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The Biofuel-Development Nexus: A Meta-Analysis

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Preliminary Draft

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Abstract

Although the production of biofuels has expended in recent years, the literature on its impact on growth and development finds contradictory findings. This paper presents a meta-analysis of computable general equilibrium studies published between 2006 and 2014. Using 26 studies, we shed light on why results differ. We investigate factors such as the type of biofuels, the geographic area and the characteristics of models. Our results indicate that the outcomes of CGE simulations are sensitive to models parameters. They also suggest a divide between developed / emerging countries versus Sub-Saharan African countries.

JEL codes

Q16; O13; C68

Keywords

Biofuel; Bioethanol; Biodiesel; Energy; Development; Meta-regression; Computable General Equilibrium Model

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1. Introduction

Energy is an essential input to development: economic development incurs an increase in energy consumption. One strand of the literature focuses on demand aspects: the energy transition (energy ladder) literature describes qualitative and quantitative changes in energy consumption (e.g. Leach, 1992). It analyses how households have an access to energy. It provides a framework for the implementation of enhanced energy services. Another strand of the literature focuses on supply issues. One crucial question is related to the Malthusian like issue of the availability of fossil energies and whether they might be a growth limiting factor (Carbonnier and Grinevald, 2011). Energy also recently got targeted by development policies. Energy was not a key component of the Millennium Development Goals, but the United Nations "Sustainable Energy for all" (universal energy access, renewable energy, and energy efficiency) renewed the interest for initiatives reducing energy poverty. Sustainable Development goals (goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all) made room for energy in development policies objectives.

Biofuels are serious candidates in addressing those global energy objectives. They deserved substantial attention in climate mitigation initiatives in the transport sector, which were reported by the Intended Nationally Determined Contributions (INDCs) to the UNFCCC[3] Secretariat: about 40% of INDCs relied on biofuels (Gota et al., 2015). Biofuels might reshape several crucial issues such as energy security or climate mitigation but also the development energy nexus especially in developing countries which underlies this paper.

Indeed, biofuels can be seen as a mean of transforming countries dependence on biomass into an additional source of income and job generating activities. This is all the more crucial in countries where poverty pervades. In addition, biofuel production may be a key element for energy security for countries which are net importers of energy. Moreover, since biofuel cropping uses atmospheric carbon dioxide, they may contribute to mitigate greenhouse gas (GHG) emissions. Environmental benefits may also be extended in the case biofuel expansion pushes upward the value of land and incentivizes land upgrading.

More pessimistic views on the consequences of biofuel expansion have however been formulated. First, weak land governance is a pull factor of land Foreign Direct Investments (FDIs) and therefore is reputed to contribute to the land rush (e.g. Arezki et al., 2013). Deleterious effects on unwritten customary land rights have been reported especially in Africa where biofuel production has been a key driver of the rising demand for land allocated to large sale cultivation of biofuels (Toulmin, 2009). Second, demand for biofuel cropping may have been inducing increases in agricultural feedstock prices (Rosegrant et al., 2008). Food security may be imperilled which can be dramatically true in countries where the food expenditure share of income is high like for instance in Sub Saharan African countries (Chauvin et al., 2012). Third, the influential paper written by Searchinger et al. (2008) questioned the positive influence of biofuels on the environment.[4] Biofuel production competes for land which generates indirect land use

[3] United Nations Framework Convention on Climate Change.
[4] This paper is quoted more than 3,800 times as of September 2016.

changes and contributes to GHG emissions. In brief, biofuel expansion is a much debated issue and yet deserves attention in the literature. This paper contributes to the debate while focusing on the income generating effect of biofuel production.

Why concentrating on this aspect? The main reason is that it has dramatic implications in developing countries especially which should jointly reach development objectives and manage environmental constraints. Biofuel policies have been endorsed by many countries. Several African countries tried to implement attractive conditions for biofuel producers owing to their land abundance (Amigun et al., 2011; Arndt et al., 2011). It is a key aspect of Brazil agricultural and energy policy (e.g. Stattman et al., 2013) as well as Asian major biofuel producers (Kumar et al., 2013).

How to assess income consequences of biofuel production? Recent upsurge in biofuel production makes it difficult to evaluate *ex post* the consequences of biofuel expansion on incomes.[5] Simulation exercises and computable general equilibrium (CGE) modelling have attractive features as policy analysis tools. They allow focusing on several key aspects of biofuel expansion. First, biofuel expansion is a worldwide phenomenon and CGE modelling allows easily taking international interdependencies into account. Second, at national level, biofuel expansion cannot be studied in isolation from other sectors of national economies (Kretschmer and Peterson, 2010). In other words, CGE modelling allows modelling a variety of feedbacks or indirect effects induced by biofuel policies.

CGE modelling results played a crucial role in the fuel versus food debate (see e.g. Chakravorty et al., 2009) and results have given many contrasted results. One crucial question therefore emerges on whether the results are sensitive to parameters, modelling choices, results reporting or data assumptions. The objective of this paper is precisely to examine the impact of biofuel policies on growth and households' welfare. In contrast to existing studies and surveys (e.g. , Gasparatos et al. 2015 ; Ji and Long, 2016) on the topic, we propose to address the subject with a meta-analysis. To the best of our knowledge, it is the first meta-analysis on the biofuel and development topic. In addition, our study is focused on CGE results.

The remainder of the paper is organized as follows. Section 2 discusses the use of a meta-analysis. Section 3 is devoted to the construction of the database. Section 4 develops the empirical strategy and economic results. Section 5 presents the results and Section 6 concludes.

2. Meta-analysis

2.1. Definition meta-analysis

A meta-analysis (or meta-regression analysis - MRA) is a quantitative summary of empirical studies on a precise topic (Paldam, 2015; Stanley, 2001). The empirical literature on the impact of the expansion of biofuels on development counts dozens of studies which cannot be fully captured in a narrative survey. Therefore, conducting an MRA on the topic will complement narrative reviews and will facilitate the understanding of factors explaining the different outcomes of existing studies. It also prevents from falling into the so-called "myth of the perfect

[5] There are several exceptions. See for instance Andrade de Sá et al. (2013).

study" which can be found in narrative reviews where researchers select studies based on idiosyncratic judgements (Hunter and Schmidt, 2004).

A MRA should be conducted according to the following steps (Nelson and Kennedy, 2008; Stanley et al., 2013) : formulation of the topic, design of the protocol for the selection of studies, definition of the economic outcome (effect size) and explanatory variables (moderators), extraction of the data and analysis.

2.2. Recent meta-analysis on energy-related topics

The contribution of our MRA is twofold. First, to the best of our knowledge, it is the first MRA on biofuels and development. Second, our primary studies rely on general equilibrium modelling, although most MRA are based on econometric studies.

Although our MRA is original, a large number of MRAs were conducted on energy-related topics. Several MRAs investigate the causality between energy use (production/consumption) and economic output/GDP (Bruns et al., 2013 ; Chen et al., 2012; Kalimeris et al., 2014; Menegaki, 2014). Those MRAs do not provide a clear-cut answer on the causality relation and its direction. Other MRAs focus on energy demand, i.e. from the perspective of experimental studies (Delmas et al., 2013) or in terms of residential consumption (Lampin, 2012). Further MRAs explore fuel/gasoline consumption (price and income elasticities) (Espey, 1998; Goodwin et al., 2004; Havranek et al., 2012; Stern, 2009). Given the recent development of the literature on renewable energies, there are fewer MRAs on the latter and these are very recent publications. Sebri (2015) examines 40 primary studies on the renewable energy consumption-economic growth nexus and finds a significant difference of short run versus long run causality and differences according to the type of data and model specification. Soon and Ahmad (2015) analyse 18 studies estimating the willingness-to-pay of renewable energy use.

While most MRAs (like those on energy previously presented) gather information from studies using econometric estimations, we focus on studies based on general equilibrium modelling. Despite the fast development of meta-analysis in economics, very few MRAs extract information from general equilibrium simulations. They cover different topics such as trade liberalisation (Hess and von Cramon-Taubadel, 2008) or climate change policies (Barker et al., 2002; Branger and Quirion, 2014; Rose and Dormady, 2011). More related to our topic, Condon et al. (2015) conducted a meta-analysis of U.S. biofuel policy with a focus on corn expansion on corn prices using 29 studies (157 estimates) published since 2007.

3. Construction of the database

3.1. Sampling procedure and sample characteristics

This MRA is based on 26 studies (see Annex 1) published between 2006 and 2014. To conduct our bibliographic research, we entered keywords such as 'Biofuels AND Poverty', 'Biofuel AND General Equilibrium', 'Biodiesel AND Poverty', 'Bioethanol AND Development' in bibliographic databases such as Science Direct, Google Scholar, etc. Using this list of studies, we performed snowballing and obtained a pool of hundreds of papers. Then we applied inclusion and exclusion criteria, e.g. including only general equilibrium studies, having simulations of biofuels, and having a measure of households' income or growth.

3.2. Effect sizes

An effect size (ES) is an outcome measure common to all primary studies. We have two different outcomes (hence two types of ESs) measuring the effect of biofuels expansion on economic development: *GDP* is the variation of the GDP growth rate (percentage points); *INCOME* is the variation of household's income growth rate (percentage points).[6] Each simulation generates a welfare variation for a single or multiple regions. An ES is the welfare change for one individual country.[7] See Table 1 for summary statistics of ESs. The range of estimates is very wide and illustrates the lack of consensus in the literature (Figure 3).

In MRAs relying on econometric estimations, it is advised to use a measure of precision for the ESs, usually standard errors of estimates or sample size (Doucouliagos and Ulubaşoğlu, 2008; Stanley and Doucouliagos, 2012; Sterne and Egger, 2001). As our focus is CGE studies, such measures of precision are not relevant.

Table 1. Descriptive statistics of effect sizes

Variable	Obs	Mean	SD	Min	Max
GDP	227	0.18	0.98	-1.62	9.82
INCOME	255	0.57	1.22	-3.84	8.90

3.3. Moderators

To explain the variability of ESs, we use various moderators providing information on the characteristics of publications, of countries, models and scenarios (Table 2).

Table 2. List of moderators

Variable	Description
Characteristics of the publication	
Year	Year of publication
Article	=1 if published article; =0 if working paper or report
Geographical area	
Africa	= 1 if African country
Europe	= 1 if European country
Asia	= 1 if Asian country
South_america	= 1 if South American country
North_america	= 1 if North American country
OECD	= 1 if OECD country
GDP_cap	GDP per capita of the country (source: World Bank Data 2014)
Model characteristics	
Time_estimation	Number of years of the simulation
Multi_country	=1 if multi-countries model

[6] Note that some studies provide the two types of ESs while other one *GPD* or *INCOME*. See Annex 2 for a detailed list.

[7] Hess and von Cramon-Taubadel (2008) propose a similar way of depicting ESs.

Dynamic	=1 if dynamic model; = 0 if static or recursive dynamic model
GTAP	= 1 if GTAP model
MIRAGE	= 1 if MIRAGE model
Model_other	= 1 if model other than GTAP or MIRAGE
Armington	= 1 if Armington specification
Scenario	
Land	= 1 if scenario with expansion of land allocated to biofuels
Land_surface	Expansion rate of land allocated to biofuels*surface of the country
Productivity	= 1 if scenario with an increase of the agricultural productivity or biofuel productivity
Type of biofuel	
Bioethanol	= 1 if bioethanol only
Biodiesel	= 1 if biodiesel only
Biodiesel_bioethanol	= 1 if biodiesel and bioethanol
Type of households (for *INCOME* only)	
HH_rural_urban	=1 if rural and urban households
HH_rural	=1 if rural households
HH_urban	=1 if urban households
HH_poor_rich	=1 if poor and rich households
HH_poor	=1 if poor households
HH_rich	=1 if rich households

Table 3. Descriptive statistics

	GPD (N=227)				INCOME (N=255)			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Year	2,012	1.3	2,007	2,014	2011	1.6	2007	2014
Article	0.5	0.5	0	1	0.36	0.48	0	1
Africa	0.3	0.46	0	1	0.64	0.48	0	1
Europe	0.18	0.39	0	1	0.04	0.19	0	1
Asia	0.22	0.42	0	1	0.16	0.37	0	1
South_america	0.12	0.32	0	1	0.08	0.27	0	1
North_america	0.17	0.38	0	1	0.08	0.27	0	1
OECD	0.33	0.47	0	1	0.12	0.32	0	1
GDP_cap	14,185.47	16,830.85	162.81	47,001.56	5,693.92	12,370.81	162.81	46,437.07
Time_estimation	11.25	5.41	1	29	11.15	4.55	1	20
Multi_country	0.53	0.5	0	1	0.09	0.29	0	1
Dynamic	0.26	0.44	0	1	0.22	0.41	0	1
GTAP	0.56	0.5	0	1	0.1	0.3	0	1
MIRAGE	0.27	0.44	0	1	0.64	0.48	0	1
Model_other	0.17	0.37	0	1	0.27	0.44	0	1
Armington	0.87	0.34	0	1	0.85	0.36	0	1
Land	0.24	0.43	0	1	0.57	0.49	0	1
Land_surface	17,800,000	38,500,000	0	110,000,000	50,200,000	50,700,000	0	110,000,000
Productivity	0.13	0.34	0	1	0.32	0.47	0	1
Bioethanol	0.07	0.26	0	1	0.22	0.41	0	1
Biodiesel	0.25	0.43	0	1	0.5	0.5	0	1
Biodiesel_bioethanol	0.68	0.47	0	1	0.29	0.45	0	1
HH_rural_urban					0.42	0.49	0	1
HH_rural					0.31	0.46	0	1
HH_urban					0.27	0.45	0	1
HH_poor_rich					0.47	0.5	0	1
HH_poor					0.27	0.44	0	1
HH_rich					0.27	0.44	0	1

Characteristics of publications

As shown in Figure 1, studies on the topic are recent and their number has increased over time. There are 23 primary studies for *GDP* and *22* for *INCOME* (with some overlapping, see Annex 1 and Annex 2). This notable increase in the number of publications from 2010 perhaps reflects the evolution of the production of biofuels as shown in

Figure 2 (For an analysis of the determinants of biofuel production, see for instance Kere, 2016). We can presume that this increasing interest of researchers for the topic reflects the surge in production and associated debates within the policy arena. In their "review of ecological and socioeconomic effects of biofuel and energy policy recommendations", Ji and Long (2016) selected 124 papers (published after 2004) to review and it appears that 66% were published after 2011 corroborating this increased interest in biofuel-related research.

Figure 1. Number of primary studies over time

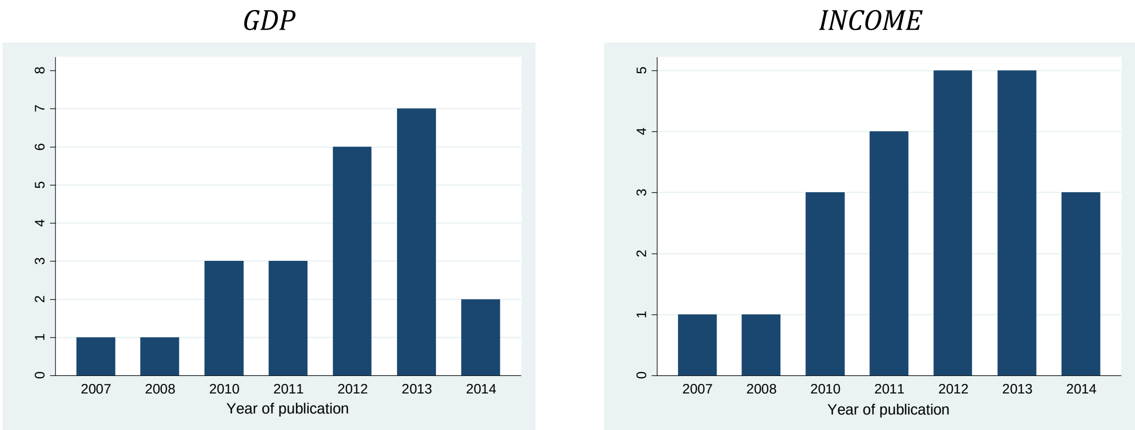
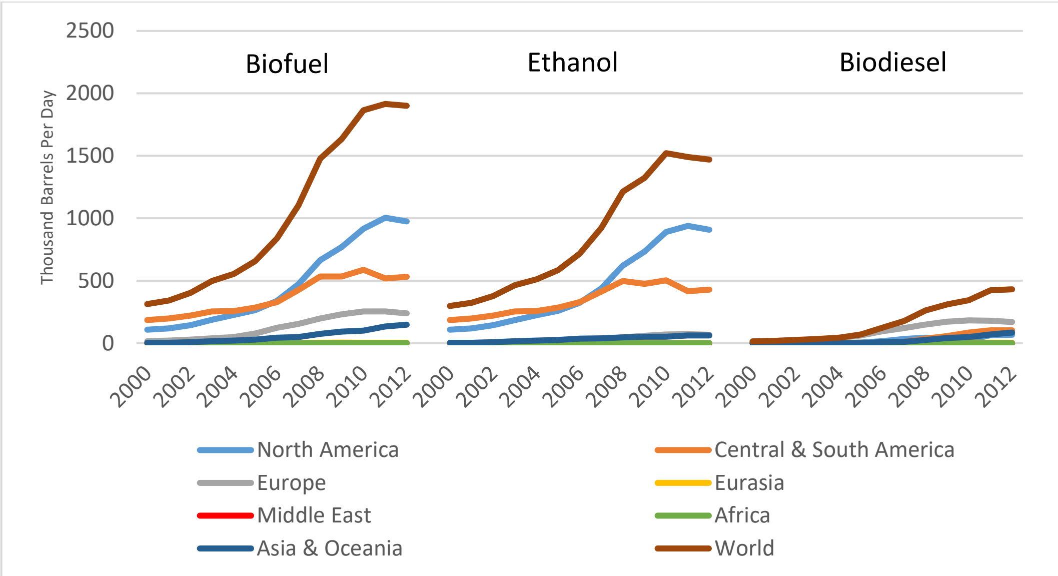


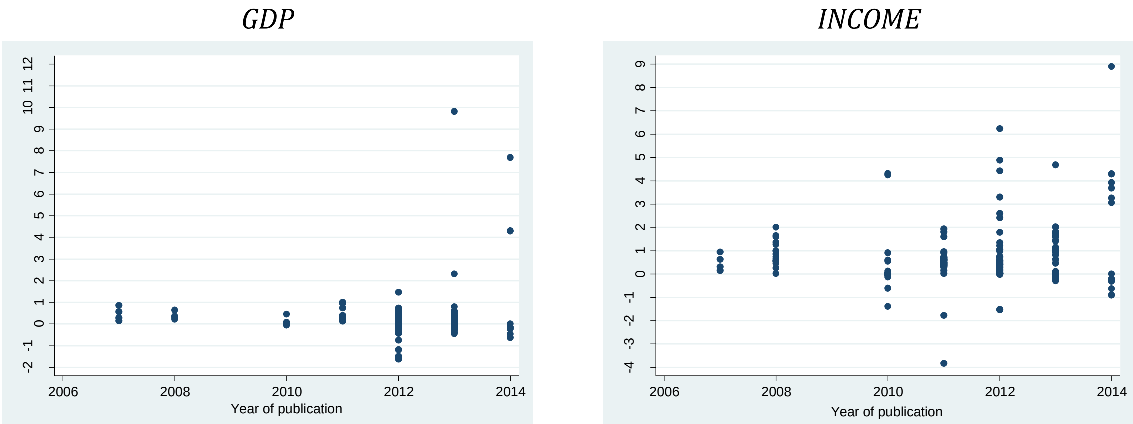
Figure 2. Evolution of biofuel production in the world (2000-2012)



Source: Authors using International Energy Statistics of the U.S. Energy Information Administration[8]

The evolution of ESs over time is shown in Figure 3. Their distribution illustrates the contrasting results found in literature reviews on the impact of biofuels on development and poverty (e.g. Ji and Long, 2016). Not only has the number of studies increased over time (therefore the number of ESs) but also the interval of the values taken by the ESs. Several hypotheses can be made (i) as they are more studies, the likelihood of finding more spread results increases as well (ii) over time the enthusiasm for biofuels has been challenged and it has become more acceptable to publish negative results (see the Introduction for an overview of pessimistic views on biofuels).

Figure 3. Evolution of effect sizes over time



[8] http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=1 (last consulted 08/07/2016).

The number of ESs per paper varies from 1 to 56 with an average of 11.5 for *INCOME*, and from 1 to 35 with an average of 20 for *GDP*. This is explained by the fact that authors run several scenarios (this will be addressed in section 4).

Regarding the publication type, we differentiate between, on the one hand, published articles and, on the other hand, working papers and institutional papers. We suspect that ESs published peer-reviewed articles will take more “conventional” values than ESs published in others supports such as working papers. This also relates to the recurrent publication bias which is faced in meta-analysis. There may be a bias in the reporting of results depending on their sign or intensity. The sources of publication bias are diverse and complex as they depend on the behaviour of authors, referees and editors. See Stanley et al. (2008) and Stanley and Doucouliagos (2012) for discussions on the publication bias and the “file drawer” problem.

Geographical area

We include several variables to control for the geographical area and the level of economic development of countries (i) binary variables for the continent where each country each located (ii) a variable *OECD* indicating whether the country belongs to the OCED (iii) a variable for the GDP per capita of the country. The driving forces behind biofuel expansion differ between countries and may lead to different outcomes on growth and households’ income. Biofuel production has followed different patterns across countries, with the USA being the largest ethanol producer and the European Union being the largest biodiesel producer. Public policies, tax exemptions, subsidies and mandatory blending targets play key roles in these expansions. See Sorda et al. (2010) for an overview of policies implemented in North America, South America, Europe, Asia and Australia. Gasparatos et al. (2015) provide an overview of the development of biofuel policies in Sub-Saharan Africa, which has been partly stimulated by FDIs.

Characteristics of the model

CGE models can be of three types, static, dynamic or recursive dynamic. We have chosen to construct a binary variable *Dynamic* =1 if the model is dynamic, and =0 if the model is static or recursive dynamic. These differences reflect different assumptions of agent’s expectations. In static models, economic agents are myopic and do not look forward, i.e. beyond the current period, to make decisions. In recursive dynamic settings, the model is solved following two steps. First, through a “within-period” static CGE framework and through a “between-period” model. In such models, it is assumed that agents cannot behave according to perfect foresight. In dynamic CGE models, agents are forward looking and their intertemporal behaviour is taken into account. Such framework tends to be used for simulations focusing on intertemporal resource allocation questions, such as climate change (Babiker et al., 2009; Dixon and Jorgenson, 2013, chap. 5; Scollay and Gilbert, 2000).

In the CGE literature the main models used are the GTAP and the MIRAGE models (*GTAP*, *MIRAGE*). The GTAP (Global Trade Analysis Project)[9] model is the standard CGE model. It is multiregion, multisector, with perfect competition and constant returns to scale. The MIRAGE (Modelling International Relationships in Applied General Equilibrium)[10] model is also a

[9] https://www.gtap.agecon.purdue.edu/models/current.asp
[10] http://www.mirage-model.eu/

multiregion, multisector CGE model with a sequential dynamic set-up, imperfect competition, product differentiation by variety and by quality, and foreign direct investment (Bchir et al., 2002). Other models used are EXTER (Boccanfuso et al., 2013; Decaluwé et al., 2001), MEGABARE[11] (see Dixon and Jorgenson, 2013), ORANI (Dixon and Jorgenson, 2013), TERM-BR (general equilibrium model of Brazil) model (Ferreira Filho, 2011), TIGER[12] (The Trade Integrated Global Energy and Resources) model (See Gunatilake et al., 2014).

Most papers rely on an Armington specification allowing domestic and imported goods to be modelled as imperfect substitutes. Standard Armington elasticities in GTAP models are low compared to other models. Simulations the international trade tend to find lower welfare gains when relying on GTAP values (Hess and von Cramon-Taubadel, 2008).

The biofuel-development nexus has been investigated through multiregion (*multi_country*) models as well as single-region models. Single-region models seem more appropriate for studies on a specific topic in a small region. However, using single-region CGE models, researchers ignore effects and feedbacks on/from other regions of the world and may therefore conduct to misleading interpretation of results (Dixon and Jorgenson, 2013). "Single-country GEs generally do not allow for endogenous capital inflows and they often assume fixed trade balances and exchange rates. They might therefore be expected to generate lower welfare gains than multi-country GEs." (Hess and von Cramon-Taubadel, 2008). Accordingly, we should expect lower welfare gains in single-region CGE models.

We introduce the length of the model (*Time_estimation*) to account for long-run versus short-run simulations. Following Hess and von Cramon-Taubadel (2008) long-run CGE models should generate higher welfare gains compared to short-run ones. This reflects that long-run CGE take into account increases in the scope of the word economy.

Scenario

Authors implement various scenarios in their simulations. It has been rather difficult to extract them. In the MRA, we control for whether the scenario involves an expansion of land allocated to biofuels (*Land*) and whether the scenario implies an increase of the agricultural productivity or biofuel productivity (*Productivity*). In some instance, we have been able to calculate the surface allocated to biofuels in the simulation by multiplying the expansion rate of land allocated to biofuels and the surface of the country (*Land_surface*).

Type of biofuels

There exist different types of biofuels, namely biodiesel and bioethanol. Biodiesel encompasses jatropha, caster bean, palm oil, soybean, rape sunflower oil; bioethanol includes sugarcane, cassava, wheat, maize, corn, potatoes and sorghum. In the primary studies, authors either carry out a simulation on biodiesel or on bioethanol or on both.

[11] MEGABARE model is developed by Australian Bureau of Agricultural and Resource Economics (Lee et al., 2007)

[12] "The TIGER model is based on the World Bank's LINKAGE model, elaborated to take fuller account of energy generally and biofuels in particular" (Gunatilake et al., 2014). The LINKAGE model is a dynamic CGE based on GTAP data.

The production of these biofuels can have multiple impacts. Gasparatos et al. (2015) list (i) economic impacts: economic development, energy security and foreign exchange savings (ii) environmental impacts: water availability, water quality, GHG emissions and biodiversity loss (iii) social impacts: poverty alleviation, food security and access to land. These impacts vary per the scale of production.

Type of households

For the ES *INCOME*, we add variable on households' characteristics, indicating whether they are rural, urban, poor or better-off.

4. Empirical strategy

4.1. Base model

We estimate two complementary models corresponding to each type of ES, *GDP* and *INCOME*. The base model is:

$$ES_i = M\beta_i + \varepsilon_i \qquad \text{or}$$
$$GDP_i = X\beta_{Xi} + \varepsilon_{Xi}$$
$$INCOME_i = Y\beta_{Yi} + \varepsilon_{Yi}$$

ES is a $L\times1$ vector of effect sizes (*GPD* and *INCOME*), that is the welfare change in a country due to a biofuel policy; M is a $L\times K$ matrix of moderators; β is a $K\times1$ vector of meta-regression coefficients. ε is a $L\times1$ vector of residuals. Most MRAs using estimates from CGE models are estimated using OLS (e.g. Barker et al., 2002; Hess and von Cramon-Taubadel, 2008). Authors of such MRAs have stressed the need to account for multiple ESs in primary studies (Barker et al., 2002; Branger and Quirion, 2014; Hess and von Cramon-Taubadel, 2008).

MRAs using ESs obtained using econometric estimations can be estimated in more ways, which are discussed in the literature (see Ringquist, 2013; Stanley and Doucouliagos, 2014a, 2014b, 2012). Stanley and Doucouliagos (2012, p. 122) advise to use very simple econometric models and promote the use of Weighted Least Squares, which is discussed in Stanley and Doucouliagos (2014a, 2014b). WLS allow for correcting for heteroscedasticity and excess heterogeneity using sample size as weight (or other precision measures). In this MRA, we cannot use such models as we do not have any precision measure. Consequently, we estimate robust OLS. Additionally, to capture dependence among ESs when multiple ESs reported in studies, we estimate cluster-robust regressions, taking a study as a cluster. The cluster-robust MRA will differ from the robust OLS MRA in terms of standard errors: these will be computed considering the potential dependence within a cluster. Finally, we estimate multi-level regressions (mixed-effect model) which are an alternative way to capture dependence among ESs reported in studies, with two levels, i.e. ESs and primary studies.

4.2. Selection of moderators and robustness checks

Firstly, our moderators present high correlations between them. Therefore, we choose to present several specifications for each model. Secondly, ESs belonging to a same primary study may be correlated, which can introduce a bias in the MRA. We take this into account by using cluster robust regressions as recommended by Stanley and Doucouliagos (2012) with primary studies as clusters. Robust OLS regressions are presented in Table 4 and Table 5. Cluster regressions are presented in Annex 3 and Annex 4 ; Multi-level regressions are presented in Annex 5 and 6.

Table 4. Robust OLS for *GDP*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	0.0717			-0.0624**					
	(0.128)			(0.0313)					
Article	-0.293				-0.102				
	(0.335)				(0.106)				
Africa	0.0987							-0.00951	
	(0.412)							(0.170)	
Europe	0.0762							-0.0947	
	(0.288)							(0.175)	
Asia	0.209							-0.0414	
	(0.203)							(0.156)	
South_america[13]	0.0118							-0.381**	
	(0.279)							(0.172)	
OECD	0.931*						0.209		
	(0.523)						(0.169)		
GDP_cap	-1.87e-05								2.78e-06
	(1.44e-05)								(4.24e-06)
Time_estimation	0.0463***	0.0482***	0.0474***	0.0540***	0.0505***	0.0449***	0.0496***	0.0477***	0.0491***
	(0.0169)	(0.0161)	(0.0182)	(0.0167)	(0.0172)	(0.0156)	(0.0160)	(0.0154)	(0.0159)
Multi_country	1.484**					1.394**			
	(0.706)					(0.570)			
Dynamic	0.404		0.213						
	(0.398)		(0.154)						
MIRAGE	1.756**	0.307***	0.323**	0.327***	0.269**	1.575***	0.406***	0.261	0.356**
	(0.708)	(0.117)	(0.131)	(0.120)	(0.125)	(0.555)	(0.156)	(0.189)	(0.151)
Model_other[14]	2.175**	0.986***	0.953***	1.006***	1.004***	2.092***	1.110***	1.023***	1.044***
	(0.888)	(0.328)	(0.322)	(0.327)	(0.332)	(0.653)	(0.367)	(0.368)	(0.355)
Armington	0.0616		0.0529						
	(0.348)		(0.225)						

[13] *North_america* is the variable of reference.
[14] *GTAP* is the variable of reference.

Land	-1.404**	-1.102**	-1.144**	-1.188**	-1.152**	-1.459**	-1.034**	-1.172**	-1.062**
	(0.643)	(0.503)	(0.497)	(0.503)	(0.527)	(0.618)	(0.478)	(0.496)	(0.486)
Land_surface	-3.58e-09								
	(3.50e-09)								
Productivity	1.052**	1.022**	1.025**	1.034**	1.053**	1.014**	1.001**	1.010**	1.015**
	(0.429)	(0.458)	(0.453)	(0.459)	(0.474)	(0.438)	(0.447)	(0.451)	(0.454)
Biodiesel	0.689*	0.496	0.484	0.566*	0.482	0.762*	0.482	0.503*	0.491
	(0.394)	(0.311)	(0.309)	(0.317)	(0.310)	(0.405)	(0.305)	(0.296)	(0.309)
Biodiesel_bioethanol[15]	-0.541	-0.0531	-0.111	-0.0359	-0.0894	-0.361	-0.00187	-0.0708	-0.0240
	(0.369)	(0.216)	(0.212)	(0.226)	(0.232)	(0.312)	(0.214)	(0.222)	(0.216)
Constant	-145.8	-0.563*	-0.602**	124.9**	-0.494*	-1.559***	-0.739**	-0.448	-0.662**
	(257.6)	(0.290)	(0.293)	(63.05)	(0.296)	(0.469)	(0.298)	(0.280)	(0.297)
Observations	227	227	227	227	227	227	227	227	227
R-squared	0.369	0.284	0.293	0.289	0.286	0.323	0.291	0.296	0.285

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[15] *Bioethanol* is the variable of reference.

Table 5. Robust OLS for *INCOME*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year	0.178			-0.0399						
	(0.117)			(0.0407)						
Article	-0.279				0.257					
	(0.343)				(0.202)					
Africa								0.827*		
								(0.451)		
Europe	2.661***							-0.153		
	(0.738)							(0.567)		
Asia	0.462							0.887*		
	(0.474)							(0.525)		
South_america	-0.155							-0.0715		
	(0.768)							(0.404)		
OECD	1.747						-0.597			
	(1.736)						(0.526)			
GDP_cap	-6.56e-05*								-2.76e-05**	
	(3.78e-05)								(1.15e-05)	
Time_estimation	0.0927**	0.0950***	0.0975***	0.0982***	0.101***	0.0845***	0.103***	0.0870***	0.110***	0.0897**
	(0.0423)	(0.0332)	(0.0357)	(0.0346)	(0.0345)	(0.0317)	(0.0361)	(0.0334)	(0.0356)	(0.0359)
Multi_country	3.262***					2.226***				
	(0.692)					(0.396)				
Dynamic	0.967**		0.458**							
	(0.424)		(0.211)							
MIRAGE	3.253***	0.446**	0.282	0.481**	0.408*	1.938***	-0.0167	-0.129	-0.282	0.487**
	(0.847)	(0.213)	(0.246)	(0.202)	(0.228)	(0.372)	(0.510)	(0.556)	(0.413)	(0.199)
Model_other	2.994***	1.063***	0.910***	1.090***	0.958***	2.279***	0.561	0.470	0.300	1.077***

	(0.664)	(0.243)	(0.227)	(0.246)	(0.240)	(0.329)	(0.466)	(0.545)	(0.336)	(0.250)
Armington	-0.660*		0.146							
	(0.358)		(0.229)							
Land	-0.743*	-0.691**	-0.780**	-0.744**	-0.614**	-0.894***	-0.826**	-0.996***	-1.008***	-0.734***
	(0.386)	(0.284)	(0.303)	(0.287)	(0.299)	(0.284)	(0.320)	(0.383)	(0.342)	(0.253)
Land_surface	-5.16e-09									
	(3.27e-09)									
Productivity	0.734***	0.830***	0.827***	0.839***	0.801***	0.860***	0.835***	0.799***	0.819***	0.714***
	(0.198)	(0.214)	(0.214)	(0.215)	(0.223)	(0.212)	(0.217)	(0.220)	(0.215)	(0.218)
Biodiesel	0.00569	0.247	0.177	0.293	0.200	0.402*	0.264	0.419*	0.288	0.496**
	(0.147)	(0.217)	(0.198)	(0.209)	(0.203)	(0.222)	(0.217)	(0.221)	(0.216)	(0.195)
Biodiesel_bioethanol	-0.422*	0.275	0.224	0.290	0.313	-0.148	0.246	0.307	0.214	0.503**
	(0.240)	(0.264)	(0.274)	(0.265)	(0.284)	(0.239)	(0.265)	(0.280)	(0.262)	(0.244)
HH_rural_urban										-0.108
										(0.228)
HH_rural										0.626***
										(0.180)
HH_poor_rich										0.395**
										(0.154)
HH_poor										0.170
										(0.132)
Constant	-360.4	-1.128***	-1.135***	79.12	-1.263***	-2.334***	-0.644	-1.089***	-0.296	-1.605***
	(236.2)	(0.369)	(0.357)	(81.84)	(0.436)	(0.416)	(0.497)	(0.351)	(0.409)	(0.543)
Observations	255	255	255	255	255	255	255	255	255	255
R-squared	0.472	0.228	0.251	0.230	0.235	0.342	0.236	0.265	0.256	0.291

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Results

The meta-regressions explain respectively 30-37% and 25-48% of the variance of ESs for GDP and INCOME.

We do not find a significant impact of the year of publication (*year*) and its type (*article*). This suggests that this topic has not resulted in fads. We find a positive and significant sign for *time_estimation*, for both *GDP* and *INCOME*, suggesting welfare gains increase with the length of the simulation. This is line with results found by Hess and von Cramon-Taubadel (2008). We also find a positive and significant impact of *multi_country* for both ESs and in all specifications. Such effect is also found by Hess and von Cramon-Taubadel (2008). This result indicates increased welfare gains in multi-region models which account for the reallocation of international factors and comparative advantages.

The results for the *Armington* variable are mixed and do not allow us to derive useful results. MIRAGE and other models tend to generate higher welfare gains compared to GTAP models. This result is again in line with Hess and von Cramon-Taubadel (2008). As previously explained, standard Armington elasticities in GTAP models are lower to other models, which could explain why simulations relying on GTAP values tend to find lower welfare gains (Hess and von Cramon-Taubadel, 2008).

Dynamic models lead to higher welfare gains for HH INCOME compared to static or recursive dynamic models. In dynamic models, economic agents are forward looking and their intertemporal behaviour is taken into account which implies time consistent behaviours.

When the scenario implies the expansion of land allocated to biofuels (*Land*), ESs for both GDP and INCOME models decrease. It suggests that competition for land with other cultures is detrimental to welfare. Interestingly, most simulations with such scenario were performed in Sub Saharan Africa, e.g. Mozambique, Tanzania, Mali, Ethiopia (e.g. Arndt et al., 2008; Arndt et al., 2011; Arndt et al., 2012; Boccanfuso et al., 2013; Ferede et al., 2013; Gebreegziabher et al., 2013; Gemechis, 2012). Several authors have put emphasis on Sub Saharan African land endowments: uncultivated land availability in this region represents roughly half the world one. But Sub Saharan African land potential is concentrated in few countries (Deininger & Byerlee 2011) and are subjected to highly heterogeneous agro-ecological conditions (Wicke et al. 2011).[16] Conversely, simulations containing a scenario with an increase of the agricultural productivity or biofuel productivity (*productivity*) consistently impact ESs positively.

Results for the geographical area are not clear-cut. They tend to indicate that OECD countries have higher gains in terms of GDP and that Africa and Asia (or countries with a lower GDP per capita) have higher welfare gains for HH INCOME. Understanding the underlying mechanisms is tricky for several reasons. First, biofuel production has more severe effects on foods prices in developing countries compared to developed ones (FAO, 2009). Second, tax exemptions, subsidies and mandatory blending targets influence the economic profitability of biofuel production. These policies have mainly been implemented in the USA, Europe and emerging economies (FAO, 2009; Sorda et al., 2010). With such distortions, determining the real economic

[16] For an in-depth discussion of bioenergy expansion in Sub Saharan Africa, see for instance Brun et al. (2016).

profitability of biofuels is a difficult task. Third, countries produce different mix of bioethanol and biodiesel. In addition, we find that the positive impact is higher for rural HH compared to urban HH and for a mix of poor and rich HH compared to rich HH only. This could suggest that biofuel production favors rural employment (FAO, 2009) and may therefore contribute to rural development.

We find that the impact of a biodiesel scenario is positive compared to bioethanol only. Recall that biodiesels encompass jatropha, caster bean, palm oil, soybean and rape sunflower oil while bioethanols include sugarcane, cassava, wheat, maize, corn, potatoes and sorghum. The production costs are much higher for rape sunflower oil (e.g. 3.29 USD per gallon in the EU) than sugarcane (0.25 USD per litre in Brazil) (FAO, 2009). More generally, biodiesels tend to be more expensive to produce which could be what is captured in the GDP growth. Also, soybean prices have been significantly rising over the past decade, with a slowdown after 2014, therefore substantially increasing the profitability of this crop.

6. Discussion and Conclusion

This meta-analysis is to the best of our knowledge the first one to look at the impact of biofuel production on economic growth and poverty. We focus on Computable General Equilibrium Studies. CGE modelling is a particularly relevant and interesting framework to investigate the impact of biofuels on various dimensions such as growth, poverty or food prices (Dixon and Jorgenson, 2013; Kretschmer and Peterson, 2010). It has indeed played a crucial role in the fuel versus food debate (see e.g. Chakravorty et al., 2009). CGE studies have provided contrasted results notably because the results are sensitive to scenario parameters, modelling choices, data assumptions... Our contribution is to precisely examine the impact of biofuel policies on growth and households' income by considering model parameters in a meta-analysis framework.

Our quantitative meta-analysis is complementary to existing narrative surveys and suggests that results are sensitive to key hypothesis on essential parameters. Simulations on longer time periods, in multi-countries lead to higher impacts of biofuel expansion on growth and households' income. Moreover, simulations with a shock in agricultural productivity lead to positive welfare gains, unlike simulations with a shock on land expansion. Lastly, biodiesels lead to higher gains compared to biofuels. Overall, by looking at the literature, the impact of biofuel expansion appears to be positive.

However, CGE models do not account for non-priced effects such as externalities. To have a comprehensive overview of the impact of biofuel expansion, this meta-analysis should be combined with models assessing their environmental and social sustainability as biofuels offer both advantages and risks. See FAO (2009) for a thorough review of environmental and social challenges.

Several questions were answered throughout this meta-analysis but it still leaves other interesting research perspectives. First, one crucial question still prevails regarding the effect of biofuel on land allocation and land use. Assuming productivity gains in agriculture could induce a rebound effect: if agriculture is more profitable, more resources will be allocated to agriculture. The underlying mechanism is similar to a Jevons' Paradox. Therefore, more research efforts should be devoted to that question of which environmental consequences are critical. Second, on the methodological side, MRA using econometric studies as primary studies include a measure for the precision of estimates. In the case of primary studies relying on CGE, such measures are not available; thus, future research in meta-analysis methodology should focus on identifying alternative precision measures. Third, as raised by Hess and von Cramon-Taubadel (2008), the results of CGE models are a "complex function of the many factor…[]…and of interactions between them". It is not possible to code all characteristics of publications given (i) the enormous amount of data and computation needed to run a CGE (ii) the fact that not all the information is provided in papers.

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Appendix

Annex 1. Full references for the 26 primary studies

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Annex 2. Primary studies used

GDP **INCOME**

1. (Arndt et al., 2008)
2. (Arndt et al., 2011)
3. (Arndt et al., 2012)
4. (Boccanfuso et al., 2013)
5. (Cabral et al., 2012)
6. (Cansino et al., 2013)
7. (Cororaton and Timilsina, 2012)
8. (de Souza Ferreira Filho, 2011)
9. (Doumax et al., 2014)
10. (Ferede et al., 2013)
11. (Ge and Lei, 2010)
12. (Gebreegziabher et al., 2013)
13. (Gemechis, 2012)
14. (Gunatilake et al., 2011)
15. (Gunatilake et al., 2014)
16. (Huang, 2010)
17. (Lee et al., 2007)
18. (Oladosu and Kline, 2010)
19. (Oladosu and Kline, 2013)
20. (Timilsina et al., 2012)
21. (Timilsina et al., 2013)
22. (Wianwiwat and Asafu-Adjaye, 2012)
23. (Wianwiwat and Asafu-Adjaye, 2013)

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1. (Arndt et al., 2008)
2. (Arndt et al., 2011)
3. (Arndt et al., 2012)
4. (Boccanfuso et al., 2013)
5. (Branca et al., 2014)
6. (Cabral et al., 2012)
7. (Cansino et al., 2013)
8. (de Souza Ferreira Filho, 2011)
9. (Doumax et al., 2014)
10. (Ge and Lei, 2010)
11. (Ge and Tokunaga, 2011)
12. (Gebreegziabher et al., 2013)
13. (Gemechis, 2012)
14. (Gunatilake et al., 2011)
15. (Gunatilake et al., 2014)
16. (Huang et al., 2012)
17. (Huang, 2010)
18. (Lee et al., 2007)
19. (Oladosu and Kline, 2010)
20. (Timilsina et al., 2013)
21. (Wianwiwat and Asafu-Adjaye, 2012)
22. (Wianwiwat and Asafu-Adjaye, 2013)

Annex 3. Cluster robust OLS for *GDP*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	0.0717			-0.0624					
	(0.191)			(0.0542)					
Article	-0.293				-0.102				
	(0.459)				(0.141)				
Africa	0.0987							-0.00951	
	(0.578)							(0.290)	
Europe	0.0762							-0.0947	
	(0.360)							(0.213)	
Asia	0.209							-0.0414	
	(0.283)							(0.190)	
South_america	0.0118							-0.381	
	(0.333)							(0.267)	
OECD	0.931						0.209		
	(0.588)						(0.183)		
GDP_cap	-1.87e-05								2.78e-06
	(1.64e-05)								(4.71e-06)
Time_estimation	0.0463	0.0482	0.0474	0.0540	0.0505	0.0449	0.0496	0.0477	0.0491
	(0.0312)	(0.0305)	(0.0326)	(0.0331)	(0.0322)	(0.0295)	(0.0304)	(0.0293)	(0.0300)
Multi_country	1.484*					1.394**			
	(0.786)					(0.627)			
Dynamic	0.404		0.213						
	(0.582)		(0.238)						
MIRAGE	1.756*	0.307	0.323	0.327	0.269	1.575**	0.406	0.261	0.356
	(0.890)	(0.240)	(0.275)	(0.240)	(0.234)	(0.701)	(0.259)	(0.335)	(0.248)
Model_other	2.175**	0.986	0.953*	1.006*	1.004*	2.092**	1.110*	1.023*	1.044*
	(0.920)	(0.576)	(0.548)	(0.567)	(0.577)	(0.881)	(0.580)	(0.558)	(0.567)
Armington	0.0616		0.0529						
	(0.464)		(0.395)						

Land	-1.404*	-1.102	-1.144*	-1.188*	-1.152	-1.459*	-1.034	-1.172*	-1.062
	(0.751)	(0.657)	(0.658)	(0.640)	(0.675)	(0.761)	(0.639)	(0.651)	(0.648)
Land_surface	-3.58e-09								
	(5.03e-09)								
Productivity	1.052**	1.022*	1.025*	1.034*	1.053*	1.014**	1.001*	1.010*	1.015*
	(0.475)	(0.508)	(0.503)	(0.510)	(0.527)	(0.464)	(0.494)	(0.497)	(0.504)
Biodiesel	0.689	0.496	0.484	0.566	0.482	0.762	0.482	0.503	0.491
	(0.459)	(0.402)	(0.396)	(0.388)	(0.401)	(0.509)	(0.398)	(0.385)	(0.402)
Biodiesel_bio ethanol	-0.541	-0.0531	-0.111	-0.0359	-0.0894	-0.361	-0.00187	-0.0708	-0.0240
	(0.425)	(0.314)	(0.309)	(0.316)	(0.316)	(0.332)	(0.308)	(0.310)	(0.303)
Constant	-145.8	-0.563	-0.602	124.9	-0.494	-1.559**	-0.739	-0.448	-0.662
	(382.8)	(0.511)	(0.544)	(108.9)	(0.473)	(0.650)	(0.485)	(0.486)	(0.455)
Observations	227	227	227	227	227	227	227	227	227
R-squared	0.369	0.284	0.293	0.289	0.286	0.323	0.291	0.296	0.285

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4. Cluster robust OLS for *INCOME*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year	0.178			-0.0399						
	(0.173)			(0.0789)						
Article	-0.279				0.257					
	(0.502)				(0.360)					
Africa								0.827		
								(0.789)		
Europe	2.661***							-0.153		
	(0.735)							(0.867)		
Asia	0.462							0.887		
	(0.679)							(0.804)		
South_america	-0.155							-0.0715		
	(1.079)							(0.563)		
OECD	1.747						-0.597			
	(2.491)						(0.807)			
GDP_cap	-6.56e-05								-2.76e-05	
	(5.74e-05)								(1.81e-05)	
Multi_country	3.262***					2.226***				
	(0.664)					(0.574)				
Time_estimation	0.0927	0.0950	0.0975	0.0982	0.101	0.0845	0.103	0.0870	0.110*	0.0897
	(0.0565)	(0.0592)	(0.0594)	(0.0620)	(0.0613)	(0.0527)	(0.0617)	(0.0545)	(0.0608)	(0.0597)
Dynamic	0.967		0.458							
	(0.629)		(0.329)							
MIRAGE	3.253***	0.446	0.282	0.481	0.408	1.938***	-0.0167	-0.129	-0.282	0.487
	(0.852)	(0.455)	(0.568)	(0.426)	(0.510)	(0.666)	(0.805)	(0.881)	(0.644)	(0.416)
Model_other	2.994***	1.063*	0.910*	1.090**	0.958*	2.279***	0.561	0.470	0.300	1.077**
	(0.472)	(0.512)	(0.527)	(0.492)	(0.528)	(0.546)	(0.716)	(0.761)	(0.511)	(0.471)

Armington	-0.660		0.146							
	(0.525)		(0.479)							
Land	-0.743	-0.691	-0.780	-0.744	-0.614	-0.894*	-0.826	-0.996	-1.008	-0.734
	(0.519)	(0.505)	(0.518)	(0.498)	(0.528)	(0.498)	(0.553)	(0.665)	(0.594)	(0.435)
Land_surface	-5.16e-09									
	(5.04e-09)									
Productivity	0.734**	0.830**	0.827**	0.839**	0.801**	0.860**	0.835**	0.799**	0.819**	0.714**
	(0.321)	(0.322)	(0.324)	(0.323)	(0.339)	(0.316)	(0.328)	(0.335)	(0.324)	(0.299)
Biodiesel	0.00569	0.247	0.177	0.293	0.200	0.402	0.264	0.419	0.288	0.496
	(0.220)	(0.308)	(0.277)	(0.289)	(0.258)	(0.329)	(0.317)	(0.321)	(0.318)	(0.318)
Biodiesel_bioethanol	-0.422	0.275	0.224	0.290	0.313	-0.148	0.246	0.307	0.214	0.503
	(0.403)	(0.467)	(0.495)	(0.473)	(0.503)	(0.353)	(0.468)	(0.503)	(0.462)	(0.478)
HH_rural_urban										-0.108
										(0.398)
HH_rural										0.626
										(0.385)
HH_poor_rich										0.395
										(0.243)
HH_poor										0.170**
										(0.0616)
Constant	-360.4	-1.128	-1.135	79.12	-1.263	-2.334***	-0.644	-1.089	-0.296	-1.605*
	(349.1)	(0.704)	(0.707)	(158.5)	(0.846)	(0.660)	(0.820)	(0.672)	(0.653)	(0.925)
Observations	255	255	255	255	255	255	255	255	255	255
R-squared	0.472	0.228	0.251	0.230	0.235	0.342	0.236	0.265	0.256	0.291

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 5. MLE for *GDP*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	0.190			0.186					
	(0.205)			(0.163)					
Time_estimation	0.0212**	0.0217**	0.0212**	0.0213**	0.0217**	0.0217**	0.0217**	0.0217**	0.0217**
	(0.00952)	(0.00963)	(0.00963)	(0.00962)	(0.00962)	(0.00963)	(0.00960)	(0.00958)	(0.00959)
Article	0.142				0.566				
	(0.725)				(0.610)				
Africa	0.334							0.0222	
	(0.344)							(0.275)	
Europe	-0.0490							-0.173	
	(0.164)							(0.144)	
Asia	0.131							-0.138	
	(0.223)							(0.144)	
South_america	0.172							-0.121	
	(0.233)							(0.151)	
OECD	0.209						0.133		
	(0.263)						(0.0960)		
GDP_cap	2.35e-06								4.08e-06
	(7.23e-06)								(2.94e-06)
Multi_country	1.186					0.592			
	(1.478)					(1.494)			
Dynamic	0.374		0.186						
	(0.679)		(0.609)						
MIRAGE	1.252	0.112	-0.0779	0.225	0.291	0.584	0.178	-0.00688	0.188
	(1.567)	(0.816)	(0.808)	(0.803)	(0.826)	(1.440)	(0.809)	(0.846)	(0.812)
Model_other	2.275	1.248*	1.293*	1.319*	1.181	1.719	1.319*	1.267*	1.327*

	(1.391)	(0.749)	(0.742)	(0.734)	(0.741)	(1.402)	(0.743)	(0.757)	(0.746)
Armington	0.512		0.909						
	(0.907)		(0.775)						
Land	-0.171	-0.284	-0.292	-0.237	-0.249	-0.287	-0.275	-0.288	-0.269
	(0.403)	(0.382)	(0.379)	(0.381)	(0.382)	(0.382)	(0.380)	(0.382)	(0.380)
Land_surface	-5.05e-09								
	(9.28e-09)								
Productivity	0.352**	0.350**	0.351**	0.351**	0.343**	0.352**	0.346**	0.346**	0.344**
	(0.149)	(0.149)	(0.149)	(0.149)	(0.149)	(0.149)	(0.149)	(0.149)	(0.149)
Biodiesel	0.0313	0.0391	0.0297	0.0251	0.0437	0.0422	0.0417	0.0383	0.0424
	(0.238)	(0.238)	(0.238)	(0.238)	(0.238)	(0.238)	(0.237)	(0.237)	(0.237)
Biodiesel_bio ethanol	-0.273	-0.229	-0.245	-0.244	-0.222	-0.236	-0.224	-0.228	-0.223
	(0.273)	(0.272)	(0.273)	(0.272)	(0.272)	(0.273)	(0.271)	(0.271)	(0.271)
Constant	-383.8	-0.115	-0.860	-375.0	-0.461	-0.585	-0.204	-0.00975	-0.226
	(412.3)	(0.654)	(0.878)	(327.1)	(0.744)	(1.352)	(0.651)	(0.664)	(0.655)
Observations	227	227	227	227	227	227	227	227	227
Number of id_article	23	23	23	23	23	23	23	23	23

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 6. MLE for *INCOME*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year	0.394***			0.206						
	(0.146)			(0.155)						
Time_estimation	0.0619**	0.0546**	0.0522**	0.0534**	0.0553**	0.0557**	0.0547**	0.0536**	0.0552**	0.0540**
	(0.0249)	(0.0246)	(0.0248)	(0.0245)	(0.0246)	(0.0243)	(0.0247)	(0.0247)	(0.0247)	(0.0242)
Article	-0.400				0.564					
	(0.495)				(0.601)					
Africa	-0.878							0.526		
	(1.708)							(1.077)		
Europe	2.759**							1.157		
	(1.176)							(1.204)		
Asia	0.346							1.074		
	(1.594)							(0.960)		
South_america	-0.855							0.0611		
	(1.140)							(0.449)		
o.oecd	-									
GDP_cap	-3.00e-05								-5.49e-06	
	(3.36e-05)								(1.21e-05)	
Multi_country	3.570***					2.201**				
	(0.839)					(0.989)				
Dynamic	1.103**		0.408							
	(0.523)		(0.639)							
MIRAGE	3.989***	0.649	0.247	0.701	0.768	1.736	0.603	0.796	0.497	0.469
	(1.215)	(1.055)	(1.119)	(1.027)	(1.046)	(1.061)	(1.103)	(1.403)	(1.102)	(1.061)
Model_othe	2.969***	1.361	1.064	1.402	1.252	2.269**	1.311	1.077	1.201	1.297

r										
	(0.940)	(0.996)	(1.021)	(0.968)	(0.987)	(0.977)	(1.055)	(1.171)	(1.051)	(0.971)
Armington	-0.827		0.625							
	(0.924)		(0.800)							
Land	-0.0655	-0.351	-0.375	-0.261	-0.328	-0.355	-0.355	-0.395	-0.373	-0.400
	(0.421)	(0.390)	(0.392)	(0.391)	(0.388)	(0.376)	(0.391)	(0.408)	(0.393)	(0.381)
Land_surface	-8.21e-09									
	(6.78e-09)									
Productivity	0.730***	0.692***	0.693***	0.688***	0.690***	0.711***	0.693***	0.685***	0.695***	0.690***
	(0.127)	(0.129)	(0.129)	(0.129)	(0.129)	(0.129)	(0.129)	(0.129)	(0.129)	(0.126)
Biodiesel	-0.0379	0.0219	0.00999	0.0153	0.0152	0.0244	0.0217	0.0178	0.0212	0.0298
	(0.194)	(0.196)	(0.196)	(0.195)	(0.196)	(0.195)	(0.196)	(0.196)	(0.196)	(0.192)
Biodiesel_bioethanol	-0.342	-0.174	-0.187	-0.177	-0.179	-0.224	-0.175	-0.167	-0.177	-0.168
	(0.233)	(0.236)	(0.237)	(0.235)	(0.236)	(0.235)	(0.236)	(0.236)	(0.236)	(0.232)
OECD							-0.0607			
							(0.422)			
HH_rural_urban										-0.0116
										(0.279)
HH_rural										0.349***
										(0.122)
HH_poor_rich										-0.0363
										(0.286)
HH_poor										0.170
										(0.122)
Constant	-794.7***	-0.612	-0.890	-415.4	-0.890	-1.713*	-0.557	-1.182	-0.422	-0.566
	(293.6)	(0.953)	(1.004)	(312.1)	(0.983)	(0.983)	(1.027)	(1.100)	(1.037)	(1.046)
Observations	255	255	255	255	255	255	255	255	255	255

Number of id_article	22	22	22	22	22	22	22	22	22	22

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1