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Abstract

The aim of this paper is to apply a gravity equation model in order to investigate if public support devoted to the biofuels sector has a negative impact on the technological path, by diverting public and private investments from other renewable energies and energy savings technologies. By using a gravity equation it is possible to investigate the role of distinct demand and supply policies for supporting biofuels on the export flows of the energy technologies different from those adopted in the biofuels sector. As export flows could be considered as a measure of the competition strength at the international level (in the form of comparative advantages), thus the gravity model allows understanding if support to biofuels has been depressing competitiveness of new energy technologies. At this purpose, several alternative policy variables have be tested to underline which policies have the major impacts on the technology path, separating fuel mandates, excise tax reductions and tariffs on import flows with data on bioethanol and biodiesel. A further complex policy variable has been calculated by aggregating all the policy instruments for bioethanol and biodiesel separately and more generally for biofuels. Results from first estimates clearly show that policies related to mandates and excise tax reductions for biodiesel are responsive for negative effects on comparative advantages mainly in the energy saving technologies sector. This confirms the research hypothesis, drawing some doubts on the win-win effects related to policies implemented by many industrialized economies, and particularly the EU, concerning biofuels production and consumption support. In order to reduce possible biases deriving from the induced technical change hypothesis when the energy sector is explored, a step ahead is represented by the formulation of a system of two equations estimated by using a two stages least squares estimator. In this way it is possible to control for endogenous technical change driven by energy price trends (that could be influenced by energy policy as well), while separating the net effects related to policy alternatives which have not direct effect in the market (and on energy price), as for instance the fuel mandates that artificially create a domestic market for biofuels without direct impacts on final energy price (at least in the short-medium term). The policy advice of this analysis is a strong warning on public policies which will be difficult to be removed in the future continuing to distort energy markets, rather than achieving competitiveness and security of energy supply. Recalling the Lisbon Strategy and the necessity to improve a European knowledge-based society, the current policy orientation in this specific sector seems to be hardly conflicting with a possible win-win outcome.

Keywords: Biofuels, Environmental Policy, Energy Sector, International Competitiveness.

J.E.L. classification: F18; H23; Q42; Q48; Q55; Q56

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1. Introduction

The last years have witnessed dramatic volatility in oil prices and growing concern about the consequences of carbon emissions from fossil fuels. The Energy, Transport and Environment Indicators published by Eurostat (2007), show that in 2005 the transport sector was responsible for about 31 per cent of total energy consumption in the European Union (EU27 members) and 19 per cent of total Greenhouse Gas (GHG) emissions. In the ten years between 1995 and 2005 there was a 21 per cent increase in energy consumption for transport, mainly driven by consumption for road transport, which represents the largest share (82%) of total transport consumption. Since crude oil accounts for 96 per cent of total energy consumption in the road sector, the 17 per cent increase in GHG emissions in this sector in 1995-2005 from transport is fully explained. This ten year trend shows that current European policies for sustainable energy are not adequate for this sector, which is highly dependent on fossil fuels, and that more effort is required on alternative energy sources.

There is growing interest in biofuels based on agricultural crops, worldwide, because they represent an inexhaustible energy source and could have a positive impact on reducing carbon dioxide (CO2) emissions. World biofuels production and consumption are characterized by pervasive and large subsidies, which has important implications for their environmental goals, in terms of their cost effectiveness. The huge increase in biofuels production is controversial in three major aspects: energy accounting; the conflict between energy and food production; the potentially distorting effect on innovation and technological specialization. While the first two aspects have been analysed extensively by academicians and international organizations (OECD 2005; Togkoz et al. 2007), the third has been less well examined.

As biofuels are just one of the alternative technologies currently available for addressing energy and environmental goals, the emphasis on biofuels support policies may be skewed in terms of technical progress in renewables and energy saving technologies. This chapter investigates whether public support for the biofuels sector is producing distortions in energy sector technological specialization by diverting public and private investments from other renewable energies and energy saving technologies.

We use a gravity equation model based on bilateral export flows of technologies for production and consumption of renewable energies (wind, solar and photovoltaic, fuel cells) and energy saving technologies. The model used is similar to that applied in other empirical studies that focus on the effects of environmental regulation on trade flows, but our application has two major advantages. It uses data for many countries and many years, whereas many empirical studies of innovation and adoption of environmental technologies focus on a single country, or on rather generally defined environmental policies. Also, in using a gravity equation, it enables investigation of the roles of distinct demand and supply policies supporting biofuels, on the export flows of technologies for renewable energy and energy saving. As export flows can be considered a measure of the strength of the competition at the international level (based on comparative advantage), use of the gravity model helps to reveal whether support for biofuels is depressing the competitiveness of new energy technologies. If the public policy to support biofuels is

diverting investments and reducing the competitiveness of energy saving and renewable energy technologies, this would imply a conflict among policy actions.
This problem could be particularly relevant in Europe, where the European Commission Energy Climate Action Plan or the '20-20-20 strategy, is combining several policy actions, such as a binding target for all EU member states of 20 per cent of energy consumption coming from renewables, and a minimum 10 per cent market share for biofuels by 2020. Also, the European Commission (EC) has declared a further effort - to improve energy efficiency in order to reduce energy consumption by 20 per cent, by 2020. The Action Plan states that the EU goal of saving 20 per cent in energy consumption by 2020 through energy efficiency is a crucial part of Europe's energy and climate policy, because it constitutes an important means of reducing CO2 emissions. In our view, this is a clear example of a set of multiple policies, setting conflicting goals and providing conflicting market signals to private investors.
Several alternative policy variables for public support to biofuels, such as separation of fuel mandates, and reductions in taxes and tariffs on import flows based on data on bioethanol and biodiesel, have been tested to underline the impact of policy on the international competitiveness of the technologies required to achieve the EU's ambitious energy and environmental policy targets.

2. Overview of Biofuels Sector: Production, Consumption and Policy Support

Due to the high dependence on energy and the need to reduce GHG emissions, biofuels for transport (e.g. ethanol and biodiesel) are attracting interest in many countries. Bioenergy is seen by many to play a key role in the short run in reducing GHG emissions; and biofuels are the only suitable substitute for fossil fuels in the transportation sector. Transport consumes 30 per cent of global energy, 99 per cent of which is supplied by petroleum, and is expected to account for about half of the total projected increase in global oil use in 2003-2030 (IEA 2007). Global production of biofuels amounted to 9.8 EJ (exajoules) in 2005, about 1 per cent of total fuel consumption in transportation, with production increasing at high rates with projected market shares pf around 13 per cent in 2050 (IEA 2007). This is based on response to market forces and is supported by government policy.
The major ethanol producers are the United States (US) with 24.6 billion litres in 2007, followed by Brazil with 19 billion litres: these two countries account for more than 87 per cent of world supply. Ethanol production is based on corn in the US and sugar cane in Brazil. EU Ethanol production is very limited (2.1 billion litres in 2007) but is growing and represent 18.5 per cent of EU biofuels production. The main member states producers are Spain, France, Germany, Sweden, plus Poland – one of the accession countries. The main feedstocks for EU ethanol production are cereals, corn and sugar beet. The EU is a leader in production of biodiesel, obtained mainly from rapeseed, sunflowers and soybean. EU biodiesel production amounted to 5.7 millions tons in 2007, half of which came from Germany. Biodiesel production is increasing in the US.

Biofuels production costs vary significantly across the main producing countries. Brazil has the highest competitive advantage for ethanol and is the only producer, based on the current state of technology, that can compete with fossil fuels. All other producing countries have to adopt some form of policy intervention.

Policy instruments for biofuels belong to the spheres of energy policy, environmental policy, agricultural policy and fiscal policy, depending on different interest in biofuels production and consumption. Policy instruments cover a fairly large set of support and regulatory measures that can be adopted at national, regional or local level. They fall into three main groups: measures that impact mainly on supply; measures that impact mainly on demand; measures that impact on technology and market developments.

Supply side policy measures currently provide most of the support for biofuels (GSI 2007), and are based mainly on tax exemptions or fuel tax rebates for gasoline and diesel, or volumetric tax credits, and border protection via tariffs. Other forms of supply side intervention comprise support for feedstock production and research and development (R&D) efforts. Comparison of world policy incentives for ethanol production is presented in Table 1.

Table 1 – Country comparison of support to ethanol production (cent $/l)

Country	Production incentive	Excise reduction	Import tariff	Reduced tariff
Australia	-	28,9	28,9	None
Brazil	-	30	-	MERCOSUR
Canada	Up to 16,4	15,1	4,3	NAFTA, CAFTA, CILE
EU	-	Up to 70,9	24,1	EFTA, GSP (excluding Brazil))
Switzerland	-	57,8	27,7	EFTA, GSP(excluding Brazil))
USA	13,5 + state incentive	Up to 8,4	2,2% + 14,3	NAFTA, CBI

Source: Steenblik (2007)

Most countries producing biofuels apply a most-favoured nation (MFN) tariff that adds at least 20 per cent to the cost of imported ethanol. Tariffs are lower in the case of biodiesel. The primary objective of border protection is to limit the benefits of direct support through fiscal policy, to domestic producers. Various exceptions to MFN tariffs and tariff-rate quotas apply to countries involved in free trade agreements.

Table 2 shows that tariff regimes vary by product and by country in determining the allocation of comparative advantage at world level.

In addition to border protection, most countries support domestic production of biofuels through favourable fiscal regimes that reduce the cost differentials with gasoline or diesel. In the US, reduced taxes for ethanol were introduced in 1978. In 200????, the Volumetric Ethanol Excise Tax Credit provides a fixed tax credit of $0.51per gallon of ethanol blended with motor gasoline (and $1.00 per gallon for biodiesel). The level of exemption does not adjust to changes in oil prices or additional state exemptions (Table 3).

The EU does not have a community level fiscal regime, but via the biofuels directive (EU 2003) authorizes member states to grant fuel tax reductions within certain limits. Tax rebates range from €0.10 to €0.65 per litre with an average of around €0.30 per litre, and they can be applied separately to bioethanol or biodiesel, or to generally defined biofuels. Some countries, such as France and Italy, have adopted a production quota system where tax rebates apply up to a given amount of production.

Table 2 – Applied tariffs on biofuels in representative countries as 1/1/2006

Country	Ethanol[(1)]		Vegetable oils[(2)]	
	Applied MFN[(3)]	Imports value (current US$ 000)	Applied MFN[(3)]	Import value (current US$ 000)
Australia	5.0	2,771	4.1	16,544
Canada	13.1	20,398	1.0	7,906
Japan	11.1	212,566	6.6	71,363
Switzerland	43.4	18,514	70.0	15,213
United States	13.5	345,708	1.8	33,884
European Union	54.7	197,705	2.1	1,831,554

Notes:

(1) Tariffs on ethanol corresponds to the Applied MFN (AHS in UNCTAD-Trains) for the code 220710 in the Harmonized Standard classification (HS 1996)

(1) Tariffs for vegetable oils are computed as an average of the tariffs corresponding to the codes 120500, 150710, 151110, 151211, 151410 (HS 1996) weighted by the relative imports values.

(3) Values expressed as ad valorem equivalent (%), calculated as a weighted average of tariffs. The values represent the real tariff applied to international imports (AHS in Trains database) and not the declared Most-favored nation tariff (MFN).

Source: UNCTAD-TRAINS database

Table 3 - Value of excise tax reduction at 1/1/2007 (€/lt)

Country	**Ethanol**	**Biodiesel**
Australia	0.23	0.23
Brazil	0.108	0.08
Canada (Federal)	0.066	0.264
EU		
Austria	0.015	0.028
Belgium	0.59	0.367
Check Republic		0.292
Denmark	0.03	0.03
France	0.37	0.37
Germany	0.65	0.47
Hungaria	0.10	0.34
Ireland	0.368	0.368
Italy	0.26	0.413
Lituania	0.25	0.25
Spain	0.42	0.29
Sweden	0.15	0.18
UK	0.32	0.32
Switzerland	0.45	0.47
USA	0.104	0.10-0.20

Source: GSI (2007).

Biofuels are based on agricultural crops and crop residues, whose costs of production range from 50 per cent of the total cost of production in the case of ethanol, up to 90 per cent for biodiesel. Thus, agricultural and agricultural products trade policies have little impact on biofuels economics. In the US, price support coupled with deficiency payments for agricultural products have substantially reduced the cost of biofuels feedstocks. Plus, in the US, up to 2006, specific direct support for biofuels was provided for in the Bioenergy Program. In the EU the biofuels sector receives support in the form of permission to grow biofuels crops on set-aside land and through the granting of direct area payment of €45 per ha to energy crops grown on other land.

Policies to increase demand for biofuels by substitution for fossil fuels include regulatory measures such as targets and mandatory requirements. While some of these do not discriminate among forms of biofuels, others specifically target ethanol and biodiesel.

Table 4 - Fuel target or mandate by country

	Fuel target or mandate	
Country	**Type**	**Quantity or blending share**
Australia	T	350 million liters by 2010
Canada	M	5% by 2010(ethanol)
		2% by 2012 (biodiesel)
EU	T	2% by 2005; 5.75% by 2010; 10% by 2020
Austria	M	2% by 2005; 5.75% by 2010; 10% by 2020
Belgium	T	2.5% by 2005, 5.75% by 2010
Czech republic	T	3.7% by 2005, 5.75% by 2010
Estonia	T	2% by 2005, 5.75% by 2010
Finland	M	2% by 2008, 4% by 2009, 5.75% by 2010
France	M	2% by 2005; 5.75% by 2010; 10% by 2020
Greece	T	0.7% by 2005, 5.75% by 2010
Hungary	T	0.6% by 2005, 5.75% by 2010
Ireland	T	0.06% by 2005 Ireland provides tax exemption within a quota
Italy	T	1% by 2005, 2.5% by 2010
Netherlands	M	2% by 2007, gradually rising to 5.75% by 2010
Latvia	T	2% by 2005, 5.75% by 2010
Lithuania	T	2% by 2005, 5.75% by 2010
Poland	T	0.5% by 2005, 5.75% by 2010
Portugal	T	2% by 2005, 5.75% by 2010
Slovakia	M	2% by 2006, 5.75% by 2010
Slovenia	M	1.2% by 2006, gradually rising to 5% by 2010
Spain	M	3.4% by 2009, rising to 5.83% by 2010
Sweden	T	3% by 2005, 5.75% by 2010
United Kingdom	M	2.5% by 2008, 3.75% by 2009, 5% by 2010
USA	M	2.78% by volume of gasoline consumption in 2006 (4 billion gallons, or 15 GL); 7.5 billion gallons (28 GL) by 2012

Source: GSI (2007). For EU countries with targets not already declared we have assigned an average value corresponding to the EU general target (i.e., Austria and Sweden).

The most significant mandates, mainly related to potential demand for biofuels, apply to the US and the EU although they are also in force in Brazil, China, India, South Africa and other countries. These kinds of measures are usually aimed at the medium term and are generally complemented by other measures designed to develop the biofuels market.

The US mandate was established within the Energy Bill in 2005 and is known as the renewable-fuel standard. It requires minimum consumption of biofuels from 11.9 million tons in 2006 to 22.1 million tons in 2012. The 2012 target level was almost achieved in 2007.

In the EU the EC Directive 2003/30 on biofuels fixed indicative targets of up to 2 per cent for 2005 and 5.75 per cent for 2010. The actual average blend rate was below 1 per cent in 2005, but nine member states have established mandatory blending requirements (see Table 4).

In Brazil support for ethanol production is provided mainly by market regulations, which impose a blending ratio for ethanol with gasoline of 20-25 per cent. There are other forms of incentives such as credit provision for ethanol storage and tax incentives for flex-fuel vehicles whose sales have increased dramatically since their introduction. In Brazil dual plants predominate in which production can be shifted easily from sugar to ethanol production, according to market conditions. Other policies specific to the biofuels sector provide support for distribution and use, support for capital investment and government action to support development and innovation. These forms of support are not considered in our model due to the difficulties this would introduce in terms of consistent data. Agricultural support through payments coupled to production or to land, or providing border protection through high tariffs for agricultural products, may be involved in the total account of support to feedstock production; however, they are also not considered here because they are not specific to final use of crops.

3. Environmental Regulation and Technological Competitiveness

Since the 1980s, many OECD countries have introduced alternative policy measures aimed at reducing the environmental impacts of economic activity. However, the effects of these policy actions on the economic system are difficult to predict, especially in terms of their effects on the pattern of technological progress.

Many empirical studies analyse the effects of environmental polices on innovation and competitiveness, using different hypotheses and empirical models. Although not exhaustive, two major strands of literature have emerged based on hypotheses that provide some useful insights: the pollution haven hypothesis, and the Porter and van der Linde hypothesis. These hypotheses are oriented towards investigation of the effects of environmental regulation on international competitiveness and, indirectly, on possible induced technical change. The pollution haven hypothesis states that the application of more lenient environmental regulation results in reduced production costs for manufactured good, which improves countries' abilities to export, but also increases domestic pollution emissions (Bommer 1999; Antweiler et al. 2001; Copeland and Taylor 2004). The Porter and van der Linde (1995) hypothesis adopts a quite different interpretation of the effects of environmental regulation on dynamic competitiveness theory, deriving from technological innovation linked to stringent environmental standards: the compliance costs related to the introduction of severe environmental regulations should stimulate a country to increase flows of green innovation and become a net exporter of environmental technologies.

Empirical studies investigating the pollution haven hypothesis do not find fully robust support for this argument (Ederington and Minier 2003; Harris et al. 2002; Jug and Mirza 2005; Levinson and Taylor 2004), while empirical findings for the Porter hypothesis are based mainly on specific industries (Albrecht 1998; Murty and Kumar 2003; Wagner 2003, 2006).

One reasons for these unsatisfactory results is the poor indicators for both regulation and environmental innovation (Jaffe et al. 2003, 2005; Jaffe and Palmer 1997; Jaffe, Peterson et al. 1995). However, the availability of data has increased since the beginning of the 2000s,which has sparked a revival in empirical studies of the existence of specific trade paths related to environmental regulation. In order to produce results valid for the whole economy, some of the more recent contributions have adopted gravity equation models, investigating both the pollution haven (Harris et al. 2002; Jug and Mirza 2005) and the Porter and van der Linde hypotheses (Costantini and Crespi 2008a,b; van Beers and van den Bergh 2003).

We adopt a similar analytical framework, following especially the original model provided in Costantini and Crespi's (2008a) study, which is based on 20 OECD countries for the period 1996-2006. We adopt this approach for two main reasons. The first is that public support policies for production and consumption of biofuels are very recent – since 2000. A gravity equation enables a wide dataset with a sufficient number of observations to provide statistical robustness to the covariates related to biofuels policies. Secondly, the ultimate aim of this chapter is to formulate some policy advice concerning the capacity of environmental policies (specifically for biofuels) to reinforce international competitiveness claimed by the recent revision to the Lisbon Agenda for the EU, in which sustainability goals are held up as examples of win-win policies, promoting environmental protection and economic development. If the effects of public support policies on biofuels are to divert investments and reduce the competitiveness of energy saving and renewable energy technologies, this could imply a noticeable conflict between policy actions, especially for the EU.

4. Empirical Model and Dataset

The empirical formulation of the gravity equation in this chapter is quite similar in structure to gravity equations used to analyse the impact on trade flows of environmental stringency.

The exporting countries in our analysis (the i countries in our gravity equation) are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the US. The sample for j importing countries includes 148 countries (including the OECD countries), and the time period analysed is 1996 to 2006.

The gravity equation analysed in a panel context is formulated as follows:

$$\text{ENEXP}_{ijt} = \alpha + \beta_1 \mathbf{GRAV}_{ijt} + \beta_2 \mathbf{ENV}_{ijt} + \beta_3 \mathbf{BIOF}_{it} + \varepsilon_{ij}$$

The dependent variable ENEXPijt is generated by the sum of the bilateral export flows from country i to country j at time t, of two different aggregations, all expressed in terms of 2000 constant US$ purchasing power parity (PPP) prices: technologies for renewable energies; technologies for energy saving. Export flow data are extracted from the United Nations Conference on Trade and Development (UNCTAD 2008) COMTRADE database, which is based on the Harmonized Commodity Description and Coding System (HS 1996). The typologies of technologies for renewable energies and energy efficiency, excluding technologies for the production of bio-energies, are defined by the OECD

(Steenblik 2005a, 2005b), based on the HS 1996 classification. The list proposed by OECD includes all processes and products with the principal purpose of environmental protection, in order to respond to the necessity of an internationally valid definition of environmental goods and services useful in World Trade Organization (WTO) negotiations. The exact definition of these kind of goods is functional to those partners requesting an early specific negotiation agreement, in order to obtain consistent tariff reductions. The sample in our analysis is restricted to technologies for the energy sector (Table 5); thus we merge the classification proposed by Steenblik (2005a,b) with a specific study on environmental technologies provided by the Italian Research Institute for New Technologies, Energy and the Environment (ENEA 2007). This methodological choice derives from the specific purpose of the analysis in this chapter to investigate the role of public support for biofuels on the export dynamics of renewable energies and energy saving technologies.

Table 5 - Technologies for renewable energies and energy savings, HS 1996

Code	Description
	Renewable energies
7321.13	Cooking appliances and plate warmers for solid fuel, iron or steel
7321.83	Non electrical domestic appliances for liquid fuel
8410.11	Of a power not exceeding 1,000kW
8410.12	Of a power exceeding 1,000 kW but not exceeding 10,000 kW
8410.13	Of a power exceeding 10,000 kW. 8410.90 – Parts including regulators
8410.90	Hydraulic turbines and water wheels; parts including regulators
8413.81	Pumps for liquids, whether fitted with a measuring device or not; [Wind turbine pump]
8419.11	Instantaneous gas water heaters
8419.19	Instantaneous or storage water heaters, non-electric — other [solar water heaters]
8502.31	Electric generating sets and rotary converters — Wind powered
8502.40	Electric generating sets and rotary converters [a generating set combining an electric generator and either a hydraulic turbine or a Sterling engine]
8541.40	Photosensitive semiconductor devices, including photovoltaic cells whether assembled in modules or made up into panels; light-emitting diodes
	Energy savings and management
3815.00	Catalysts
7008.00	Multiple-walled insulating units of glass
7019.90	Other glass fibre products
8404.20	Condensers for steam or other vapour power units
8409.99	Parts suitable for use solely or principally with the engines of HS 8407 or 8408; other
8418.69	Heat pumps
8419.50	Heat exchange units
8419.90	Parts for heat exchange equipment
8539.31	Fluorescent lamps, hot cathode
8543.19	Fuel cells
9028.10	Gas supply, production and calibrating metres
9028.20	Liquid supply, production and calibrating metres
9032.10	Thermostats

Source: ENEA (2007) and Steenblik (2005a, 2005b).

The variables we include as independent covariates are aggregated into five groups reported in Table 6. This choice is functional to the interpretation of the econometric results, which focus on different aspects of our framework to evaluate the role of the drivers considered here, both separately and together.

Table 6 – Definition of variables

Variable*	Definition	Source
	Dependent variables	
ENEXPijt	Total bilateral export flows in renewable energies and energy saving technologies (at constant 2000$ PPP) (HS definition Table A2) of countries *i* and *j*	UNCTAD-COMTRADE
	Standard gravity (GRAV)	
$GDP_{i,j,t}$	Natural logarithm of GDP (constant 2000 US$) of country *i* and *j*	World Bank WDI
$POP_{i,j,t}$	Natural logarithm of total population of country *i* and *j*	
$LAND_j$	Natural logarithm of land area of country *j* (sq. km)	
$GEODIST_{ij}$	Bilateral geographic distances (CEPII calculation, Mayer and Zignago, 2006)	CEPII
COL_{ij}	Existence of colonial relationships between country *i* and *j* (dummy variable)	
$CONT_{ij}$	Geographic contiguity between country *i* and *j* (dummy variable)	
	Environmental regulation (ENV)	
$CO2_{i,j,t}$	Natural logarithm of CO_2 emission (kg per 2000 PPP $ of GDP) of country *i* and *j*	World Bank WDI
$PACE_{it}$	Current environmental protection expenditure (public+industry) as % of GDP	OECD
$ENVTAX_{it}$	Revenues from environmental taxes as % of GDP	
$ENVREG_{it}$	Sum of environmental regulation policies $PACE_{it}+ENVTAX_{it}+ENVRD_{it}$ (%)	
	Support policies for biofuels (BIOF)	
$AHSBF_{it}$	Applied MFN tariff ad valorem for biofuels,[1] weighted with import flows (%)	UNCTAD-TRAINS
$AHSET_{it}$	Applied MFN tariff ad valorem for ethanol,[2] weighted with import flows (%)	
$AHSBD_{it}$	Applied MFN tariff ad valorem for biodiesel,[3] weighted with import flows (%)	
$MANDBF_{it}$	Fuel Mandate, targets of blending shares of total consumption (%)	GSI
$EXCBF_{it}$	Arithmetic mean of EXCET and EXCBD (US$ per litre of biofuels)	
$EXCET_{it}$	Value of excise tax reductions for Ethanol or ETBE (US$ per litre of pure ethanol equivalent)	
$EXCBD_{it}$	Value of excise tax reductions for Biodiesel or pure plant oil (US$ per litre of pure biodiesel equivalent)	
$TAXBF_{it}$	Arithmetic mean of TAXET and TAXBD (%)	
$TAXET_{it}$	Share of excise tax reduction for ethanol on total excise tax on gasoline (%)	
$TAXBD_{it}$	Share of excise tax reduction for biodiesel on total excise tax on diesel (%)	
$POLICYBF_{it}$	Arithmetic mean of AHSBF, MANDBF, and TAXBF (%)	

Notes:
(*) Symbols for the identification of countries and time period must be interpreted as follows:
ijt represents the bilateral interaction between exporting and importing countries with a temporal dimension.
ij represents the bilateral interaction between exporting and importing countries without a temporal dimension.

i,j,t represents the value of the variable for country i and j respectively, with a temporal dimension.
it represents the value of the variable for country i with a temporal dimension.
jt represents the value of the variable for country j with a temporal dimension.
(1) Average weighted tariff for codes (HS 1996): 2207.10 (Ethanol), 2905.11 (Methanol), 1205.00 (Rape or colza seeds, whether or not broken), 1507.10 (Crude oil, whether or not degummed), 1511.10 (Crude oil), 1512.11 (Crude oil), 1514.10 (Crude oil).
(2) Average weighted tariff for codes (HS 1996): 220710 (Ethanol), 290511 (Methanol).
(3) Average weighted tariffs for codes (HS 1996): 120500 (Rape or colza seeds, whether or not broken), 150710 (Crude oil, whether or not degummed), 151110 (Crude oil), 151211 (Crude oil), 151410 (Crude oil)

The first group (GRAV) collects the variables included in a standard gravity equation model, as income (GDP) and population (POP) for countries i and j (World Bank, 2009), bilateral geographic distance (GEODIST) between trading partners, following the calculations provided by CEPII (2006; Mayer and Zignago 2006), total land area as a dimensional variable (LAND), and two dummy variables explaining the existence of past colonial relationships (COL) and geographic contiguity (CONT)which take the value 1 if the two trading partners are neighbours.[1]

The second group refers to alternative measures of environmental regulation (ENV) represented by a set of indicators, in order to investigate more generally the role of regulation in environmental fields, as a driver of international competitive advantage, and to identify the different impacts related to alternative policy measures. The reason for the choice of these variables is explained in Costantini and Crespi (2008a) and OECD (2008); they represent the environmental protection expenditure attributable to the public and private sectors (PACE) as a percentage of GDP and the share of environmental tax revenues on GDP (ENVTAX). A synthetic measure of environmental regulation (ENVREG) is derived as the sum of the three environmental regulation policies previously described.[2]

In order to test our model accounting for the role of the environmental policies adopted in importing countries, we adopt an indirect measure of environmental stringency as the level of CO_2 emission (expressed as kg per unit of GDP at 2000 constant PPP international $). Since the developing countries (the majority of the 148 importing countries) are excluded from any commitment to the Kyoto Protocol, if they take action towards reducing CO_2 emissions per unit of GDP, their development strategies will be oriented towards energy savings and the adoption of renewable energies, which is an indirect indication that they are adopting environmental regulation.

The third group (BIOF) is related specifically to public support for the biofuels sector. As already mentioned, there is a vast range of public policies that are complementary or substitutes. Here, we consider some specific policy measures based on two criteria: that policy actions are implemented by the whole sample of exporting countries, thus reducing possible biases in the estimation results coming from lack of data; that policy

[1] In this chapter, we adopted simple distances as our distance measure, in which only one city is necessary to calculate international distances. Simple distances are calculated following the great circle formula, which uses latitudes and longitudes for the most important city (in terms of population) or the official capital of a country (Mayer and Zignago 2006).

[2] The two indices (PACE and ENVTAX) represent a sort of market-based instruments quantification in monetary terms.

measures are based on an easily identifiable start date. This results in three types of public support policies:

The first is calculated as tariffs imposed on international import flows of biofuels, split between ethanol and vegetable oils (raw material for biodiesel), derived from the UNCTAD-TRAINS database, expressed in terms of MFN applied duties in ad valorem equivalents. MFN applied tariffs are preferred to bound duties in terms of reducing the biases related to the possibility that bound tariffs for protected sectors are inflated to reap advantages in the WTO negotiations process.3 There are three variables involved, referring specifically to ethanol and vegetable oils (AHSET and AHSBD, respectively) and to biofuels in general (AHSBF). All tariffs are calculated as averages of the ad valorem equivalent weighted by the corresponding trade flow.

The second is fuel mandates (MANDBF) expressed as a percentage target relative to the corresponding specific fossil fuel (gasoline for ethanol, diesel for biodiesel). In this case we consider only one policy measure for all biofuels (expressed as a simple average of the mandates in the case of two separate targets) because the differences between ethanol and biodiesel are minimal.

The third is linked to excise tax reductions favouring bioethanol and biodiesel consumption. Here, we take the values of the tax reductions (US$ per litre) for ethanol (EXCET), biodiesel (EXCBD), and globally for biofuels (EXCBF). We compute the share of excise tax reduction on total excise tax for the two biofuels separately (TAXET and TAXBD), and generally for biofuels (TAXBF), to homogenize the unit values (percentage) of this specific policy action and others. Data for this policy measure and for fuel mandates are provided by the International Institute for Sustainable Development's Global Subsidies Initiative (GSI).

Lastly, we build a synthetic policy measure (POLICYBF) to assess more generally the impact of public support for biofuels on the competitive advantage of other clean energy technologies. Our variable is based on the arithmetic means of AHSBF, MANDBF and TAXBF, all expressed in percentage terms.

5. Empirical Results

As in previous empirical studies, the gravity equation model provides a good framework of analysis to test the effects of environmental policies in driving technological competitiveness in the energy sector. Table 7 reports the results for a standard gravity equation model augmented with environmental policy variables. In this analysis the market dimension of the exporting country seems to be a more incisive driver of export dynamics than the dimension of the receiving market. Also, the variables related to the proximity of trading countries play a significant role.

The results show that environmental regulation has an impact on renewable energy and energy saving technologies export flows. The coefficients associated to all the proxies for environmental stringency are statistically significant, and with the expected (positive)

[3] The so-called phenomenon of the water in tariffs corresponds to a wide range between bound duties (those declared to WTO) and applied duties (imposed on importing countries in international trade). For further details, see Bouët *et al.* (2008).

sign. For the sample including all countries, this confirms the results obtained in previous studies that consider measures of environmental regulation for European countries only (Costantini and Crespi 2008b).

Note that PACE and ENVTAX the variables representing market-oriented policy measures – show higher coefficient than the global environmental regulation measure (ENVREG). This confirms the increasing need for an investigation of the real effects of alternative environmental regulation policies on the market, which could constitute an interesting future research task.

Table 7 - The role of environmental regulation

Dependent variable	Exports of Renewable energies and Energy saving technologies (ENEXP)			
	CO2	PACE	ENVTAX	ENVREG
GDPj	0.012	0.056*	0.024	-0.007
	(0.38)	(1.84)	(0.78)	(-0.22)
GDPi	1.76***	1.47***	2.414***	2.24***
	(30.29)	(25.05)	(40.94)	(37.31)
POPj	-.103**	-0.11***	-0.099**	-0.100**
	(-2.35)	(-2.50)	(-2.31)	(-2.32)
POPi	-0.724***	-0.51***	-1.19***	-1.14***
	(-12.40)	(-8.77)	(-20.47)	(-19.12)
GEODIST	-1.530***	-1.55***	-1.437***	-1.52***
	(-74.52)	(-79.34)	(-73.46)	(-77.58)
COL	1.34***	1.50***	1.34***	1.42***
	(27.34)	(30.57)	(28.01)	(29.21)
CONT	-0.28***	-0.39***	-0.109	-0.294***
	(-3.61)	(-5.06)	(-1.44)	(-3.82)
LANDj	-0.553***	-0.55***	-0.55***	-0.556***
	(-23.09)	(-23.05)	(-23.71)	(-23.49)
CO2j	-0.11***	-0.135***	-0.127***	-0.110***
	(-2.65)	(-3.29)	(-3.13)	(-2.68)
CO2i	-0.317***			
	(-9.54)			
PACEi		0.523***		
		(22.87)		
ENVTAXi			0.550***	
			(37.13)	
ENVREGi				0.183***
				(25.75)
Adjusted R2	0.69	0.70	0.71	0.70
Obs	24569	24569	24569	24569

Statistics for t-Student in parenthesis. *** p-values < 0.01, ** p-values < 0.05, * p-values < 0.1.

After assessing the impact of environmental regulation generally, we introduce a number of variables into the analysis, for policy measures favouring the production and consumption of biofuels. The first three columns in Table 8 present the results of the models testing the impact on competition of biofuels tariffs for energy technologies

exports. The coefficients are negative and significant, suggesting a relevant influence of such policy measures on the direction of technological change in the energy sector.
This result holds when the share of excise tax reduction for biofuels is considered (Columns 4 to 6), since the values of the variables increase with the incentives for the production and consumption of biofuels. Finally we constructed and tested the influence of a synthetic variable related to policies for biofuels (POLICYBF) which considers tariffs, fuel mandate and excise tax reduction: this is significant and has the expected (negative) sign.

Table 8 - The role of policies for biofuels

Dependent variable	Exports of Renewable energies and Energy saving technologies (ENEXP)						
Biofuels policy	AHSBF	AHSET	AHSBD	TAXBF	TAXET	TAXBD	POLICYBF
GDPj	0.049*	0.053*	0.051*	0.113***	0.083***	0.075**	0.074**
	(1.59)	(1.73)	(1.65)	(3.65)	(2.73)	(2.42)	(2.43)
GDPi	1.515***	1.47***	1.641***	1.92***	1.94***	1.565***	1.82***
	(25.58)	(24.86)	(26.95)	(29.70)	(30.87)	(25.15)	(28.92)
POPj	-0.109***	-0.109***	-0.108***	-0.112***	-0.109***	-0.110***	-0.111***
	(-2.51)	(-2.50)	(-2.50)	(-2.59)	(-2.54)	(-2.54)	(-2.57)
POPi	-0.562***	-0.507***	-0.703***	-0.920***	-0.900***	-0.604***	-0.851***
	(-9.49)	(-8.62)	(-11.46)	(-14.48)	(-14.67)	(-9.74)	(-13.59)
GEODIST	-1.54***	-1.55***	-1.55***	-1.53***	-1.50***	-1.56***	-1.51***
	(-78.04)	(-76.64)	(-79.53)	(-78.85)	(-76.71)	(-79.49)	(-76.98)
COL	1.49***	1.49***	1.49***	1.48***	1.47***	1.49***	1.47***
	(30.46)	(30.45)	(30.40)	(30.30)	(30.27)	(30.52)	(30.19)
CONT	-0.371***	-0.388***	-0.381***	-0.364***	-0.325***	-0.394***	-0.334***
	(-4.81)	(-5.02)	(-4.95)	(-4.75)	(-4.25)	(-5.12)	(-4.35)
LANDj	-0.55***	-0.55***	-0.548***	-0.54***	-0.547***	-0.545***	-0.545***
	(-23.08)	(-23.08)	(-23.11)	(-22.98)	(-23.22)	(-22.97)	(-23.07)
CO2j	-0.130***	-0.135***	-0.134***	-0.180***	-0.163***	-0.149***	-0.152***
	(-3.17)	(-3.28)	(-3.27)	(-4.40)	(-4.00)	(-3.61)	(-3.72)
CO2i							
PACEi	0.518***	0.523***	0.538***	0.490***	0.517***	0.510***	0.494***
	(22.67)	(22.87)	(23.55)	(21.51)	(22.78)	(22.14)	(21.65)
AHSBFi	-0.002***						
	(-6.00)						
AHSETi		-0.001*					
		(-1.47)					
AHSBDi			-0.007***				
			(-10.41)				
TAXBFi				-0.008***			
				(-16.22)			
TAXETi					-0.007***		
					(-20.12)		
TAXBDi						-0.002***	
						(-4.44)	
POLICYBFi							-0.005***
							(-15.05)
Adj. R2	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Obs	24569	24395	24569	24569	24569	24569	24569

Statistics for t-Student in parenthesis. *** p-values < 0.01, ** p-values < 0.05, * p-values < 0.1.

6. Conclusions

The analysis in this chapter tested an empirical model based on a gravity equation, in order to provide evidence of the negative impact produced by public policies supporting the biofuels sector, on the export capacity of selected industrialized countries, for renewable energies (excluding biofuels) and energy saving technologies.

Our gravity equation model applied to a very specific definition of energy technologies, provides a clear indication that pervasive public policies can be detrimental to investment in and competitiveness of new energy technologies. While countries with stricter environmental standards show higher comparative advantage in the export markets for energy technologies, the introduction of specific public support for the biofuels sector is strongly negatively related to competitiveness internationally.

These results confirm our research hypothesis, which introduces some doubt about the win-win effects related to the policies being implemented by many industrialized economies, and particularly the EU, to support the diffusion of biofuels. The econometric estimates indicate clearly that technological specialization and export competitiveness in energy technologies can be affected by heavy subsidization of biofuels production and consumption.

The policy implications of this analysis are that the pervasive use of public policies, which may be difficult to remove in the future should be avoided: such policies may work to distort energy markets rather than to achieve competitiveness and security of energy supply.

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