Conference Paper - 22nd Annual Conference on Global Economic Analysis

in Warsaw, Poland June 19-21, 2019

Conference Paper

Using Used Cooking Oil (UCO) for biofuel production: Effects on global land use and interlinkages with food and feed production.

Ruth Delzeit* ruth.delzeit@ifw-kiel.de

Tobias Heimann* (presenting author) tobias.heimann@ifw-kiel.de

Franziska Schuenemann* franziska.schuenemann@ifw-kiel.de

Mareike Soeder * mareike.soeder@ifw-kiel.de

*** Affiliation: Kiel Institute for the World Economy**

Abstract

The production of advanced biofuels aims at replacing food and feed crops with feedstocks without negative side effects on food prices and land use. Biodiesel from so-called used cooking oil (UCO) has reached a substantial market share particularly in the EU due to political support schemes. This paper quantifies the market effects of an increased use of UCO for biofuel production on agricultural and related markets by using the global recursive-dynamic general equilibrium model DART-BIO which accounts for the interlinkages with food and feed production This paper describes in detail how to introduce UCO and the related biodiesel production (UCOME) into the GTAP 9 database and how to integrate the sectors into the disaggregated conventional biofuel production sectors in the DART-BIO model. We quantify and analyze the effects of an increased use of UCO for biofuel production on global food prices and land use by comparing scenarios of global biofuel production with and without UCO in the production portfolios. In addition, we test for the effect of the different mechanisms of the EU biofuel mandate such as the double-counting of advanced biofuels and the cap on conventional biofuels. Our main focus is the question whether the use of UCO indeed decreases the market effects of conventional biofuels and how the double-counting mechanism affects the use of UCOME and other transportation fuels. In addition, we evaluate the amount of UCO used for UCOME production in the different scenarios against limited collection rates of UCO inside and outside the EU.

1. Introduction

Since the beginning of biofuel support programs, the production of conventional biofuels from food and feed crop feedstock has raised concerns about tradeoffs with food prices and land use change (e.g. Searchinger et al. 2008, Britz and Hertel 2011, Labord and Valin 2012). The production of advanced biofuels aims at replacing food and feed crops with feedstock without these tradeoffs. However, the production of advanced biofuels from non-food crop feedstock, such as grasses, miscanthus or algae, is still limited due to lacking technology readiness (IEA 2017). Production of advanced biofuels from waste and residue feedstocks reached a significant share of biodiesel production of which major parts are produced from so-called used cooking oil (UCO) (e.g. USDA 2017a). UCOs are oils and fats that have been used for cooking or frying in the food processing industry, restaurants, fast foods and in households (IEA 2017). This paper analyses whether the increased use of UCO for biofuel production indeed alleviates the impact of biofuel support programs on food and feed prices and land use.

UCO is already the major feedstock for biofuel production in China, Japan and Korea (USDA 2017a, USDA 2017b). Other countries with high shares of UCOME (used cooking oil methyl esther, biodiesel based on UCO) in their biofuel production portfolios are India and Canada (USDA 2017c, USDA 2017d). In the European Union (EU), UCO contributed to almost 20% of biodiesel production in 2017 (USDA 2017a), after introducing double counting of the contribution of advanced biofuels (including UCO) towards the 10 percent biofuel target of energy used in the transportation sector until 2020 (European Union 2015). The respective Directive (European Union 2015) sets a 7% cap on the contribution of conventional biofuels towards the original 10% biofuel target.

With the support of advanced biofuels such as UCO, the European Commission intents to reduce price effects of its biofuel mandate on agricultural markets in order to limit impacts on food security and land use (European Union 2015). The general influence of biofuels on regional and global food prices has been analyzed in several studies showing that a detailed representation of the complex production and value chains of agricultural goods, such as the multi-functionality of many agricultural raw materials and the multi-product aspect of many farming activities, reveals price effects of biofuel mandates at the lower range (see e.g. Delzeit et al. (2018) for a review). In particular, models allowing substituting production of primary crops used as fodder for livestock with by-products from biofuel production within the model specification of biofuel production sectors considerably dampens changes in land use and crop prices of biofuel policies compared to models without these specifications (e.g. Taheripour et al. (2010), Calzadilla et al (2016)).

The available literature on the effect of advanced biofuels on agricultural markets and land use is still limited. Taheripour and Tyner (2011) introduce advanced cellulosic biofuels based on agricultural and forest residues and dedicated crops such as miscanthus and switchgrass into the GTAP-Bio model.

Philippidis et al. (2018) implement advanced lignocellulose biofuels into the Modular Applied General Equilibrium Modelling Tool (MAGNET) encompassing not only advanced biofuel technologies and bioelectricity, but also recognizing the competition for sources of non-food lignocellulose biomass with latent biochemical and thermochemical material technologies. They observe a certain degree of competition for biomass with advanced biomass material industries but significantly alleviated land use pressures. Biodiesel production from domestic UCO collection is implemented by Zhou and Kojima (2011) for some countries into the GTAP 7 database by not accounting for the recent development in the EU following the implementation of the double-counting mechanism. Boutesteijn et al. (2017) study the effect of the EU double-counting of UCOME by using a partial equilibrium model and find that it supports the production of advanced biodiesel such as UCO at the expense of a lower share of conventional biodiesel, and it increases the consumption of fossil diesel as compared to treating conventional and advanced biodiesel equally.

This paper quantifies the market effects of an increased use of UCO for biofuel production on agricultural and related markets by using the global recursive-dynamic general equilibrium model DART-BIO which accounts for the interlinkages with food and feed production (Calzadilla et al 2016). The generation of the DART-BIO database is described in detail in Delzeit et al. (2019). This paper describes in detail how to introduce UCO used for UCOME production and the related UCOME production into the GTAP 9 database and how it is integrated into the DART-BIO model.

The effects of increased use of UCO for biofuel production on global food prices and land use are quantified and analyzed by comparing scenarios of global biofuel production with and without UCO in the production portfolios. In addition, we test for the effect of the different mechanisms of the EU biofuel mandate such as the double-counting of advanced biofuels and the cap on conventional biofuels. Our main focus is the question whether the use of UCO indeed decreases the market effects of conventional biofuels and how the double-counting mechanism affects to use of UCOME and other transportation fuels. In addition, we evaluate the amount of UCO used for UCOME production in the different scenarios vis-à-vis possibly limited collection rates of UCO inside and outside the EU.

2. Materials and Methods

2.1. DART-BIO: Theory and Model Structure

The Dynamic Applied Regional Trade (DART) model is a multi-sectoral, multi-regional recursive dynamic Computable General Equilibrium (CGE) model of the world economy (e.g. Springer 1998)It is based on recent data from the Global Trade Analysis Project (GTAP) covering multiple sector and regions (Aguiar et al. 2016). . The economy in each region is modelled as a competitive economy with flexible prices and market clearing conditions. DART-BIO is the land use version of the DART model and shares the same core characteristics. However, DART-BIO focuses on the heterogeneity of land, the complex production process chains of biofuels and therefore includes several activities/commodities not present in the original GTAP database.

The regional aggregation which is shown in table 1 differentiates the main biofuel producing and consuming countries in line with the focus of the model on analyzing dynamic effects of bioenergy and land use policies.

Table 1: List of regions in DART-BIO

Central and South America		Europe	
BRA	Brazil	FSU	Rest of former Soviet Union
PAC	Paraguay, Argentina, Uruguay, Chile	CEU	Central European Union with Belgium, France, Luxembourg, Netherlands
LAM	Rest of Latin America	DEU	Germany
		MED	Mediterranean with Cyprus, Greece, Italy, Malta, Portugal, Spain
Middle East and Northern Africa		MEE	Eastern European Union with Austria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Romania, Bulgaria, Croatia
MEA	Middle East and Northern Africa	NWE	North-Western European Union with Denmark, Finland, Ireland, Sweden, United Kingdom
AFR	Sub-Saharan Africa	RNE	Rest of Northern Europe: Switzerland, Norway, Lichtenstein, Iceland
Asia		**Northern America**	
CHN	China, Hong Kong	CAN	Canada
IND	India	USA	United States of America
EAS	Eastern Asia with Japan, South Korea, Taiwan, Singapore		
MAI	Malaysia, Indonesia	**Oceania**	
ROA	Rest of Asia	ANC	Australia, New Zealand, Rest of Oceania
RUS	Russia		

Table 2: Sectors in DART-BIO

Agricultural related products (29)		Energy products (14)	
Crops		COL	Coal
PDR	Paddy rice	CRU	Oil
WHT	Wheat	GAS	Gas
MZE[1]	*Maize*	*MGAS*	*Motor gasoline*
GRON	Other cereal grains	*MDIE*	*Motor diesel*
PLM	*Oil Palm fruit*	OIL	Petroleum and coal products
RSD	*Rapeseed*	ELY	Electricity
SOY	*Soy bean*	*ETHW**	*Bioethanol from wheat*
OSDN	Other oil seeds	*ETHM**	*Bioethanol from maize*
C_B	Sugar cane and sugar beet	*ETHG**	*Bioethanol from other grains*
AGR	Rest of crops	*ETHS*	*Bioethanol from sugar cane*
		ETHC	*Cellulcc Bioethanol from straw*
Processed agricultural products			
VOLN	Other vegetable oils	Biofuels	
SGR	Sugar	*BETH*	*Bioethanol*
FOD	Rest of food	*BDIE*	*Biodiesel*
*PLMoil**	*Palm oil*		
*RSDoil**	*Rapeseed oil*	**Non-energy products (3)**	
*SOYoil**	*Soy bean oil*	CRPN	Other chemical rubber plastic products
*OSDNoil**	*Oil from other oil seeds*	ETS	Paper, minerals and metals
*SOYmeal**	*Soy bean meal*	OTH	Other goods and services
*OSDNmeal**	*Meal from other oil seeds*		
*PLMmeal**	*Palm meal*	**Forest and forest products (2)**	
*RSDmeal**	*Rapeseed meal*	FRS	Forestry
*DDGSw**	*DDGS from wheat*	FRI	Forest related industry
*DDGSm**	*DDGS from maize*		
*DDGSg**	*DDGS from other cereal grains*		
UCO	*Used cooking oil*		
STRAW	*Starches, straw*		
Meat and dairy products			
OLVS	Outdoor livestock and related animal products (cattle and other grazing animals, raw milk and wool)		
ILVS	Indoor livestock (swine, poultry and other animal products from indoor livestock)		
PCM	Processed animal products		

The DART-BIO model is calibrated based on the GTAP 9 database (Aguiar et al. 2016), which represents the global economy in 2011 and covers 57 sectors and 140 regions. To incorporate biofuels and their by-products into the DART-BIO model, several sectors are split and added to the standard GTAP 9 database as explained in detail in Delzeit et al. (2019). As a result, DART-BIO contains 38 sectors and 45 products (see Table 2). The current DART-BIO model includes conventional bioethanol production from sugar cane/beet, wheat, maize and other grains; and conventional biodiesel production from palm oil, soybean oil, rapeseed oil and other oilseed oils. In addition to the former DART-BIO version, the updated version of the model includes two types of advanced biofuels: biodiesel production from UCO and cellulosic bioethanol production from straw, where the latter is implemented as a latent technology and not used in this analysis (see Schuenemann et al. 2019). The introduction of UCO biodiesel is explained in detail in the next section. DART-BIO includes the production of by-products generated during the production process of biofuels like dried distillers grains with solubles (DDGS) of the production of bioethanol from grains and oilseed and meals/cakes of the vegetable oil industry (see Calzadilla et al. 2016 for details). In addition, DART-BIO includes separate sectors for motor gasoline and motor diesel because members of the European Union set explicit biofuel targets to substitute gasoline and diesel. Figure 1 shows the implemented production pathways for biodiesel.

In order to account for land heterogeneity, the DART-BIO model incorporates the AEZ methodology. Thus, we use 18 GTAP-AEZs, covering six different lengths of growing period spread over three different climatic zones. Within each AEZ and region, land is allocated to different uses (i.e. cropland, pasture and forest) via a constant elasticity of transformation (CET) structure (for details see Delzeit et al. 2019).

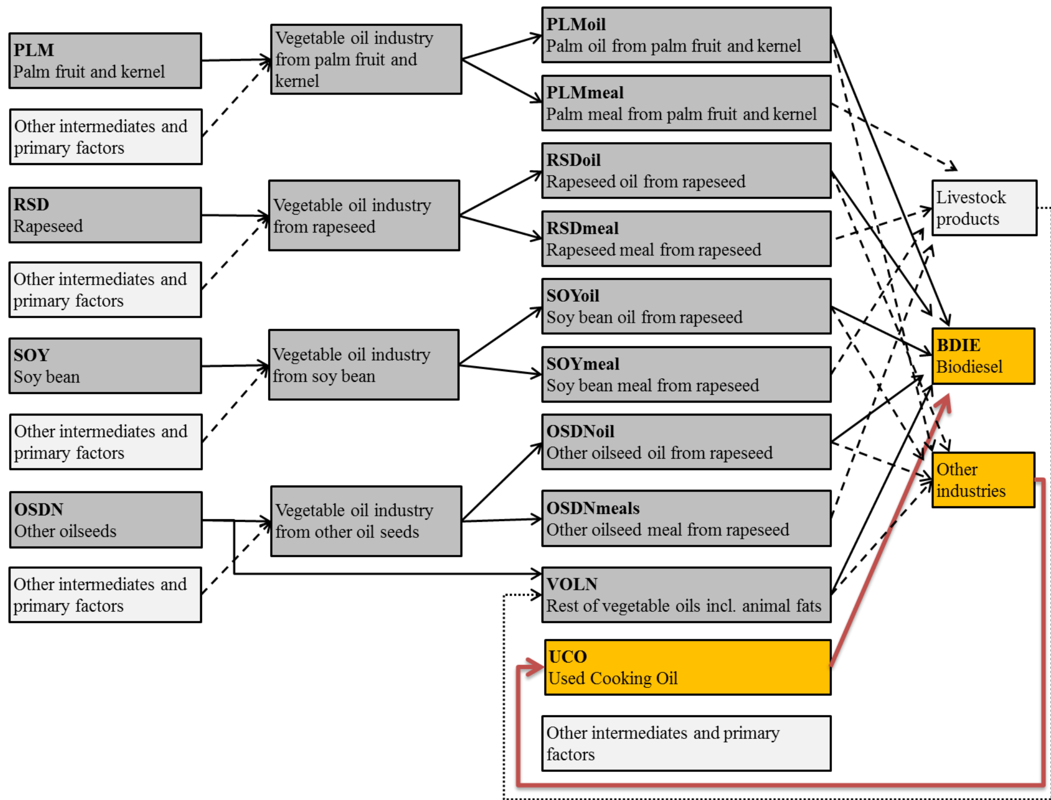

Figure 1: Biodiesel Production Pathways in DART-BIO

2.2. UCO in DART-BIO

2.2.1. Legislation

In DART-BIO we implement existing global quotas and biofuel mandates until 2030. In the following we only go into detail of the European legislation since it explicitly contains regulations relevant for the use of UCO for UCOME production which is accountable for the recently seen sharp increase in the consumption of biodiesel produced from UCO (Boutesteijn, Drabik, & Venus, 2016).

Within the European Union (EU), the Renewable Energy Directive (RED) requires 10 percent of all transport fuels to be delivered from renewable sources by 2020, of which more than 85 percent is expected to come from biofuels (European Union 2009). An amendment of this directive which entered in force October 2015 includes among other regulation a double counting mechanism of the contribution of advanced biofuels including UCO towards the 10 percent target. In addition, it sets a seven percent cap on the contribution of first-generation or conventional biofuels to the transportation sector’s 10 percent target (European Union 2015). The final proposal of a RED II setting the path for Renewable Energy production for the period between 2020 and 2030 raises the overall EU target for Renewable Energy Sources consumption by 2030 to 32% including a minimum share of renewables in road and rail transport of 14%

(European Union 2018). The 14% transport sub-target includes a specific target for advanced biofuels produced from feedstocks listed in Part A of Annex IX of at least 3.5% of transport energy by 2030. Advanced biofuels will be double-counted towards both the 3.5% target and towards the 14% target. Used cooking oils and animal fats will not count as advanced biofuels anymore and will be capped at 1.7% in 2030. However, UCOME will still be double counted towards the 14% target. The maximum contribution of biofuels produced from food and feed crops will be limited to 2020 consumption levels plus an additional 1% with a maximum cap of 7% of road and rail transport fuel in each Member State (European Union 2018).

2.2.2.Production Pathway

The production pathway for UCO consist mainly of the collection and recycling of used oils and fats used for cooking and frying in hotels, restaurants, the food industry but also in private households (Tsoutsos and Stavroula 2013). Depending on the local cooking habits, UCO originates from both vegetable and animal fats and oils. It is estimated that currently around 90% of cooking oils and fats used in the EU are produced from vegetable oils (Peters et al. 2013). Given the variety of sources and origins, UCO is not a homogenous good but varies substantially in its quality but also in its availability throughout the year (Toop et al. 2014). Compared to other biodiesel, UCO collection and processing for UCOME production is most typically characterized by a large number of relatively small feedstock ‘producers’ with a local collection infrastructure (Toop et al. 2014).

2.2.3. Splitting UCO and UCOME production from the GTAP Database

We introduce UCO collection and UCOME production in the full disaggregated version of DART-BIO (140 countries, 48 sectors) based on the full disaggregated version of GTAP (140 countries, 57 sectors, 22 primary factors) which allows us more accuracy and flexibility when choosing different aggregations of the model. We split the sectors form embedded sectors using the SplitCom program. The splitting of conventional biofuels and related agricultural sectors is described in detail in Delzeit et al. (2019).

The splitting of UCO and UCOME is closely related to the splitting of conventional biodiesel. We base the whole biodiesel production, meaning the sum of biodiesel production from palm, soy, rape seed, other vegetable oils and UCO on a balance sheet that records production, consumption, exports and imports for each country in the GTAP database. This balance sheet is largely based on the world biofuel reports published by F.O.Licht. F.O.Licht reports quantity data, we use market price information for biodiesel to express the balance sheet in monetary terms. The amount of each type of biodiesel production and trade is calculated as a share of total biodiesel production and trade. The share of each biodiesel in the producing regions is based on various sources on the market share of each biodiesel option in 2011 in each region. Thus, by determining the market share of UCOME in 2011, we derive the production and trade of

UCOME biodiesel from the F.O.Licht data by multiplying the total biodiesel production and trade with this share.

In order to determine the cost share of UCO in UCOME production we use the average price difference (~ 200€/t Greenea (2016)) between one tone of UCO and one tone of UCOME and assume that the difference in prices mirrors the value added of converting UCO to UCOME. In addition, we take into account that 1.04 tons of UCO is needed to produce 1 ton of UCOME (Behrends 2018). The remaining cost are allocated to energy, capital and labor inputs based on estimates on the general production costs of the biodiesel industry made by the meó Consulting Team which are also applied to the other biodiesel industries when constructing the DART-BIO Database. The resulting production technology of UCOME is displayed in table 3. We split the production and trade of UCOME from the GTAP crp (chemical rubber products) sector.

Table 3: Production Cost Shares of UCOME

Type of cost	Share in production cost (%)
UCO	82.11
Energy	03.11
Capital	14.03
Labor	0.75

The amount of UCO to be split is determined by the amount of UCOME production. Thus, we split only the necessary amount of UCO to produce UCOME and not total UCO collection which might be also used for other purposes such as animal feeding or in the chemical sector. This results from a lack of consistent data on total UCO collection rates and varying alternative uses due to regional differences in quality and regulation of UCO collection and use.

International Standard Industrial Classification (ISIC) sectors (Revision 4) includes the collection of used cooking oils and fats in the reference code 3811 (Collection of non-hazardous waste) (UN 2008). This corresponds to the reference code 9000 in Revision 3 which corresponds to the GTAP *osg* (other services (Government)) sector (McDougall et al. 2013). Thus, we split production of UCO from this sector. Since UCO is collected from hotels and restaurants as well as from food production we assume a production technology that includes the GTAP sectors *trd* (trade including hotels and restaurants), *ofd* (other food) and *otp* (other transport) as intermediate inputs. Due to lacking information about actual cost shares in UCO production technology, we assume as cost shares of these inputs their proportional cost share in the original *osg* sector.

For production of UCOME outside the EU, we assume that only domestically collected UCO is used for UCOME production. Since the double counting mechanism strongly increased the demand for UCO in the EU, it triggered imports of UCO for UCOME production. UCO is traded under the HS Code 1518 which can be related to the ISIC 242 code, subsumed under the GTAP *crp* sector. Thus we use the *crp* sector to split UCO trade. For calculating the amount of traded UCO, we first determine the share of imported UCO in total UCO used for UCOME production and secondly determine the exporting country. We calculate the import share by approximating the share of domestically collected UCO. We approximate the domestic share by dividing information on local collections rates in the EU (Greenea 2016) with the sum of these local collection rates and total imports under the HS Code 1518 (Eurostat 2019). Multiplying the domestic share with the amount of UCO demanded by the UCOME production industry (derived from the cost share of UCO in UCOME production as described above) provides the amount of domestic UCO production for the European Member States. The remaining UCO is assumed to be imported to the EU. In order to determine the UCO exporting countries to the EU, we use the trade shares of each country in the total trade listed under the HS Code 1518. Thus, in the final data set, countries outside the EU produce UCO for their own UCOME production (if any) and for exporting to the EU. Countries within the EU produce UCOME both from domestic collection of UCO and from importing UCO from outside the EU.

3. Scenario Definition and Implementation

Table 4 gives an overview on the implemented scenarios. In the **Baseline (BL)** scenario we assume that the currently implemented biofuel mandates until 2030 are met. In the EU we do not set any restrictions on the maximum share of conventional biofuels and assume a 10% minimum share of renewables in transport. UCO is not double-counted towards the quota in the EU. Biofuel policies are implemented as shares on total transport fuels. The implementation of the biofuel policy targets follows Calzadilla et al. (2016) which implement them as a quota imposed on the regional consumption (Armington aggregation) from domestic or imported production of biofuels.

In the **NoUCO** Scenario we analyse the effect of biofuel policies based solely on conventional biofuels on global agricultural markets, production, land use and trade. We implement the same biofuels mandates as in the BL scenario except that we do not allow an accountability of UCOME towards the biofuel quotas. As such, the NoUCO Scenario complements the BL scenario by providing a reverence scenario without any UCO in biofuel production.

In the **Double** Scenario we analyze the effect of the double-counting mechanism in the EU on the amount of UCOME production in the European Union. In the Double Scenario we implement the same biofuel mandates as in the BL scenario but now we implement the double-counting mechanism of UCOME towards the biofuel quota in the European Union. We do not set any specific target for the use of UCO.

In the **Limit** Scenario we analyze the effect of limiting the amount of conventional biodiesel accountable for the European biofuel mandate. We implement the same biofuel mandates as in the BL scenario but limit the production of conventional biofuels to 7% in the European Member States. Thus, UCO will contribute the remaining 3% by producing 1.5% of energy consumption in transport which is double-counted towards the quota.

Table 3: Overview of Scenarios

Scenario		Biofuel mandates	UCO	Double counting of UCO	Limit to conventional biofuels in the EU	Palm oil for biodiesel in the EU
BL	Baseline Scenario	Yes	Yes	No	No	Yes
noUCO	No UCO for biofuel production	Yes	No	No	No	Yes
Double	Double-counting of UCOME	Yes	Yes	Yes	No	Yes
Limit	Limiting conventional biofuels production	Yes	Yes	Yes	Yes	Yes

3.1. Sensitivity analysis

As a sensitivity analysis we implement a scenario without any trade of UCO for biofuel production. This sensitivity analysis addresses concerns about the risk of fraud if virgin vegetable oil is sold as UCO (Toop et al. 2014), in particular when supply chains are difficult to verify e.g. due to long and in-transparent routes of transports. We implement the scenario with limiting conventional biofuels to 7% and thus 1.5% of UCOME in final energy consumption which is only allowed to be sourced from domestic collectors.

4. Results and Discussion

(Preliminary) results show that even though the overall potential of UCO is limited, its use for biofuel production further decreases the price effects of biofuel mandates and therefore extenuates effects on food security and land use change. UCO mainly replaces vegetable oils for biodiesel production decreasing the overall demand for vegetable oils. However, since this replacement decreases the availability of by-products of vegetable oils for feeding livestock, additional primary production of forage, e.g. from soy, to meet global demand weakens the leverage effect of UCO on the overall sustainability of biofuel mandates.

Cited literature:

Aguiar, A., Narayanan, B., & McDougall, R. (2016). An Overview of the GTAP 9 Data Base. Journal of Global Economic Analysis, 1(1), 181-208. doi:dx.doi.org/10.21642/JGEA.010103AF

Boutesteijn, C., Drabik, D., & Venus, T. J. (2017). The interaction between EU biofuel policy and first-and second-generation biodiesel production. Industrial crops and products, 106, 124-129.

Boutesteijn, C., Drabik, D., & Venus, T. J. (2017). The interaction between EU biofuel policy and first-and second-generation biodiesel production. Industrial crops and products, 106, 124-129.

Britz, W., & Hertel, T. W. (2011). Impacts of EU biofuels directives on global markets and EU environmental quality: An integrated PE, global CGE analysis. Agriculture, Ecosystems & Environment, 142(1-2), 102-109.

Calzadilla, A.; Delzeit, R.; Klepper,(2016). G. Assessing the Effects of Biofuel Quotas on Agricultural Markets. World Scientific Reference on Natural Resources and Environmental Policy in the Era of Global Climate Change, 3, 399-442, 10.1142/9789813208179_0013.

Delzeit, R., Winkler, M., Söder, M. (2018). Land-use change under biofuel policies and a tax on meat and dairy products: considering complexity in agricultural production chains matters. Sustainability, 10(2), 419.

Delzeit, R.; Heimann, T., Schünemann, F.; Söder, M. (2019). DART-Bio – A technical description. Kiel Working Paper (unpublished document).

Delzeit, R.; Heimann, T., Schünemann, F.; Söder, M.; Zabel, F.(2019). Scenarios for an impact assessment of bioeconomy strategies: results from a co-design process. Under review.

European Union (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Official Journal of the European Union, L140/16 of 5.6.2009.

European Union (2015). Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources (Text with EEA relevance). Official Journal of the European Union, L239/1 of 15.9.2015.

European Union (2018). DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance). Official Journal of the European Union, L 328/82 of 21.12.2018.

Eurostat(2019). EU Trade Market Access Database. Retrieved from http://madb.europa.eu/madb/statistical_form.htm

Greenea (2016). Waste-based biodiesel market in 2016. Presentation on Biofuels International 2016 Conference. 20th – 22nd September 2016, Ghent, Belgium. Retrieved from https://www.greenea.com/wp-content/uploads/2016/09/Biofuels-International-2016.pdf

IEA (International Energy Agency) (2017): Tracking Clean Energy Progress 2017: Energy Technology Perspectives 2017 Excerpt Informing Energy Sector Transformations. OECD/IEA 2017. Available at https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf, accessed 2017/01/13.

ILUC Impact Assessment". ECOFYS Netherlands B.V. Utrecht: ECOFYS Netherlands B.V.

Laborde, D. and Valin, H. (2012): Modelling Land Use Changes in a Global CGE: Assessing the EU biofuel mandates with the MIRAGE-BioF model, Climate Change Economics, 3(3) 1250017.

McDougall, R., Walmsley, T., & Huff, K. (2013). *Concordances - ISIC/CPC to GTAP sectors* (Center for Global Trade Analysis). Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). Retrieved from https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=325

Peters, D., Toop, G., van den Bos, A., & Spöttle, M. (2013). Assessing the EC ILUC proposal "Dutch national

Philippidis, G., Bartelings, H., Helming, J., M'barek, R., Smeets, E., & van Meijl, H. (2018). The Good, the Bad and the Uncertain: Bioenergy Use in the European Union. Energies, 11(10), 2703.

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., ... & Yu, T. H. (2008). Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. Science, 319(5867), 1238-1240.

Taheripour, F., & Tyner, W. E. (2011). Introducing first and second generation biofuels into GTAP data base version 7. GTAP, editor. GTAP Research Memorandum, (21).

Taheripour, F.; Hertel, T.W.; Tyner, W.E.; Beckman, J.F.; Birur, D.K..(2010. Biofuels and their by-products: Global economic and environmental implications. Biomass Bioenerg, 34(3), 278-289, 10.1016/j.biombioe.2009.10.017.

Toop, G., Alberici, S., Spoettle, M., & Van Steen, H. (2014). Trends in the UCO market. Ecofys, London.

Tsoutsos, T., & Stavroula T. (2013). Assessment of best practices in UCO processing and biodiesel distribution - D4.3 - Guide on UCO processing and biodiesel distribution methods. Greece: Technical University of Crete, RecOil Project report (supported by the European Commission within the frame of the Intelligent Energy for Europe Programme)

United Nations (UN) (2008). International Standard Industrial Classification of All Economic Activities. Statistical papers Series M No. 4/Rev.4. UN - Department of Economic and Social Affairs - Statistics Division, New York. Retrieved from https://www.bundesbank.de/resource/blob/612626/067f5294c6df434ea4528bdb62551f9b/mL/isic-rev-4-data.pdf

USDA Foreign Agriculture Service (USDA) (2017a). EU Biofuels Annual 2017. Gain Report Nr. NL7015.

USDA Foreign Agriculture Service (USDA) (2017b). China Biofuels Annual 2017. Gain Report Nr. CH16067

USDA Foreign Agriculture Service (USDA) (2017c). Japan Biofuels Annual 2017. Gain Report Nr. A5022.

USDA Foreign Agriculture Service (USDA) (2017d). India Biofuels Annual 2017. Gain Report Nr. IN7075
USDA Foreign Agriculture Service (USDA) (2017e). Canada Biofuels Annual 2017. Gain Report Nr. CA16038
Zhou, X., & Kojima, S. (2011). Biofuels data and social accounting matrices prepared for policy assessment models based on the GTAP 7 data base. Technical Report February, Institute for Global Environmental Strategies, Arlington, VA.
Springer, K. (1998). The DART General Equilibrium Model: A Technical Description. In Kiel Working Paper No. 883.Kiel Institute for the World Economy: Kiel, Germany.