1. Introduction

Many authors have documented the complex relationship between energy and economic development. To date, no consensus has been reached regarding this so-called energy-development nexus which has mainly focused on evidencing a causal relationship between energy consumption and economic growth (see e.g. the review of Ozturk, 2010). Two avenues of research are still opened. One strand of the literature focuses on the demand aspects of energy consumption while the literature on energy transition (energy ladder) describes qualitative and quantitative changes in energy consumption and analyses how households switch from traditional to modern fuels (e.g., Leach, 1992 or van der Kroon et al. 2013). It also 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). Access to energy has also recently been targeted by global development policies. It was not a key component of the Millennium Development Goals, but in 2012 the United Nations "Sustainable Energy for All" Initiative (universal energy access, renewable energy, and energy efficiency) renewed the interest for initiatives to reduce energy poverty. In 2015, Sustainable Development Goal #7 (Ensure access to affordable, reliable, sustainable and modern energy for all) made room for energy initiatives in development policy objectives.

Biofuels are serious candidates for addressing global energy objectives. They received substantial attention in climate mitigation initiatives in the transport sector, and targets were reported by the Intended Nationally Determined Contributions (INDCs) to the UNFCCC[1] Secretariat: about 40% of INDCs submitted by countries in 2015 relied on biofuels (Gota et al., 2015). The use of biofuels might reshape several crucial issues such as energy security and climate mitigation as well as the development energy nexus, especially in developing countries.

Indeed, biofuel expansion can be seen as a means of transforming national dependence on biomass into an additional source of income and job generating activities, particularly in countries where poverty pervades. In addition, biofuel production may be a key element for energy security in countries that are net importers of energy. Moreover, since biofuel cropping uses atmospheric carbon dioxide, biofuels may contribute to mitigating greenhouse gas (GHG) emissions. Further environmental benefits may also be gained if biofuel expansion pushes up land values and incentivizes land upgrading.

However, more pessimistic views on the consequences of biofuel expansion have also been put forth. First, weak land governance is a pull factor of Foreign Direct Investments (FDIs) and is therefore reputed to contribute to 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-scale cultivation of biofuels (Toulmin, 2009). Second, demand for biofuel cropping may induce increases in agricultural feedstock prices (Rosegrant et al., 2008). Food security may be imperiled in countries where the food expenditure share of household income is high, such as in

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[1] United Nations Framework Convention on Climate Change.

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[2] and pointed out that biofuel production competes for land, which generates indirect land use changes and contributes to GHG emissions. In short, biofuel expansion is a much-debated issue that deserves further study in the literature. This paper contributes to the debate while focusing on the income generating effect of biofuel production.

Why concentrate on income generating effect of biofuel production? The main reason is that it has dramatic implications in developing countries especially those that need to jointly reach development objectives and manage environmental constraints. Biofuel policies have been endorsed by many countries. Several African countries have tried to implement attractive conditions for biofuel producers owing to their land abundance, for instance Tanzania and Mozambique (Amigun et al., 2011; Arndt et al., 2011). Land abundance 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 financial consequences of biofuel production? A recent upsurge in biofuel production makes it difficult to evaluate *ex post* the consequences of biofuel expansion on national and household incomes.[3] Simulation exercises and computable general equilibrium (CGE) modeling have attractive features as policy analysis tools and allow to focus on several key aspects of biofuel expansion. First, biofuel expansion is a worldwide phenomenon and CGE modeling allows to easily take international interdependencies into account. Second, at the national level, biofuel expansion cannot be studied in isolation from other sectors of national economies (Kretschmer and Peterson, 2010). In other words, CGE modeling allows for modeling a variety of feedback or indirect effects induced by biofuel policies.

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

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[2] This paper has been quoted more than 3,800 times as of September 2016.
[3] There are several exceptions. See for instance Andrade de Sá et al. (2013).

2. Meta-analysis

2.1. Definition of 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 includes dozens of studies which cannot be fully captured in a narrative survey. Therefore, conducting an MRA on the topic will complement narrative reviews and facilitate the understanding of factors that contribute to the different outcomes of existing studies. This approach also helps us to avoid the so-called "myth of the perfect study" which can be found in narrative reviews where researchers select studies based on idiosyncratic judgments (Hunter and Schmidt, 2004).

The usual way of checking the results obtained in any applied work is to perform robustness tests or sensitivity analyses such as running alternative estimators, using alternative measures of interest variables or varying the geographical coverage of the dataset in econometric studies. Robustness tests can also take the form of elaborating additional scenarios or changing key parameter values in CGE simulation exercises. Conducting an MRA can be considered more thorough than robustness tests, which relate only to the sets of hypotheses made in one study. MRAs are meta-robustness analyses in the sense that they are deemed to comprehensively collect the set of hypotheses used in the existing literature. While robustness analyses mainly allow for checking the sensitivity of results to a set of particular hypotheses, MRAs help to identify the hypotheses that drive the results and explain their heterogeneity (Nelson and Kennedy, 2008, p. 346).

An 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), and 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 modeling, although most MRAs are based on econometric studies.

Although our MRA is original, a large number of MRAs have been 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). These MRAs do not provide a clear-cut answer on the causality relationship 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). Still others explore fuel/gasoline consumption (price and income elasticities) (Espey, 1998; Goodwin et al., 2004; Havranek et al., 2012; Stern, 2009). Given the recent growth of the literature on renewable energies, there are fewer MRAs on this topic 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-term versus long-term

causality and differences according to the type of data and model specification. Soon and Ahmad (2015) analyze 18 studies estimating the willingness-to-pay for renewable energy use of households.

While most MRAs (like those on energy previously mentioned) gather information from studies using econometric estimations, we focus on studies based on general equilibrium modeling. Despite the rapid development of meta-analysis in economics, very few MRAs extract information from general equilibrium simulations. They cover different topics such as trade liberalization (Hess and von Cramon-Taubadel, 2008) or climate change policies (Barker et al., 2002; Branger and Quirion, 2014; Rose and Dormady, 2011). More closely related to our topic, Condon et al. (2015) conducted a meta-analysis of U.S. biofuel policy with a focus on the impact of 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 150 papers. We then applied inclusion and exclusion criteria to publications, e.g., those including only general equilibrium studies, having simulations of biofuels, and having a measure of household income or growth. A collection grid was then used to codify the information from each article. Two databases were created, one for the impact of biofuel on GDP growth and one for the impact on household income. Although most variables are common to the two databases, there are variables specific to each one. The last step in the construction of these databases was the processing of the data, coding and labelling the variables, and searching and correcting errors in entries.

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 biofuel expansion on economic development: *GDP* is the variation of the GDP growth rate (percentage points); *INCOME* is the variation of household income growth rate (percentage points).[4] Each simulation generates a welfare variation for a single or multiple regions. An ES is the welfare change for one individual country.[5] 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 recommended 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, countries, models and scenarios (Table 2).

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

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

Table 2. List of moderators

Variable	Description
Publication characteristics	
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
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
Biofuel type	
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

Variable	GPD (N=227)				INCOME (N=255)			
	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

Publication characteristics

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 in 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

GDP   *INCOME*
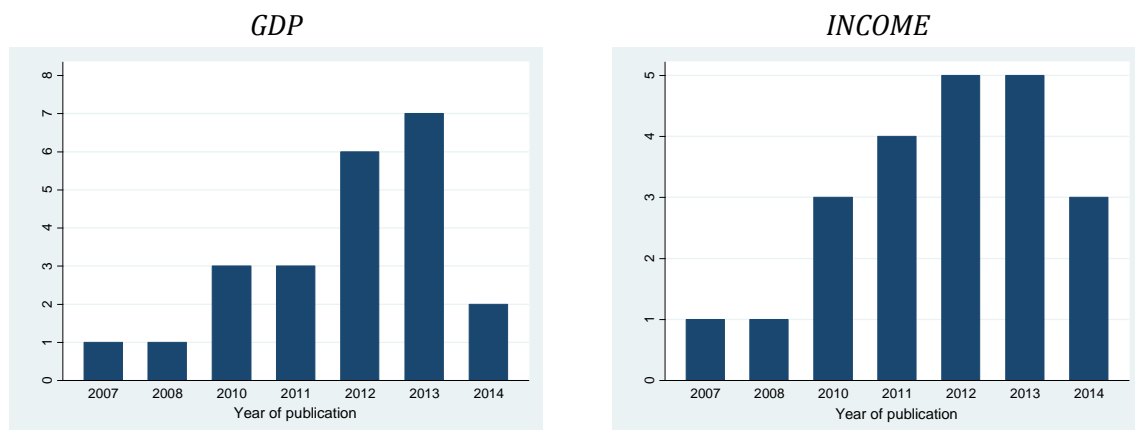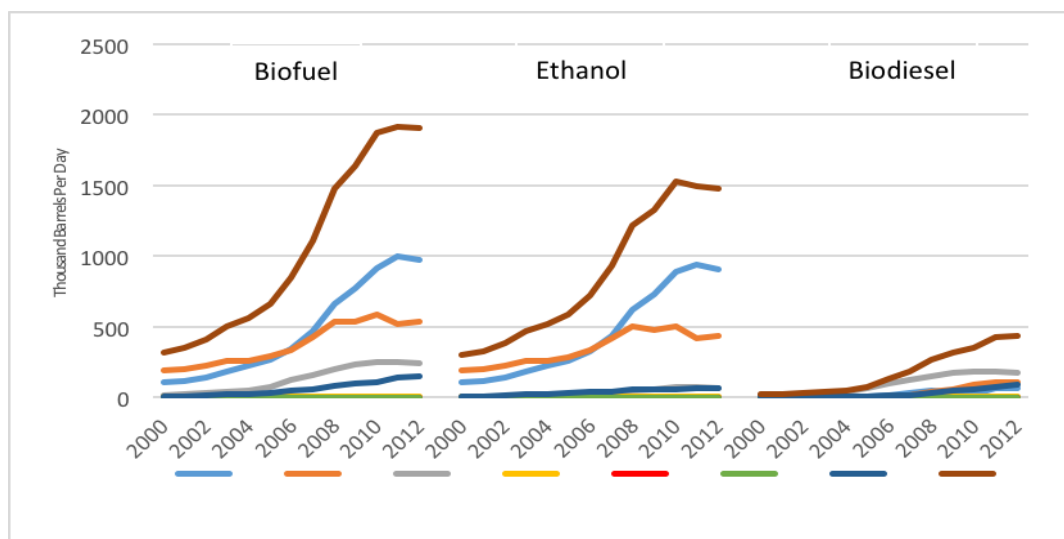

Figure 2. Evolution of biofuel production in the world (2000-2012)

Source: International Energy Statistics of the U.S. Energy Information Administration[6]

The evolution of ESs over time is shown in Figure 3. Their distribution illustrates the contrasting results on the impact of biofuels on development and poverty found in literature reviews (e.g., Ji and Long, 2016). Not only has the number of studies increased over time (and therefore the number of ESs) but also the interval of the values taken by the ESs. This may be explained by the following hypotheses: (i) As there are more studies, the likelihood of finding more varying results increases (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 ESs over time

GDP
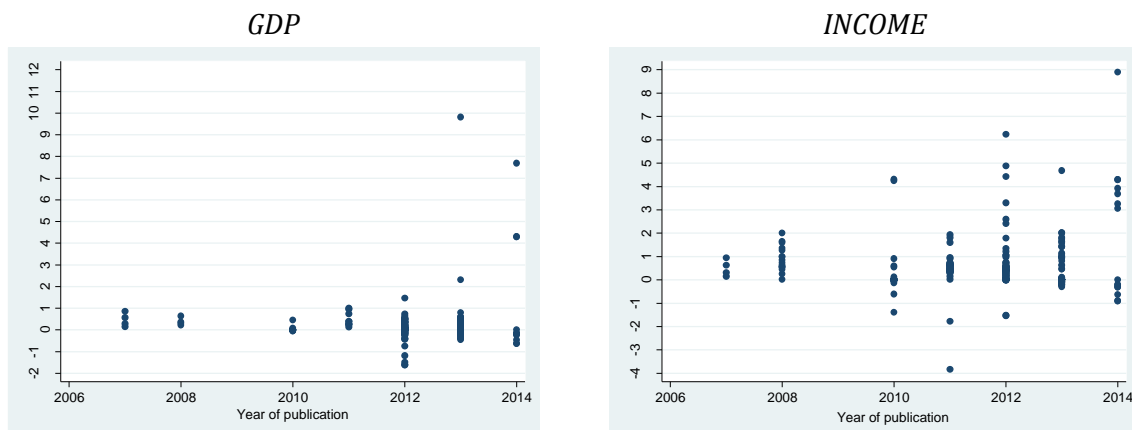
INCOME

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 in peer-reviewed articles will take more "conventional" values than ESs published in others formats 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 behavior 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 is located (ii) An *OECD* variable 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 household 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 have been partly stimulated by FDIs.

Model characteristics

CGE models can be 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 agents' 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 behavior is taken into account. Such a 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)[7] 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)[8] model is also a 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[9] (see Dixon and Jorgenson, 2013), ORANI (Dixon and Jorgenson, 2013), the TERM-BR (general equilibrium model of Brazil) model (Ferreira Filho, 2011), and the TIGER[10] (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 modeled as imperfect substitutes. Standard Armington elasticities in GTAP models are low compared to other models. Simulations on 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 through 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, may lead researchers to ignore effects and feedback from other regions of the world and may therefore cause misleading interpretation of results (Dixon and Jorgenson, 2013). "Single-country GEs generally do not allow for endogenous capital inflows and they often assume fixed

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[7] https://www.gtap.agecon.purdue.edu/models/current.asp
[8] http://www.mirage-model.eu/
[9] MEGABARE model is developed by Australian Bureau of Agricultural and Resource Economics (Lee et al., 2007)
[10] "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.

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 than short-run ones. This reflects that long-run CGE models take into account increases in the scope of the world economy.

Scenario

Authors implement various scenarios in their simulations and extracting them was rather difficult. 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 in agricultural productivity or biofuel productivity (*Productivity*). In some instances, 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*).

Biofuel type

There are two 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 carry out a simulation on biodiesel, bioethanol or both.

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.

Household type

For the ES *INCOME*, we add a variable on household 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 $L \times 1$ 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 $K \times 1$ vector of meta-regression coefficients. ε is a $L \times 1$ 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 several ways, which are discussed in the literature (see Ringquist, 2013; Stanley and Doucouliagos, 2014a, 2014b, 2012). Stanley and Doucouliagos (2012, p. 122) advise using very simple econometric models and promote the use of Weighted Least Squares (WLS), 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 are 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 Annexes 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[11]	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[12]	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)						

[11] *North_america* is the variable of reference.
[12] *GTAP* is the variable of reference.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
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[13]	-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

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[13] *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_amer ica	-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_estim ation	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_count ry	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_othe r	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							

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(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 30-37% and 25-48% of the variance of ESs for GDP and INCOME, respectively.

We do not find a significant impact of the year of publication (*year*) or its type (*article*). 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 an effect is also found by Hess and von Cramon-Taubadel (2008) and 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 than 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 than 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 behavior is taken into account, which implies time-consistent behaviors.

When the scenario implies the expansion of land allocated to biofuels (*Land*), ESs for both GDP and INCOME models decrease. This suggests that competition for land with other agricultural crops is detrimental to welfare. Interestingly, most simulations with such scenarios 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 an emphasis on Sub Saharan African land endowments: uncultivated land availability in this region represents roughly half the world's endowments. However, Sub Saharan African land potential is concentrated in a few countries (Deininger and Byerlee 2011) and is subjected to highly heterogeneous agro-ecological conditions (Wicke et al. 2011).[14] Conversely, simulations containing a scenario with an increase in 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 food prices in developing countries than in developed ones (FAO, 2008). 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, 2008; Sorda et al., 2010). With such distortions, determining the real economic

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[14] 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 mixes 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, 2008) 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, 2008). 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 to look at the impact of biofuel production on economic growth and poverty. We focus on Computable General Equilibrium Studies. CGE modeling is a particularly relevant and interesting framework to investigate the impact of biofuels on various dimensions such as growth, poverty and 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 contrasting results notably because the results are sensitive to scenario parameters, modeling choices, data assumptions, etc. Our contribution is to precisely examine the impact of biofuel policies on growth and household income by considering model parameters in a meta-analysis framework.

Our quantitative meta-analysis is complementary to existing narrative surveys and confirms that results are sensitive to key hypotheses on essential parameters. Simulations on longer time periods and simulations in multi-countries lead to higher impacts of biofuel expansion on growth and household income. Moreover, simulations with a shock on 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, according to the literature, the impact of biofuel expansion appears to be positive on both growth and household welfare.

However, CGE models do not account for non-priced effects such as externalities. To get a comprehensive overview of the impact of biofuel expansion, this meta-analysis should be combined with models that assess the environmental and social sustainability of biofuels as they both offer advantages and risks. See FAO (2008) for a thorough review of these environmental and social challenges. One way forward might consist in better integrating damage functions into CGE models. This is done, for instance, in long-term growth models that assess the social benefits of greenhouse gases abatement, following the pioneering work of Nordhaus (1991). Crucial hypotheses pertaining to the convexity of the damage functions induce substantial variations in the social outcome (see, for example, e.g., the analysis of Dietz and Stern (2015).

Several questions were answered through this meta-analysis but other interesting research avenues remain. One crucial question that prevails involves 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 addressing the question of which environmental consequences of biofuel expansion are the most critical. Furthermore, on the methodological side, MRAs that use 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. Finally, as raised by Hess and von Cramon-Taubadel (2008), the results of CGE models are a "complex function of the many factors…[]…and of interactions between them". It is not possible to code all characteristics of publications given the enormous amount of data and computation needed to run a CGE and the fact that not all of the information needed for a CGE is provided in published 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)	1 (Arndt et al., 2008)
2 (Arndt et al., 2011)	2 (Arndt et al., 2011)
3 (Arndt et al., 2012)	3 (Arndt et al., 2012)
4 (Boccanfuso et al., 2013)	4 (Boccanfuso et al., 2013)
5 (Cabral et al., 2012)	5 (Branca et al., 2014)
6 (Cansino et al., 2013)	6 (Cabral et al., 2012)
7 (Cororaton and Timilsina, 2012)	7 (Cansino et al., 2013)
8 (de Souza Ferreira Filho, 2011)	8 (de Souza Ferreira Filho, 2011)
9 (Doumax et al., 2014)	9 (Doumax et al., 2014)
10 (Ferede et al., 2013)	10 (Ge and Lei, 2010)
11 (Ge and Lei, 2010)	11 (Ge and Tokunaga, 2011)
12 (Gebreegziabher et al., 2013)	12 (Gebreegziabher et al., 2013)
13 (Gemechis, 2012)	13 (Gemechis, 2012)
14 (Gunatilake et al., 2011)	14 (Gunatilake et al., 2011)
15 (Gunatilake et al., 2014)	15 (Gunatilake et al., 2014)
16 (Huang, 2010)	16 (Huang et al., 2012)
17 (Lee et al., 2007)	17 (Huang, 2010)
18 (Oladosu and Kline, 2010)	18 (Lee et al., 2007)
19 (Oladosu and Kline, 2013)	19 (Oladosu and Kline, 2010)
20 (Timilsina et al., 2012)	20 (Timilsina et al., 2013)
21 (Timilsina et al., 2013)	21 (Wianwiwat and Asafu-Adjaye, 2012)
22 (Wianwiwat and Asafu-Adjaye, 2012)	22 (Wianwiwat and Asafu-Adjaye, 2013)
23 (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								

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(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_bioethanol	-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)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
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)						

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
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_bioethanol	-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_other	2.969***	1.361	1.064	1.402	1.252	2.269**	1.311	1.077	1.201	1.297
	(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)							

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
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