% are foreseen, which puts rapeseed production for biodiesel under pressure. With this target, rapeseed would no-longer qualify for certification under the RED and would be excluded as a possible feedstock.

In Europe, and particularly in Germany, rapeseed oil is the most important feedstock for biofuel production, accounting for over 65% of the total feedstock used in the EU in 2012. In Germany, the predominance of rapeseed oil in biofuel production is even more pronounced. From the perspective of the vegetable oil market, the demand of the biofuel industry has become, with a two-thirds share of total vegetable oil demand, the most important component of demand. In light of these market structures, an exclusion of rapeseed oil will have notable market implications.

The consequences of such an exclusion from the market are analysed in this paper. A quantitative scenario analysis was conducted to derive the effects of a ban. We show that the ban will primarily affect vegetable oil production and trade in the EU. Rapeseed oil is diverted away from biodiesel production and towards consumption and feed use. The resulting gap in the demand for vegetable oil for biodiesel production is mainly filled by palm and soybean oil. Given the limited possibility for the domestic production of these crops in EU countries, EU biofuel policy serves to stimulate international trade in vegetable oil and results in the production of the aforementioned feedstocks in regions such as South America and Southeast Asia. At the same time, we have shown that the EU becomes a net exporter of rapeseed due to lower prices, which also causes farm income to decline. The overall decline in farm area devoted to rapeseed production is calculated to be 6%. Although the scenario analysis reflects the current political setting, the simulation is conservative with regard to the emission-saving potential of rapeseed, as we do not assume an improvement in GHG-saving technologies when growing rapeseed or processing rapeseed oil into biodiesel.

We, therefore, discuss possible advancements in processing technologies that might increase the savings potential of rapeseed. The findings are that meaningful progress can only be reached from improved oil extraction and processing technologies. We also show that rapeseed can only reach the 2017 targets if technological progress is accompanied by reduced-emissions fertiliser schemes.

Our analysis has shown that the emissions values from rapeseed cultivation seem to be quite optimistic in terms of fertiliser requirements and corresponding yields. Moreover, the exclusion of emissions from iLUC effects overestimates emissions savings compared to fossil fuel sources. These weaknesses endanger the credibility of the sustainability of biofuels and potentially the entire bioeconomy concept. There is an urgent demand for well-grounded methods to assess the sustainability of technical options in the bioeconomy in combination with reliable certification schemes, which remains a challenge for society and policy-making.

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