Renewable energy – new forces in global ethanol trade?

Petra B. Salamon, Ernst-Oliver von Ledebur, Kamal Elmahdi and Rainer Klepper
Federal Agricultural Research Centre – FAL-MA, Institute of Market Analysis and Agricultural Trade Policy
Bundesallee 50, 38116 Braunschweig, Germany, email: petra.salamon@fal.de or oliver.ledebur@fal.de,

Paper prepared for presentation at the 98th EAAE Seminar 'Marketing Dynamics within the Global Trading System: New Perspectives', Chania, Crete, Greece as in: 29 June – 2 July, 2006

Renewable energy – new forces in global ethanol trade?

Petra B. Salamon, Ernst-Oliver von Ledebur, Kamal Elmahdi and Rainer Klepper
Federal Agricultural Research Centre – FAL-MA, Institute of Market Analysis and Agricultural Trade Policy
Bundesallee 50, 38116 Braunschweig, Germany, email: petra.salamon@fal.de or oliver.ledebur@fal.de,

Abstract

The paper presents an extended gravity equation application for the global trade with ethanol. The background and different attempts for a theoretical foundation of the standard approach are discussed. The econometric work takes regional integration schemes into account, as well as the influence of the production factor agricultural land and the level of oil prices on the world market. Results indicate that global bilateral trade flows of ethanol can be explained by a set of comprehensive explanatory variables, including regional agreements and the price level of oil. From a global perspective the EU effect on trade flows is trade diverting as the regional agreement reduces the linkage to world markets and increases the intra-regional level of trade with ethanol. The analysis over time however indicates that the decoupling of the EU ethanol market from the world market is decreasing, potentially reflecting demand increases within the EU.

Keywords: gravity equation, bilateral trade flows, trade with renewable energy, biofuels, and econometric estimation

Introduction

The actual significance of biofuels in the discussion around alternative sustainable energy sources is explained by several aspects, among them geopolitical, economic, and ecological reasons. Sharply increased crude oil prices and the insecurity about the short and long run supply of fossil fuels have propelled incentives for using alternative fuel sources, and encouraged research in this area. Continuously rising fossil oil demand has lead to a growing dependency on a relatively small number of fossil oil supply regions which themselves are recurrently affected by political instability, thus considered geopolitically at risk. On top, farmers' organisations notably in developed countries search for alternative uses and markets for agricultural products as a way to compensate for declining governmental support. Ethanol is basically produced by fermentation of the sugar present in the juice of sugarcane or sugar beet to alcohol. The fermented liquid is then distilled to extract the water content. If cereals are used, the available starch first has to be subject to an enzymatic process where the starch is broken down into sugars that can then be fermented to alcohol.

In this paper the world-wide market of ethanol is depicted and its trade relations is analysed with a special focus on biofuel usage. Especially, it aims to extract determinants of international trade flows allowing future trade potentials to be derived. Here a gravity approach is used to estimate econometrically the parameters. In the first section of the paper, as an example of policy measures implemented by Brazil, the first country with a major biofuel initiative and the EU are shortly discussed subsequently followed by a description of the global ethanol market. In the adjacent section the most important features of the gravity approach is sketched and applied to the ethanol trade. Results are discussed in the following section leading to conclusions concerning further trade potentials as well as to a qualification of the adopted approach.

Some policies to path the ways to biofuels

The most well known initiative to set-up a large scale biomass alternative to petroleum is the Brazilian Alcohol Programme (PROALCOOL) that started in 1975. The major aim of the programme was to reduce Brazil's oil import expenditures, since the country was strongly dependent on imported oil. A direct effect of the programme was the expansion of traditional demand for the domestic grown sugarcane. In 1979, with the second oil-shock, the government enlarged the programme. Several governmental investment support programmes were implemented in the 1980s leading to an ethanol production capacity of over 16 billion litres of ethanol per year. But changes in the macro economic conditions induced criticism as the Brazilian debt crisis in 1982 led to a shortage of public finances enhanced by declining international oil prices from 1986 on. Additionally, inconsistent ethanol supply and demand management led to serious market disruptions in the early 1990s and resulted in a deterioration of consumer credibility in ethanol fuel and a declining production of ethanol powered cars. The government undertook radical programme reforms over the 1997-1999 period. The only measure still available to the government is to set the anhydrous blend ratio for gasoline. With the current rise of oil prices, demand for ethanol increased again additionally supported by the development of the flex-engines running with any blend of ethanol and gasoline. Compositions may vary between pure gasoline and pure ethanol giving the consumer large freedom regarding the choice of the cheapest fuel.

But in most countries, the bioethanol and biodiesel production are more costly than fossil fuels. As a consequence, governments developed support measures such as tax concessions or production subsidies to encourage development and implementation of renewable biofuels. When facilitating biofuels crops at least varieties with potentially high productivity and longer term sustainable performance will be favoured. Actual policy design and measures implemented vary greatly but the policy design within the EU provides a good example how the aims are tried to be achieved. The so-called Biomass Action Plan of the EU Member States although obviously linked to the agricultural sector as supplier of renewable sources uses primarily fiscal and market policy instruments more related to the energy sector and the budgets. Within this concept, petrol stations and fuel distributors play a certain role as this distribution bottleneck of fuel is used to collect taxes on mineral oil providing an important source to national budgets. Most widely-used approaches supporting the biofuel market are the tax exemptions representing an indirect subsidy to the biofuel, and the governmental obligations to blend the mineral fuel with a defined share of biofuel. Thus, refineries are forced to buy biofuels inducing production or imports of the necessary agricultural goods.

Discussed, implemented and some already abandoned policy instruments of EU Member States include fuel tax exemptions and blending obligations for renewable agricultural energy sources. The first are subject to pure state control while the second is imposed by law on fuel distributors. Several Member States turned to or are discussing the implementation of biofuels obligations. France and Austria have already adopted the biofuels obligations, while in Slovenia it should be introduced in 2006 and in the Czech Republic and the Netherlands by 2007. Further discussions are taking place in the United Kingdom and Germany. Obligations provide a promising way to overcome national budget difficulties which will or are arising from tax exemptions and allowing for a cost-effective tracing of the Directive's[1] targets.

Beneath these general policies, basic elements of the Common Agricultural Policy (CAP) play an important role for the emerging markets of renewable energy. Starting with Agenda 2000 and amplified with the following Luxembourg Agreement, the implementation of the Single Farm Payments constituted an important reform step shifting the formerly coupled to a

[1] Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (OJ L 123, 17.5.2003).

decoupled support. Income support is no longer dependent on the amount of agricultural goods produced. Thus, farmers can freely respond to stimuli from the food, feed and also energy markets. Regarding renewable energy, the Luxemburg-Agreement introduced a special aid for energy crops. Furthermore, the use of mandatory set-aside land to grow non-food crops including energy crops has been maintained after the reform. Particular directives exist to rule support and use of renewable energy sources for heating, electricity and biofuel.

Domestic policy is supplemented by trade policy instruments with tariffs on ethanol already being reduced during the past years. Developments of EU import tariffs applied on ethanol imports can be found for some important countries, as shown in Table 1. Imports from important producing countries, like Brazil and the USA are subject to tariffs. Only the African, Caribbean and Pacific countries (ACP) are allowed to enter the EU tax-free but due to lacking production capacities, imports from these regions are not likely to raise in the short run. Additional 15% tariff reductions are granted on imports from developing countries since the beginning of the year 2002. In the light of the negotiations within the World Trade Organization (WTO) the introduction of new or higher tariffs or non-tariff barriers on bioethanol seems to be impossible. Thus third country producers of biofuels might indirectly benefit from the tax exemption in Germany and other European countries as the overall demand increases and in succession prices also rise thus providing space for higher imports. Blend obligations for biofuel have similar impacts as the distributors are free to purchase biofuels from the cheapest suppliers as long as minimum technical standards are met.

Table 1: Ad valorem tariffs of selected countries

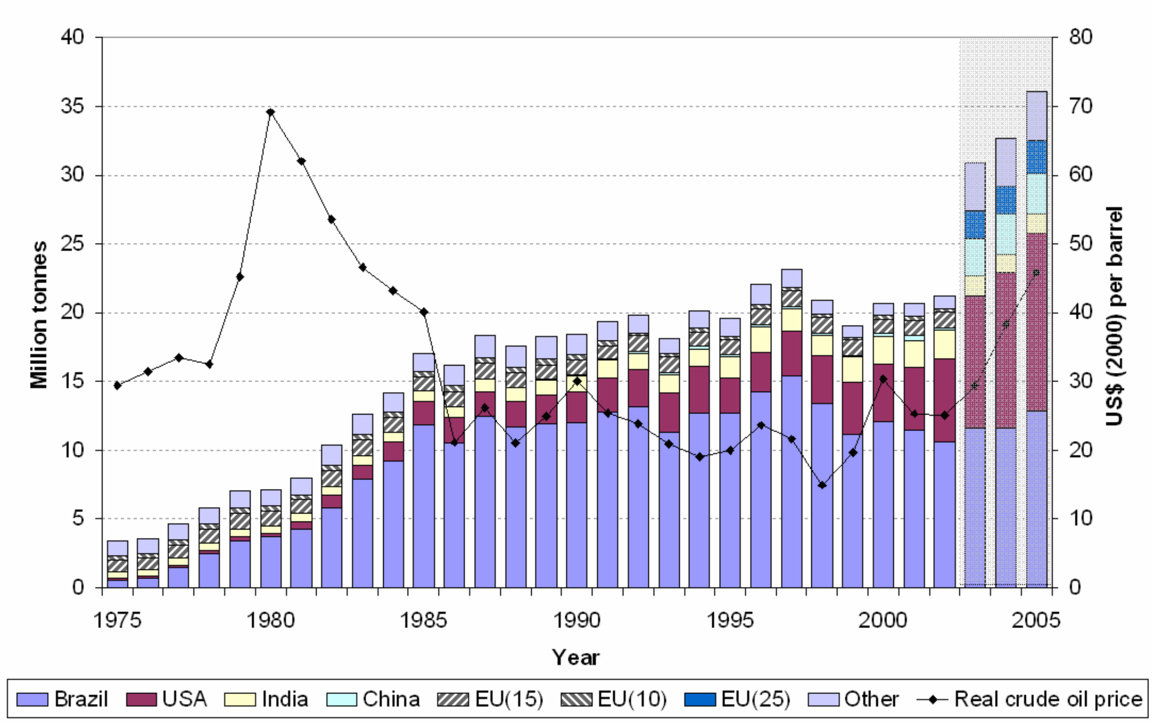
Destination	Source	1995/96	1996/97	1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	2003/04
EU	**Brazil**	65.83	40.16	49.71	53.65	46.67	0.00	0.00	0.00	0.00
EU	**USA**	41.95	40.16	49.71	53.65	46.67	0.00	0.00	0.00	0.00
USA	**Brazil**	2.60	2.80	15.75	17.67	3.08	8.05	11.30	13.65	3.75
USA	**EU**	6.27	2.65	9.02	0.00	3.08	4.97	6.60	7.77	3.75
USA	**Saudi Arabia**	9.95	2.80	15.75	17.67	4.25	8.05	11.30	13.65	5.60
Japan	**Brazil**	30.40	29.60	28.80	28.00	9.07	13.60	22.67	9.07	9.07
Japan	**USA**	30.40	29.60	28.80	28.00	18.13	20.40	22.67	18.13	18.13
Japan	**China**	30.40	29.60	28.80	28.00	9.07	13.60	18.13	9.07	9.07
India	**EU**	144.50	137.50	N.A	N.A	113.25	122.50	106.00	N.A	N.A
India	**USA**	144.50	137.50	N.A	N.A	113.25	122.50	182.00	N.A	N.A

Global ethanol market

Production of ethanol, formerly produced mainly for pharmaceutical industries requirements and some specific technical uses, has seen a rise following increased crude oil prices in the mid-1970s before slowing down in the mid-1980s. Ethanol production used to be dominated by Brazil, started to rise again particularly in the US, but in other regions as well (Figure 1). More recently, with the increase in oil prices in combination with the reform of the sugar market organisation of the EU, new ethanol production plants have been constructed in a number of countries; many of them are developing ones.

In the past, the ethanol world market was characterised by an uncertain supply situation in the Brazilian market, the largest producer that in some years appears as supplier and in others as demander. Table 2 reveals that the USA is the major ethanol importer during the period 1985-2004, followed by Japan, Germany and India. Among the top 20 ethanol importing countries, the United Kingdom and Sweden appear as importers only in 1995. All top 20 importers listed in 2004 show increasing imports but also reflect some variations.

Figure 1: World non-food alcohol production, 1975-2005



Source: OECD (2006) Production data for 1975 to 2002 are from FAOSTAT 2005; production data from 2003 to 2005 are from F.O. Licht (2005). Crude oil prices are from the Aglink data base.

Note that the two sources for ethanol production are not directly comparable. For 2001 and 2002, F.O. Licht reported global ethanol production 19% and 27% higher than FAO data, respectively.

Table 2: Main ethanol importers, trade value in US$ ´000 (1985-2004)

Importers	**1985**	**1990**	**1995**	**2000**	**2004**
USA	160 470 976	90 840 993	187 228 112	178 181 073	300 445 986
Japan	78 179 520	129 007 835	190 373 440	143 150 848	156 480 198
Germany	23 712 000	50 411 000	111 972 000	74 424 888	146 041 000
India	6 413 903	152 544	1 364 889	149 465	115 559 684
Belgium	20 912 940	47 418 876	98 592 448	68 020 288	89 966 013
Canada	22 653	1 271 247	7 966 384	36 482 127	73 323 541
United Kingdom	0	0	51 962 604	31 431 222	70 973 738
Italy	16 050 320	26 740 692	21 732 442	24 615 142	69 859 838
Rep. of Korea	8 923 767	26 926 900	62 903 344	52 669 596	67 456 646
France	11 577 591	62 031 188	82 250 208	34 500 846	62 528 453
Mexico	0	4 024 218	22 212 000	51 015 196	53 521 660
Netherlands	13 669 127	28 254 912	52 966 444	29 739 902	50 913 240
Sweden	0	0	155 805	10 310 989	41 503 948
Spain	1 631 664	9 713 833	48 864 304	12 091 891	31 300 836
Aruba	0	0	0	102 116	25 493 242
Finland	1 933 105	7 374 675	6 347 717	3 302 240	25 352 676
Singapore	456 008	711 334	2 084 348	6 717 398	22 943 137
Denmark	10 223 275	12 131 260	14 687 290	11 077 777	19 366 915
Turkey	572	2 687 242	1 028 074	58 690	17 977 975
Austria	0	895 527	10 161 561	5 987 524	17 054 229

Remark: Sorted according to imports in the year 2004, intra-EU-trade included.-
Source: COMTRADE (2006).

Table 3 presents the main ethanol exporting countries. The figures indicate that countries like Brazil and France seemed to have identified the opportunities of the ethanol market and have occupied an important market segment. A closer look at the available data shows some erratic figures concerning the trade flows with huge fluctuations among years. However, it should be noted that the reliability of the export statistics is not that high, as the export data available from the COMTRADE database often differ significantly from data published by other sources e.g. F.O.Licht. Deviations can also be identified if import and export statistics are compared.

Table 3: Main ethanol exporters, trade value in US$ ´000 (1985-2004)

Exporters	1985	1990	1995	2000	2004
Brazil	94 577 200	7 406 859	106 920 040	34 807 592	497 814 399
France	54 717 520	170 653 040	250 856 768	144 568 599	208 328 241
USA	3 645 833	193 587 522	363 511 520	143 725 504	118 078 722
United Kingdom	0	0	14 412 317	70 022 887	100 881 327
South Africa	0	0	0	52 859 804	66 765 018
Germany	16 216 000	39 214 000	48 923 000	31 409 446	57 929 000
Netherlands	11 797 085	41 489 448	0	0	53 915 834
Spain	28 571 792	14 614 051	24 166 928	26 456 864	42 934 651
Italy	1 111 224	41 101 152	95 823 744	21 086 784	41 346 438
Belgium	1 368 975	9 343 963	45 224 848	15 198 089	38 613 134
China	241 588	8 424 690	17 364 715	42 549 137	32 998 972
Canada	0	3 213 691	219 003	22 190 717	25 693 359
Aruba	0	0	0	0	23 375 673
Pakistan	1 097 641	3 461 409	3 150 765	6 059 000	20 696 632
Argentina	16 502 196	33 170 362	17 800 794	21 783 518	16 027 043
Australia	0	1 804 947	10 806 240	11 194 813	15 919 003
Bolivia	64 199	1 152 524	3 642 092	3 861 733	12 669 518
El Salvador	0	1 143 053	3 031 268	6 495 677	9 923 266
Indonesia	2 736 406	8 603 060	4 183 928	9 856 782	9 180 495
Ecuador	0	702 168	0	6 078 244	8 887 092

Remark: Sorted according to exports in the year 2004, intra-EU-trade included.-
Source: COMTRADE (2006).

The gravity model approach

For an ex post analysis of the dynamics in the global ethanol trade, a descriptive gravity model is implemented.[2] It owes its name to the analogy known from classical physics, the General Gravity law of Isaac Newton. The basic model equation of the gravity approach, to explain bilateral trade flows[3], proves that in principle the size of the flows between exporting country i and importing country j depends on different factors: the Gross Domestic Product (GDP) of the exporter and the importer, the population of the exporter and the importer, and the distance between both countries. Formally, the equation can be written as follows:

Equation 1 $$X_{ij} = \alpha_0 GDP_i^{\alpha_1} \left(\frac{GDP_i}{POP_i} \right)^{\alpha_3} GDP_j^{\alpha_2} \left(\frac{GDP_j}{POP_j} \right)^{\alpha_4} DIST_{ij}^{\alpha_5}$$

[2] "The gravity models are strictly descriptive." (LEAMER and LEVINSOHN, 1995:1387).

[3] This equation was proposed by LINNEMANN (1966) who called it trade-equation.

X_{ij} stands for the bilateral trade flow between the exporter (country i) and the importer (country j), *GDP* and *POP* stand respectively for the GDP and the population of the countries; *DIST* represents the distance between the considered countries.

Equation 1 can be rewritten as:

Equation 2 $$X_{ij} = \alpha_0 GDP_i^{(\alpha_1+\alpha_3)} POP_i^{-\alpha_3} GDP_j^{(\alpha_2+\alpha_4)} POP_j^{-\alpha_4} DIST_{ij}^{\alpha_5}$$

Or in a logarithmic form:

Equation 3 $$\ln X_{ij} = \ln \alpha_0 + (\alpha_1 + \alpha_3)\ln GDP_i - \alpha_3 \ln POP_i + (\alpha_2 + \alpha_4)\ln GDP_j - \alpha_4 \ln POP_j + \alpha_5 \ln DIST_{ij}$$

In line of studies conducted by authors like SAXONHOUSE (1989, 1993, 1995) and FRANKEL (1991, 1993, 1997), a modification of the Linnemann's trade equation more related to new trade theory can be found. Thereby, the variables capturing the economic size of the trade partners are considered as products in the equation. In the logarithmic form the gravity equation equals then:

Equation 4: $$\ln X_{ij} = \ln \beta_0 + \beta_1 \ln(GDP_i\ GDP_j) + \beta_2 \ln\left[\left(\frac{GDP_i}{POP_i}\right)\left(\frac{GDP_j}{POP_j}\right)\right] + \beta_3 \ln DIST_{ij}$$

There have been different attempts to find out the theoretical foundations of the gravity model.[4] An intuitive explanation is given by BALDWIN (1994). There the author resorts to a day-to-day case of a family and its purchasing habits. The family lives near two shopping centres and its purchasing patterns will be characterised as follows (BALDWIN, 1994: 82-3):

i. The richer the family is, the more it will purchase in both shopping centres.

ii. Besides the per capita income, the growing family size will lead to higher purchased quantity.

iii. In the same way, the shopping centre which is located next to the family will be preferred.

This explanation supports the assumptions of intra-industry trade model by KRUGMAN (HELPMAN and KRUGMAN, 1985). There it is assumed that trade rises with increasing income level and with growing preference diversity. A rich country will tend to compete strongly in the international division of labour and specialisation. From this model, an equation similar to the gravity equation is derived (BALDWIN, 1994: 83). LEAMER and LEVINSOHN (1995:1383) emphasized the arguments of LINDER (1961), whereby the intensity of trade between countries tends to increase, depending on the level and similarity of their per capita income as it is to be found in the specification of the gravity models. However, they reveal that tested results of the LINDER-Hypothesis have not been uniform and consistent. The synthetic formulation of the gravity equation 4 with symmetric terms multiplicatively linked, gives a proof concerning the development level of countries involved. On the one hand this supports the approach of LINDER, but on the other hand it also captures the unconsidered case of poor countries, which tend to trade more with rich countries than among each other (FRANKEL, 1997:58-61).

Nevertheless, within the foundation of the gravity approach also unsolved questions remain: If the gravity model is applied and the per capita income of the exporter as well as the distance is constant, the trade flow tends to increase with rising per capita income of the importer.

[4] "The equation has thus apparently gone from an embarrassing poverty of theoretical foundations to an embarrassment of riches!" (FRANKEL, 1997:53).

FRANKEL (1997:58-61) has already mentioned this question as a field for further research as the role of GDP per capita is not completely understood in the context of the gravity model. Thus approaches theoretically close to the LINDER's model and analogous to the HECKSCHER-OHLIN model can be employed. Generally these can be implemented for the trade in commodities, even if the assumption of product homogeneity does not hold[5]

The interpretations of the coefficients concerning the typical explanatory variables are normally as follows: GDP is interpreted as production potential of the exporting country (i) and as a purchasing power as well as degree of openness of the importing country (j) and it is expected that the estimated coefficients have a positive sign. If detailed trade flows are analysed the coefficient of the GDP variable displays a negative sign (see e.g. GRANT and HERTEL, 2005:31). Thus the interpretation of the GDP of exporting countries may also be that it reflects the purchasing power of the exporter and not so much production potentials. The population size (POP) is considered, in this specification form, as a proxy variable of the size of the respective country (WANG and WINTERS, 1991:3). The distance (DIST) between two countries, is considered, in all specification forms, as a proxy variable for trade related transaction costs. FRANKEL (1997:40-46) distinguishes three types of costs: physical shipping costs, costs arising from financing and costs occurring due to the unfamiliarity with the foreign market. So, for example, inadequate, inaccurate or uncertain market information as well as language burdens have certainly an inhibitory impact on trade.

A further group of explanatory variables deals with the trade influencing effects of trading blocs. In the gravity equation, the membership to a trading bloc is explained through a dummy variable. It has the value one if the exporting and the importing countries are members of the same trading bloc. For all other trade flows, the dummy variable is set to zero. In this case, the estimation equation is the following:

Equation 5
$$\ln X_{ij} = \ln\alpha_0 + \alpha_1 \ln GDP_i + \alpha_3 \ln\left(\frac{GDP_i}{POP_i}\right) + \alpha_2 \ln GDP_j + \alpha_4 \ln\left(\frac{GDP_j}{POP_j}\right) + \alpha_5 \ln DIST_{ij} + \alpha_6 ID .$$

In doing so, the dummy variable is thought to capture the effects of a set of trade policies common to the members of the same trading bloc and affect their intra-trade (trade creation).

The formal approaches except the one by DEARDORFF (1998), are based on the assumption of product differentiation. That means imported products are differentiated according to their origin (ARMINGTON, 1969a and 1969b). This assumption is used in market and trade models when the considered products are not perfectly substitutes (SADOULET and DE JANVRY, 1995:342-356; FRANCOIS and HALL, 1997:135-142). BERGSTRAND (1985) applied a CES utility function and the assumption of product differentiation based on origin (the Armington approach), in which different substitution elasticities between imports on the one hand and between imports and domestic products on the other hand are adopted, in order to derive a reduced form of the equilibrium of supply and demand on the basis of price indices of bilateral trade flows.

ANDERSON and VAN WINCOOP (2003) derive a gravity model that differs from others by including specific and ad-valorem tariffs and export subsidies as well as extending the non-economic factors by variables shared border, common language, and colonial relation.

[5] See in this context the analysis done by GOTO (1997) and KOO and KAREMERA (1991).

Introducing these formerly omitted variables allow capturing indirectly the so-called ‘multilateral resistance’ term which describes the country i's and country j’s resistance to trade (KUIPER, and VAN TONGEREN, 2006). They use exporter and importer fixed effects as proxies for this multilateral resistance terms. The inclusion of these fixed effects also allows asymmetric trade flows with symmetric trade barriers, allowing a better fit with the data.

Econometric estimation and data of an ethanol gravity model

Based on the fundamental specification of Equation 3, an econometric model of the world-wide ethanol trade is generated, following, in principle, the approach described in VON LEDEBUR (2001). In the analysis that carried out in this paper, different data sets and specifications are tested. The basic Equation 3 is extended as follows:

Equation 5:

$$\begin{aligned}\ln X_{ij} &= \alpha_0 + \alpha_1 \ln GDP_i + \alpha_3 \ln\left(\frac{GDP_i}{POP_i}\right)\\ &+ \alpha_2 \ln GDP_j + \alpha_4 \ln\left(\frac{GDP_j}{POP_j}\right) + \alpha_5 \ln DIST_{ij}\\ &+ \alpha_6 \ln(Area_i) + \alpha_7 \ln(Area_j) + \alpha_8 (ID)\\ &+ \alpha_{10}(JD_T) + ... + \alpha_{T+n}(JD_{T+n}).\end{aligned}$$

Although the proxy for transaction costs namely the distance DIST between partners is included in the implemented specifications, the often used indicators for common language, shared land borders, colonial heritage, or landlocked countries are neglected here due to limited data availability and inter-correlation of the variables. Because in this paper a special focus is given to trade in ethanol as one example of biofuels, the land availability could additionally affect trade by the potential to produce the necessary primaries. Thus two variables comprising agricultural area of the importing country ($Area_i$) and those of the exporting country ($Area_j$) are introduced in the specification.

Further extensions of the standard approach are the introduction of regional trade agreements (RTA) in the model by a particular dummy (ID) to capture trade creation (dummy_inRTA) and trade diversion effects (dummy_exRTA) of regional trade agreements. In this context only the EU, NAFTA, and MERCOSUR are regarded as relevant RTAs which are considered as the big players within the ethanol trade. The dummy variable dummy_inRTA_{ijt} equals one if countries i and j belong in a certain year t to the specific RTA regarded whereas the trade diversion dummy variable dummy_exRTA_{ijt} is introduced to estimate the extent by which trade is diverted from non-member sources in case of an RTA. These variables equal one if an RTA member imports from a third country and the year (t) is greater than or equal to the year when the agreement was signed.

For each year included in the estimation a time dummy is introduced to capture other time-dependent, trade-influencing factors. Since the regarded trade flows of ethanol are quite specific, they could not be compared to general trade or agricultural trade in total. Some other economic variables are introduced in the specification: One variable is thought to comprise price effects (PRICE) varying over time. To generate this price, unit values of the trade flows are calculated. Here, due to missing values, the number of observations is halved. Often prices are subject to trade interventions like tariffs so we also try to include applied tariffs in the specification. To capture the impact of energy prices on ethanol trade flows we introduce a price variable (OILPRICE) of crude oil prices using data from the BP (2005) in US dollars per barrel.

Based on these considerations, the implemented basic specification is as follows:

Equation 6: logX = f (logGDP, logGDP_E, logDistance, log_GDP/POP, log_GDP_E/POP_E,
dummy_inEU, dummy_exEU, dummy_inNAFTA, dummy_exNAFTA,
dummy_inMSUL, dummy_exMSUL, logAREA_E, TARIFF, PRICE,
OILPRICE)

The relevant data to estimate the gravity model is generated as described in the following section. The commodity trade data is maintained by the United Nations (www.un.org) in its COMTRADE data base, which includes bilateral annual trade data on a world-wide basis. The import data for ethyl alcohol (ethanol) are compiled for all trading countries according to the 5-digit SITC Revision 2 level for the period from 1974 to 2003 and the values are in US Dollars. Information on applied tariffs were collected using the World Integrated Trade Solution (WITS) (http://wits.worldbank.org) developed by the World Bank in collaboration with the United Nations Conference on Trade and Development (UNCTAD). For the period 1974-2003, applied import tariffs are compiled according to the SITC Revision 2 level for all trading countries. Data on population and GDP are obtained from the United Nations Statistics Division. GDP data as a proxy for national income are published at current prices in US Dollars. Agricultural area for each country is provided by the FAO (FAOSTAT, 2006) measured in 1000 ha. Distance between economic centers is obtained from the data base of the Centre d´Etudes Prospectives et d´Informations Internationales (CEPII) (www.cepii.fr). Because of the envisaged impacts of oil and sugar prices on ethanol trade flows, information on these prices are collected from BP (www.bp.com) and USDA (www.usda.gov), respectively. The data on crude oil prices are recorded at current US Dollars from 1970 to 2003 whereas sugar prices are obtained for the period 1980-2003.

In general, estimations are conducted using pooled data for the period from 1970 to 2004, but due to data availability the period is adjusted if necessary. Thereby the statistical package SAS (Version 9.1) is used as a software, whereas OLS estimators and a stepwise approach are applied. Finally, a further working hypothesis is that the behaviour of the trade flows might have changed over time, especially if the impact of the oil price on the trade flows is regarded it would only be traceable during periods in which the oil price outrun certain limits. Therefore the total pooled data are subdivided into 6 different time periods, covering, on average, five year periods (1974-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, and 2000-2004).

Results

The estimation results from different regression scenarios of the total pooled data are presented in Table 4 with the specifications for the global gravity equation for the period from 1975 to 2004 (Model 1). Here the whole data set is used, but in a second approach, the EU intra trade flows are excluded from the pooled data in order to suppress probable impacts of the EU intra trade on the parameters (Model 2). In the estimation process, variables are not included in the respective model if the considered parameters are insignificant or display behaviours that are inconsistent with economic theory.

In terms of the standard gravity approach, the variables size of importing economies (LOGGDP) as well as their income (LOGGDP_POP) are significant and show a positive sign in all cases. Estimates of variables concerning size and income of the respective exporting region are also significant, but display a negative sign as already found in other studies (e.g. GRANT and HERTEL, 2005). So the size of the economy might not so much reflect the production potential but the potential to find an outlet in the country, especially when the supply is limited and discontinuous like one harvest per year. However, the pull of the magnitude of the importing region is stronger than the retention of the exporting country. When the income per capita is regarded it is just the other way around. Comparing the income effect of the importing countries with that of the exporting one is much bigger in magnitude meaning that per capita income increases in exporting regions like Brazil will over-proportionally absorb ethanol quantities leaving limited space for exports. This might indicate that the distribution of ethanol is easiest within in the domestic regions with no trade barriers at all and non-existing other obstacles like insufficient infrastructure.

Table 4: Estimated parameters of the gravity approach for the ethanol trade, pooled data1975-2004

	Model 1 including EU intra trade	***Model 2 excluding EU intra trade***
Intercept	-1.50191**	-13.78432**
logGDP	0.43016**	0.46238**
logGDP_e	-0.15383**	-0.1131**
logDistance	-0.19773**	-0.17721**
Log_(GDP/POP)	0.03586**	0.01712**
Log_(GDPe/POP_e)	-0.0793**	-0.04606**
logPRICE		-0.69685**
logOILPRRICE		0.22686**
logAREA_e	0.05602**	0.01978**
dummy_inEU	1.05025**	
dummy_exEU	-0.28247**	0.01969**
dummy_inNAFTA	0.83964*	0.54269**
$R^2/\overline{R}^2$	0.2312/0.2306	0.3943/0.3941

** Significance at a level of 1%,
* Significance at a level of 10%
Source: Own calculations.

Model 1 covering the total pooled data set doesn't reflect a significant impact of own prices, oil prices and applied tariffs, so these additional variables are not included in the standard approach. Even though area to generate the primaries for ethanol might play a roll, in the estimates this is not always reflected. Especially the agricultural area of the importing regions is not significant and shows an unexpected sign whereas the area of exporting regions is significant and displays a positive sign, as expected. A feasible reason for this result can be the fact that the majority of importers do not produce regularly ethanol but import it thus changes in area do not have an impact on their demand and imports. Although the remaining variables display correct signs and are all significant, the R^2 of all estimations so far are quite low for gravity equations. However, this is typical for commodity specific estimations and in accordance with results of other estimations (see Grant and Hertel, 2005; GOTO, 1997; KOO and KAREMERA, 1991, and LEDEBUR, 2000). Furthermore, one has to keep in mind that the trade in ethanol is quite disaggregated as it is derived on a 6-digit-level of SITC-Rev.2 which is almost identical to the equivalent classification in HS-1992. At this detailed level the probability is much lower to compensate erratic movements or measurement errors in the trade figures as when it comes to trade flows on 2 or 4-digit-classification-level.

When the trading-bloc variables are depicted, most variables display significant impact. As estimation results of Model 1 illustrate, the creation of the NAFTA and the different accession rounds of the EU show positive and significant trade creation effects in the case of ethanol. Compared to the other coefficients of integration dummies, the parameter of the different EU enlargements is large and positive indicating the trade creation effect. In contrast, the variable dummy_exEU captures the negative impact of the trade diversion effect of the EU on the ethanol trade in third countries. A similar but less pronounced integration effect emerges concerning ethanol trade in the NAFTA region indicating an increase in trade among NAFTA members, resulting from the abolition or at least reductions of tariffs and other trade barriers between members. The correspondent dummy for the MERCOSUR displays no significant effect on intra-regional trade flows reflecting that at least in the case of ethanol there is no difference in the overall bilateral trade pattern.

When the estimation results of Model 2 (excluding EU intra trade) are compared to those of Model 1 (including EU intra trade), the parameters of the size variables show values within a similar range whereas the coefficients of the income variables are about half the size in the former equation, instead the PRICE and the OILPRICE variables become significant and display the expected sign which indicates that the enlargement process is probably masking the price effects.

Results for period pooled data are revealed in Table 5. While the parameter of the variable size of the importing economy remains at a comparable level, the impact of the same variable for exporting countries varies over time. With the exception of the period 1985-1989 in which the coefficient is much higher, the effect on the ethanol trade increases indicating that the domestic demand for ethanol in the producing countries become more important, which is not necessarily associated with the income level. But the same is true for the income variables.

Table5: Estimated parameters of the gravity approach for the ethanol trade, period pooled data excluding EU intra trade

	Model – 2000-2004	***Model – 1995-1999***	***Model – 1990-1994***	***Model – 1985-1989***	***Model – 1980-1984***	***Model – 1975-1979***
Intercept	-13.7843**	-15.1088**	-13.73233**	-14.87546**	-22.14089**	-16.4709**
logGDP	0.46238**	0.33372**	0.48404**	0.49184**	0.40268**	0.49891**
logGDP_E	-0.1131**	-0.1019**	-0.09344**	-0.17454**	-0.08925**	-0.03073
logDistance	-0.17721**	-0.02596	-0.21877**	-0.1918**	-0.15669*	-0.09108
Log_(GDP/POP)	0.01712	0.03069	0.00667	0.05572*	0.02645	0.03082
Log_(GDP_E/POP_E)	-0.04606**	-0.02152**	-0.02523*	-0.00549	-0.06004**	-0.03082
logAREA_E	0.01978	0.01542	-0.00803	-0.02366	-0.07864*	-0.15309*
logPRICE	-0.69685**	-0.8686**	-0.88617**	-0.88692**	-0.82673**	-0.57107*
logOILPRICE	0.22686	0.33914	-0.83885*	-0.18759	2.46253**	0.67944*
dummy_exEU	0.01969	0.55687**	-0.39705**	-0.59908**	-0.44947	-0.43579*
dummy_inNAFTA	0.54269	0.64661	0.32259	0.85184	1.78123*	1.16407
$R^2/\bar{R}^2$	0.38/0.38	0.40/0.40	0.43/0.43	0.50/0.50	0.40/0.39	0.31/0.30
Observations	7072	5055	3465	2307	1730	846

** Significance at a level of 1%,
* Significance at a level of 10%
Source: Own calculations.

In contrast to the estimation of the totally pooled data set, the effect of agricultural area (logAREA_E) is not statistically significant or shows the wrong sign. Although the most up-to-date periods indicate at least a positive impact so this production factor may increasingly shapes the export potential. In all time periods, the trade flows react according to prices, whereas the effect is always significant and vary only within limits between periods. The impact of the OILPRICE on the international ethanol trade is less consistent than the PRICE variable. During most periods, there exists a positive impact of the OILPRICE variable on the ethanol trade with the exception of the periods 1985-1990 and 1991-1995, although not all coefficients are positive. The highest parameter is to be regarded in the period 1980-1984 characterized by a very marked peak in the OILPRICE due to an oil crisis. The growing number of usable observations for the estimations as well as declining negative values of the intercept show that the intensity in global ethanol trade increased remarkably during the last 30 years. The relatively high R^2 is owed to the lower degree of variance in each sub-set used in the estimations.

The enlargement of the EU has in principle a trade diverting effect as the member states of a regional trade agreement intensify their internal trade because the trade barriers between these countries have been abolished or at least reduced, as shown in the estimation using the total pooled data on ethanol. However, if the period pooled data is analysed the effect is less clear cut. Here the analysis points to the fact that the decoupling of the European ethanol market from the world market is decreasing. When the period 1995-2000 is regarded there has been no EU enlargement round thus this dummy variable can be interpreted as the normal trade growth. The positive NAFTA effect indicates that there is an intense exchange due to the free-trade area, which could not be observed for the Mercosur countries.

Summary and conclusions

The aim of the paper is to analyse the main factors driving the bilateral trade in ethanol as one prominent example for bio-energy and to derive whether trade increases if ethanol as a renewable energy substitutes mineral-oil based fuel. In the paper, a gravity estimation of the bilateral trade flows of ethanol is presented in which a standard gravity approach that introduces the variable, namely the economy size (GDP), income of the importing and exporting countris (GDP/POP), distance between the regions, and extended by additional variables like agricultural area of exporter (AREA), price, oil price and different dummies to capture the effects of the trade agreements (EU, NAFTA and Mercosur). The estimations are conducted using the totally pooled trade data and period pooled trade data as well as data excluding EU intra trade. In the estimations most of the chosen variables are proved to be significant but the size of the economy variable displays a negative sign as to be found in other estimates. Not in all cases the price and oil price variables and the integration variables are significant and consistent with theory. Here inter-correlation may play a role. The degree of determination is quite low partly is explained by the fact that we investigate a very disaggregated commodity in which measurement errors and erratic movements do not counterbalance. Also the use of another estimator capturing zero trade values like in KUIPER and VAN TONGEREN (2006) may improve the results. Against expectations, the impact of the tariff variable is not significant. A result which could have been influenced by the fact that only applied tariffs are introduced in the estimation thus the combination of applied and bound tariffs could overcome the problem.

However, the following conclusions can be drawn:

- The trade in ethanol increases with the growing size and income of the importer.
- Within limits, the area availability becomes more important for future trade in ethanol.
- The price variables indicates that the price has an influence on the trade flows of disaggregated goods and that especially the trade in ethanol is driven by the oil price in periods of oil price peaks. Therefore if the oil price is high and increases that is expected to induce a further increase in the trade in ethanol as a renewable energy source.

- Trade creation and diversion effects of the EU and NAFTA are proved, but not in the case of Mercosur. It seems that the trade flows in the case of Brazil are more directed to developed countries and not so much to its neighbours. Furthermore, trade barriers between these countries have already been reduced before the formation of the Mercosur.

References

ANDERSON, J. E. AND E. V. WINCOOP (2003). "Gravity with Gravitas: A Solution to the Border Puzzle." The American Economic Review 93(1): 170-192.

ARMINGTON, Paul (1969a). *A Theory of Demand for Products Distinguished by Place of Production.* International Monetary Fund Staff Papers 16: 159-178.

ARMINGTON, Paul (1969b). *The Geographic Pattern of Trade and the Effects of Price Changes.* International Monetary Fund Staff Papers 16:179-199.

BALDWIN, Richard E. (1994). *Towards an Integrated Europe.* London, Centre for Economic Research, chapter 3.

BERGSTRAND, Jeffrey H. (1985). *The gravity equation in international trade: some microeconomic foundations and empirical evidence*, The Review of Economics and Statistics 67: 474-481.

BERGSTRAND, Jeffrey H. (1989). *The generalized gravity equation. Monopolistic competition and the factor-proportions theory in international trade.* The Review of Economics and Statistics 71:143-153.

BP - BRITISH Petroleum Company (2000) *Statistical Review of World Energy*, online in June 2005 (http://www.bp.com/statisticalreview 1861 - 2004)

Centre d´Etudes Prospectives et d´Informations Internationales – CEPII. In: internet home page : http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

DEARDORFF, Alan V. (1998). *Determinants of Bilateral Trade: Does Gravity Work in a Classical World?* In: FRANKEL, Jeffrey. (Hrsg.) *The Regionalization of the World Economy*. Chicago, Chicago University Press: 7-22.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS – FAO, FAOStat (last updated February 2006). In: internet home page: http://faostat.fao.org.

FRANCOIS, Joseph F. and HALL, H. Keith (1997). *Partial Equilibrium Modelling.* In: FRANCOIS, Joseph F. and REINERT, Kenneth A. (Hrsg.) *Applied methods for trade analysis: a handbook.* Cambridge, New York, Melbourne, Cambridge University Press.

FRANKEL, Jeffrey (1991). *Is a Yen Bloc forming in Pacific Asia?* In: BRIEN, R. (Hrsg.) "Finance and the international economy", Oxford University Press.

FRANKEL, Jeffrey (1993). *Is Japan Creating a Yen Block in East Asia and the Pacific?* In: FRANKEL, Jeffrey and KAHLER, Miles (Hrsg.) "Regionalism and rivalry: Japan and the United States in Pacific Asia" University of Chicago Press (A National Bureau of Economic Research conference report): 53-87.

FRANKEL, Jeffrey (1997). *Regional Trading Blocs in the World Economic System.* Washington, Institute for International Economics.

GRANT, Jason H. and HERTEL, THOMAS (2005) *Regionalism In World Agricultural Trade: Lessons From Gravity Model Estimation.* Paper prepared for presentation at the Global Economic Conference Lübeck, Germany, June 8-11, 2005

HELPMAN, Elhanan and KRUGMAN, Paul (1985). *Market Structure and Foreign Trade.* MIT Press, Cambridge.

HUANG, S. (1993). *Explaining East-West Trade Flows*. GIIS-Genf (Dissertation).

KOIZUMI, Tatsuji (2003) *The Brazilian ethanol programme: impacts on world ethanol and sugar markets*. Rome, FAO, Commodity And Trade Policy Research Working Papers.

KUIPER, MARIJKE and VAN TONGEREN FRANK (2006) *Using gravity to move Armington - An empirical approach to the small initial trade share problem in general equilibrium models.* Paper presented at the Ninth Annual Conference on Global Economic Analysis, June 15-17, 2006 in Addis Ababa, Ethiopia.

LEAMER, Edward E. and LEVINSOHN, James (1995). *International trade theory: the evidence.* In: GROSSMAN G. and ROGOFF, K. (1995) "Handbook of International Economics, Band III." Amsterdam, Elsevier Science: 1339-1394.

OECD (2006) *Agricultural Market Impacts of Future Growth in the Production of Biofuels*. Paris, OECD.

SADOULET, Elisabeth and de JANVRY, Alain (1995). *Quantitative Development Policy Analysis.* Baltimore, the Johns Hopkins University Press.

SAXONHOUSE, Gary R. (1989). *Differentiated Products, Economies of Scale and Access to the Japanese Market*, in: W. Cline (Hrsg.) "Trade Policies for International Competitiveness", Chicago, University of Chicago Press for National Bureau of Economic Research.

SAXONHOUSE, Gary R. (1993). *Pricing Strategies and Trading Blocs in East Asia.* In: FRANKEL, Jeffrey and KAHLER, Miles.(Hrsg.) (1993) "Regionalism and rivalry: Japan and the United States in Pacific Asia", Chicago, University of Chicago Press (A National Bureau of Economic Research conference report): 89-124.

SAXONHOUSE, Gary R.(1995). *Trading Blocks and East Asia.* In: de MELO, Jaime., PA-NAGARIYA, Arvind.(Hrsg.) (1995) "New dimensions in regional integration", Cambridge, New York, Melbourne, University of Cambridge Press: 51-54.

UNITED NATIONS COMMODITY TRADE STATISTICS DATABASE – UN COMTRADE. In: internet home page: http://unstats.un.org/unsd/comtrade/.

UNITED STATES DEPARTMENT OF AGRICULTURE – USDA. In: internet home page: www.usda.gov.

WANG, Zhen Kun and WINTERS, L. Alan (1991). *The Trading Potential of Eastern Europe.* London, Centre for Economic Policy Research, Discussion Paper 610.

WORLD INTEGRATED TRADE SOLUTION – WITS. In: internet home page: http://wits.worldbank.org.