The Harmonization of Technical Barriers to Trade, Innovation and Export Behavior: Theory with an application to EU data.

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Abstract

A key feature of the EU harmonization of technical barriers to trade (TBT's) is that exporting firms may entail a compliance costs. This paper provides theoretical and empirical work that examines the effect of such a fixed cost. In a two-country, three-stage model, the home and the foreign firm must incur an additional cost to sell to a third market but two asymmetries are present. The first asymmetry is that firms differ in their capacity of internalizing the spillover coming from the R&D activity. The second asymmetry is that for the home firm the domestic governement intervenes by providing R&D subsidies. From the welfare analysis, it is shown that a R&D subsidy is optimal only when the firm has a technological advantage over a potential rival in exploiting the spillovers deriving from R&D activity. Using a self-constructed database, which specifically identifies sectors where the EU has sought to introduce harmonized environmental regulations, we find evidence that support this prediction of the theory.

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1 Introduction

In recent years, there has been a growing interest in the extent to which technical barriers to trade (TBT's) may distort or restrict trade. TBT's can arise when exporters have to comply with requirements for, amongst other issues, health, safety, environmental and consumer protection that differ from those in the domestic market. The need to adapt product design, re-organize production systems, re-labeling costs and the costs of multiple testing and certification can entail additional fixed costs for suppliers of exported goods to a particular country. The removal of such TBT's due to differences in technical regulations amongst member states and accession countries is central to the Single Market Program (SMP).

EU policy oriented towards technical regulations and testing and certification requirements, deals with the harmonization of technical regulations amongst the member states.[1] Directives are then adopted which require member states to replace national regulations by harmonized procedures and standards. Once these regulations are adopted, this implies that each exporter still has to pay a fixed cost to adapt to the harmonized regulatory process. So a key feature of the harmonization of technical regulations that is stressed in this paper, is their effect on a fixed cost, which is entirely supported by the exporting firm. As a further example, environmental rules on recycling arrangements, emissions, use of renewable materials may incur a (one time) burden for exports as a result of the compliance with the harmonization of EU environmental regulations.

This paper provides theoretical and empirical work. We consider a two-country, three-stage model, in which a home firm competes against a foreign firm for exports to a third market. Furthermore, we address the issue of government intervention in supporting R&D activity. In the first stage home government can commit to an R&D subsidy; in the second stage the two firms decide

[1] For a more detailed analysis on the sources of the EU approach to eliminate technical barriers to trade, see Brenton, Sheehy and Vancauteren (2001)

upon the process innovation activity while in the third period they compete in quantities.

Our main assumption is that process R&D has a positive spillover effect in lowering the compliance cost. Moreover, two kinds of asymmetries are present. The first asymmetry is that firms differ in their capacity of internalizing the spillover that is generated from the R&D activity. Whether or not, one firm has a cost advantage in its compliance cost depends on the intensity of a positive R&D spillover. The intensity of a positive R&D spillover may have different degrees. It may well be so, that the type of R&D required for process development (cost-reducing R&D) may generate the advantage that firms have been able to develop configurations of equipment that can, with little modification, adapt to varying circumstances. Thus the need to completely redesign most of the productive process can be reduced and products can be manufactured easily without too much effort.[2] As an example, minor product modification and adaptation has been considerably eased with the use of CAD. Edquist and Jacobsson (1988) point out that CAD software embodies enough accumulated design and knowledge as to adapt product design to local market conditions, match raw material and component availability. The regulation of toxic substances in particular has been viewed as an industry where technological advancement has led to significant advances in preventing pollution (Ashford, 2002).

The second asymmetry considered in this model, is that for the home firm the domestic government intervenes by providing R&D subsidies. The role for the government is to provide direct support of R&D and incentives for innovation through providing an appropriate subsidy to stimulate a favorable climate for engaging in R&D activities.

[2] It may well be so, that some degree of re-configuration of the production process may not be so easily implemented for more complex machinery that entails a lot of process innovation R&D. An example might be, the development of sophisticated robots or microelectronics that have created complex advancement in the industrial automation of industries. We ignore this effect. Thus the externality of R&D only interacts positively with the fixed cost of adaptability.

To check the empirical relevance of our model, we consider two hypotheses that need a further econometric investigation:

(1) R&D spillovers have a positive impact on a country's export performance while the compliance cost with EU harmonized regulations has a dampening effect.

(2) government subsidized R&D is complementary to a firm's R&D.

To test the first hypothesis, we use the gravity model of international trade flows between 14 EU countries and 6 CEEC countries. In order to reliably measure the incidence of the harmonization of EU standards and the compliance cost, this model is applied to trade data that differentiate sectors according to a European classification, which specifically identifies sectors where the EU has sought to introduce the harmonized of environmental regulations. Following much of theoretical and empirical literature on R&D spillovers, the gravity equation is augmented with R&D expenditure taken as a proxy for innovation.[3] Although most studies have concentrated on the effects of spillovers on productivity, few attempts have analyzed the impact of innovation on export performance.[4] The second hypothesis is tested using a Box-Cox procedure allowing for non-linear relationship similar to that of Levy (1990), where we control for country specifics based on data compiled by the OECD statistical compendium.

A series of articles (at the abstract level) have studied the economic effects of international (governmental) standardization policies (Wallner, 1998; Baldwin, 2000; Suwa, Eisenmann, Verdier, 2002, Fisher and Serra, 1999). However, an important difference is that we allow for the interaction of R&D externalities with a fixed adaptation cost when firms export abroad. In general, the literature on minimum quality standards, (Shy, 1991; Kende, 1991); respectively, consider the effect of compatibility international standards on licensing and on the incentives for conducting

[3] A number of papers have examined the relationship between R&D and productivity. Examples include Coe and Helpman (1993), Nadiri and Prucha (1997).

[4] See for instance, Soete (1987), Léon-Ledesma (2000)

R&D. The literature analyzing the strategic use of governmental standards and R&D (Jensen and Thursby, 1991; Regibeau and Rockett, 1994) formalize the idea that standardization policy may be used to protect the research of domestic firms and improve the chances of domestic firms in R&D competition. Gandal and Shy (1996) also focuses on the link between the effect of standardization policies and protection, but analyze how this affect trade and also looks on how institutions such as standardization unions affect trade.

The paper proceeds as follows. Section 2 sets up the theoretical model. In Section 3 we solve the three-stage game and draw the main results on market competition and government policy. Section 4 considers the empirical models and provides the main econometric results. Section 5 concludes followed by some policy implications for CEEC countries.

2 A Simple Duopoly Model

The model that we use is similar to that of Spencer and Brander (1983). We examine a duopoly model in which two firms, i and j, are located in two different countries and export a homogeneous good to a third country.[5] For the sake of simplicity, we assume that firm i is the home firm while firm j is the foreign firm. In order to export the good, they have to comply with standard requirements that bring an additional fixed cost. Firms invest in process innovation to reduce their production cost. Moreover, we assume that this kind of R&D activity creates a positive spillover that lowers the compliance cost. Finally, the government where firm i resides can grant an R&D subsidy to its home firm.

The game takes place in three stages. In the first stage government commits to the R&D subsidy; in the second stage firms choose the level of R&D and in the third stage they compete

[5] The third market framework has often been used before. Examples include Spencer and Brander (1983), Brander and Spencer (1985) and Eaton and Grossman (1986) among others.

in the market by setting quantities. The temporal sequence reflects the conventional wisdom that government can commit to an R&D subsidy at the start of the game, while firms carry out R&D before that production takes place.

The inverse demand function is given by:

$$p = a - b\,(q_i + q_j)\,, \tag{1}$$

where a and b are positive constants, q_i and $q_j$indicates respectively firm i's and firm j's export. Marginal cost of production c is equal for both firms. However, by investing in process innovation this cost can be reduced by a quantity x_i (x_j). Following the common assumption of diminishing returns (see d'Aspremont and Jacquemin, 1988), firms incur in R&D costs given by $\gamma\frac{x_i^2}{2}$ and $\gamma\frac{x_j^2}{2}$ respectively, where γ relates to the efficiency of the R&D technology: the higher the value of γ, the more expensive (i.e. the less efficient) is process R&D, and viceversa.

As we introduced before, R&D activity creates a positive externality that acts in reducing the adaptation cost. The empirical models of the next section will support this hypothesis. The adaptation cost is then given by:

$$\begin{aligned} s_i\,(x_i) &= \overline{s} - \theta_i\, x_i \\ s_j\,(x_j) &= \overline{s} - \theta_j\, x_j \end{aligned}$$

where $\theta_{i,j} \in [0,1]$ is a parameter indicating the intensity of the spillover effect. We assume that firms differ in the ability to internalize the spillover from process R&D, hence $\theta_i \neq \theta_j$. Furthermore, $s_i(x_i) > 0$, i.e. $\theta_i < \frac{\overline{s}}{x_i} = \widetilde{\theta}_i$ and similarly for $s_j\,(x_j)$.

The profit functions of the two firms are defined as:

$$\pi_i = (p - c + x_i)q_i - s_i\,(x_i) - \gamma\frac{x_i^2}{2} + \delta x_i.$$

$$\pi_j = (p - c + x_j)q_j - s_j\,(x_j) - \gamma\frac{x_j^2}{2} \tag{2}$$

where δ is the per unit R&D subsidy.

Home government maximizes welfare, given by profits net of subsidy payments:

$$W_i = \pi_i - \delta x_i = (p - c + x_i)q_i - s_i\,(x_i) - \gamma \frac{x_i^2}{2} \tag{3}$$

Our strategy in the next section is to solve the game backwards in order to get the equilibrium level of the R&D subsidy and to evaluate its policy implications.

3 The three stage game

Let us solve backwards the three stage game. Firms choose their outputs given both the subsidy and the R&D and output levels of the rival. The home and foreign first-order conditions for output satisfy:[6]

$$\begin{aligned} \frac{\partial \pi_i}{\partial q_i} &= a - c - bq_i - b(q_i + q_j) + x_i = 0 \\ \frac{\partial \pi_j}{\partial q_j} &= a - c - bq_j - b(q_j + q_i) + x_j = 0 \end{aligned}$$

from which we get the output levels as a function of R&D expenditures:

$$q_i(x_i, x_j) = \frac{a - c + 2x_i - x_j}{3b} \tag{4}$$

$$q_j(x_i, x_j) = \frac{a - c + 2x_j - x_i}{3b} \tag{5}$$

By plugging the above output levels into the original profit functions (**??**) and (2), we get the optimal profits as a function of the R&D levels, indicated by $\pi_i(x_i, x_j)$ and $\pi_j(x_i, x_j)$, that we omit for the sake of brevity.

[6] Second-order conditions are always satisfied, as one can easily check.

We now pass to the second stage of the game, in which firms decide upon the R&D levels. From first order conditions we get:[7]:

$$\begin{aligned}\frac{\partial \pi_i(x_i, x_j)}{\partial x_i} &= \frac{4}{9b}\left(a - c + 2x_i - x_j\right) - \gamma x_i + \delta + \theta_i = 0 \\ \frac{\partial \pi_j(x_i, x_j)}{\partial x_j} &= \frac{4}{9b}\left(a - c + 2x_j - x_i\right) - \gamma x_j + \theta_j = 0\end{aligned}$$

These two expressions can be combined to obtain the R&D levels as a function of home government's R&D subsidy:

$$x_i(\delta) = \frac{16c + 4a\,(3b\gamma - 4) + 3b\,[(9b\gamma - 8)\,(\delta + \theta_i) - 4(\theta_j + c\gamma)]}{(3b\gamma - 4)\,(9b\gamma - 4)} \tag{6}$$

$$x_j(\delta) = \frac{4\,[4c + a\,(3b\gamma - 4) - 3b(c\gamma + \delta + \theta_i)] + 3b\,(9b\gamma - 8)\,\theta_j}{(3b\gamma - 4)\,(9b\gamma - 4)}. \tag{7}$$

We complete the backwards solution by considering the first stage of the game, where home government sets the R&D subsidy. By substituting (6) and (7) into (3) we obtain an expression of home welfare as a function of δ and of the parameters of the model. Finally, through $\dfrac{\partial W(\delta)}{\partial \delta} = 0$ we obtain the optimal R&D subsidy:

$$\delta^* = \frac{8}{3}\frac{\gamma\,[4c + a\,(3b\gamma - 4) - 3b\,(c\gamma - 2\theta_i + \theta_j)] - 4\theta_i}{b\gamma[160 + 27b\gamma\,(3b\gamma - 8)] - 32}. \tag{8}$$

Second order condition holds when $(b\gamma[160 + 27b\gamma\,(3b\gamma - 8)] - 32) > 0$ and this implies that the denominator of (8) is always positive. The sign of the optimal subsidy depends then on the numerator; in particular, one can notice that the *relative* dimension of θ_i *vis à vis* θ_j can be useful to discriminate between a negative and a positive subsidy.

It is worth noting that $\frac{\partial \delta^*}{\partial \theta_i} > 0$ and $\frac{\partial \delta^*}{\partial \theta_j} < 0$; as a consequence, home government increases the amount of the R&D subsidy when the local firm is able to capture the spillovers deriving from R&D activity. At the same time, it tends to decrease such a subsidy when the ability of the rival firm to exploit the spillover increases.

[7] Second order conditions require $\gamma > \frac{8}{9b}$.

One can prove that, in the interval of θ_i for which equilibrium quantities are positive, the home government will always provide a subsidy. It is possible to state the following:

Proposition 1 *The home government always grants a positive R&D subsidy that is proportional to the advantage that the home firm displays in the exploitation of the spillover.*

Proof First of all, the sign of the optimal subsidy depends on the numerator, given that the denominator is assumed to be always positive for second order conditions to hold. The threshold value of θ_i such that the numerator becomes positive is:

$$\theta_i > \frac{3b\left(c\gamma + \theta_j\right) + \gamma\left[a(4 - 3b\gamma) - 4c\right]}{6b\gamma - 4}$$

which is positive in the interval of parameters that we consider and it is increasing in θ_j. For the home firm, hence, the higher the spillover of the rival, the higher the value of the own spillover necessary to get the subsidy.

Secondly, when we check for non-negativity of quantities, it appears that $q_i > 0$ when the above condition on θ_i is satisfied, otherwise the firm is out of the market. In all the intervals of the parameters for which the duopoly game has an economic meaning, then, the government intervenes to support local R&D through a subsidy. ■

From the simple model described above it emerges a very interesting result. The degree of the spillovers, captured by θ_i and θ_j respectively, becomes an indicator of the relative performance of firm's efficiency in exploiting process R&D to reduce the compliance cost. A government wishing to help its local firm should then provide a subsidy proportional to the technological advantage of its local firm over the rival.

In the next sections we will provide empirical results that support the above conclusion.

4 The empirical model and data

In this section, we focus on two issues, which are quite different and have different implications. First of all, we are interested in investigating the relationship between innovation, the harmonization of regulations and export performance. Here we present evidence by pooling data of 21 European countries, for the period 1995-1998, by employing different specification of the gravity equation. Pointed out by the empirical literature on innovation, we also capture systematic deviations of trade patterns by controlling for domestic and international spillovers. Due to the nature of our data (harmonization of EU environmental regulations), we also control for differences between EU membership and 6 CEEC applicant countries. Secondly, we are interested in the existence of differences/similarities in the technology intensity between countries by focusing on the relationship between R&D subsidies and the level of R&D expenditure by industry (firm). However, we are also interested in analyzing whether this relationship varies from country to country: we employ aggregate level time series observations in panel form for two different samples consisting of 6 EU and 6 CEEC countries for the period of 1991-2000 and control for individual country-specific effect.

4.1 Export performance, harmonized EU regulation and R&D spillovers

The standard framework to account for bilateral trade flows is the gravity model. The empirical success can be attributed from the model's consistently high statistical fit. Typically in a log-linear form, this model takes its name from the prediction that trade between countries is promoted by their economic size (income, production) and constrained by their geographic distances. Other important features characterizing the international exchange of products between countries can easily be added. For example, Frankel et al. (1994) add dummy variables for country pairs, which share a common language and a common border, as well as trading blocks dummy variables, which evaluate the effect of preferential trading agreements. The coefficients for these dummy variables are expected to be positive. Although its empirical success can be attributed from the model's consistently high statistical fit, it was also criticized because it lacked a theoretical foundation. These foundations were, subsequently, developed by many authors. More recent applications show that this model is compatible with monopolistic competition models of trade: allowing for economies of scale, (Helpman (1987), Anderson and van Wincoop (2001)), and for technological differences across countries, (Davis (1996)).

Given its performance in explaining trade flows, the gravity model considered here takes the following form:

$$\begin{aligned} \ln X_{ij,t} &= \alpha_i + \beta_{1,t} \ln Y_i + \beta_{2,t} \ln Y_j + \beta_{3,t} \ln D_{ij} + \beta_{4,t} \ln ADAPT_i + \beta_{5,t} \ln R\&D_i + \\ & \beta_{6,t} \ln(wR\&D_j) + \sum_n \delta_{k,t} DUM_{ij} + \varepsilon_{ij,t} \end{aligned} \quad (9)$$

where

X_{ij} are exports from country i to country j at time t;

Y_i and Y_j are the total production from country i and j;

DUM_{ij} are a set of n dummy variables (separate dummy variables are included to reflect the effects of adjacency between i and j, the case when i and j share the same language, (interacting) dummies for the exporting CEEC and EU countries and time dummies);

D_{ij} is the distance between the trading centres of the two countries;

$ADAPT_i$ is the total cost of compliance with the EU environmental standards;

$R\&DSPILL_i$ is the R&D intensity of country, i, and is given by the amount of R&D expenditure per unit of output produced.

$R\&DSPILL_j$ denotes the R&D intensity of country j, weighted by a coefficient, w, which is measured by country $j\prime s$ share in country $i\prime s$ aggregate imports;

The economic variables in the gravity model (incomes, distance) define the 'normal' level of trade. On the assumption that the gravity model is well-specified the dummy variables seek to capture systematic deviations from this normal pattern of trade due to physical adjacency and language. However, our theoretical model points out three additional important factors in trade performance.

First of all, for those sectors where differences in national technical regulations are important, an additional trade cost arises when exporting countries comply with the harmonization process of EU environmental standards. In the gravity equation, this effect is captured by $ADAPT_i$, which is defined as the industry-expenditure on environmental protection of country i. It is reasonable to assume that the compliance process in the area of environmental protection will have a significant impact of the overall trade performance of EU countries. For example, it has been observed that in the production process of heavy polluting industries such as, chemicals, petrochemical, steel and paper, firms may face substantial costs as a result of the compliance with environmental directives related to pollution emissions and waste (Dziegielewska, 1999).

The second determinant of trade is the technological endowment of a country. In our model, R&D intensity, $R\&DSPILL_i$, is defined as R&D expenditure undertaken by firms relative to production by country i.. We also construct the R&D intensity of country j, $R\&DSPILL_j$, in order to capture the effect of foreign innovation on domestic imports.[8] This estimate is an imported share weighted average to reflect the relative importance of bilateral trade between a given pair of countries. Empirical work indicates that technology is positively related to export performance.[9]

[8] Coe and Helpman (1995) provide evidence on the extent and importance of foreign R&D spillovers for explaining productivity growth.

[9] See, amongst other, Wakelin (1998), Soete (1987), Miguel Leon-Ledesma 2000), Fagerberg (1988).

As we have mentioned in the introduction, evidence based on case studies, suggests that high R&D intensity increases the capacity and flexibility of production facilities. Since we are utilizing information on the sectorial incidence of environmental EU regulations (through mandated directives), embodied in our trade data, we expect that high levels of R&D expenditure will facilitate the development of new technologies/products in response to environmental regulations, lower productions costs and improve trade performance. The regulation of toxic substances in particular has been viewed as an industry where technological advancement has led to significant advances in preventing pollution (Ashford, 2002).

Thirdly, it should be noted that the choice of the group countries (15 EU countries and 6 CEEC countries) that we included in our sample was chosen for three reasons. The first reason is that the asymmetric nature of our theoretical model stipulates that we should be focusing on countries with different levels of R&D intensities. Our data on the level R&D intensity reveals that with the exception of Poland and Czech Republic, all other CEEC countries have the lowest level. The second reason is that the compliance procedure, in the area of EU environmental regulations, does not perfectly coincide between the EU and the CEEC countries. As pointed out by Dziegielewska (1999), "the EU countries are mainly concerned with global environmental problems, such as decreasing greenhouse gas emissions, ozone-layer protection, acidification reductions, etc. while the candidate countries are primarily interested in solving the most pressing local environmental problems such as, waste, lead reductions". An additional factor may be a time-varying effect. For the current member countries, the compliance with that the EU environmental standards assume instant harmonization while CEEC countries are still in a transition period. As a result, we therefore control for the interaction of country group dummies in one of our gravity specifications. Finally, the choice of 6 CEEC countries was also limited by data availability.

4.2 The relationship between governmental R&D subsidies and firm's R&D expenditure

We rely on a simple R&D investment model borrowed from Levy (1990) that considers a firm's funded R&D as a function of output, government funding of R&D performed by firms and country-specific fixed effect. To estimate the model, we employ a Box-Cox procedure simultaneously with the pooled estimation. We run this regression for two samples: six EU countries (France, Germany, Italy, Spain, Portugal and the UK) and 6 CEEC countries (Poland, Hungary, Czech Republic, Romania, Slovenia and Slovakia) using a sample period of 1990-2000 and 1991-2000, respectively. The basic model is

$$\begin{aligned}(INDFINR\&D_i^{\lambda} - 1)/\lambda \quad &= \quad \alpha_i + \beta_{1,t}(GOVFINR\&D_i^{\lambda} - 1)/\lambda + \beta_{2,t}(Y_i^{\lambda} - 1)/\lambda + \\ &\quad + \beta_{3,t}CTRYD * (GOVFINR\&D_i^{\lambda} - 1)/\lambda + \varepsilon_{i,t}\end{aligned} \tag{10}$$

where:

t are the time periods and i are the countries;

$INDFINR\&D_i$ is the private industry R&D expenditure by country i;

$GOVFINR\&D_i$ is the government funding of R&D expenditure performed by country i;

Y_i is the total production of country i;

$CTRYD$ is a country-specific dummy.

4.3 Data Sources and Methodology

Data are available from different sources. Trade data comes from EUROSTAT and are collected at 8-digit level of the European combined nomenclature trade classification, which covers more than 10000 products. Our data set comprises bilateral exports for the period 1995-1998 between each of the 14 EU countries including bilateral exports between each of the 14 EU countries and the following CEEC countries: Czech Republic, Hungary, Poland, Slovenia, Slovakia and Romania.[10] The sample therefore covers a total of [(14*19 + 6*14)*3] =1400 observations. We derived the trade data according to the NACE industrial classification, which covers around 100 manufacturing industries. Since a partial focus of our empirical work is the relationship between exports, the harmonization of EU environmental standards and the compliance cost, we need to reliable measure the sectorial incidence of environmental regulations. To do so, we first utilize information coming from a detailed study undertaken for the Commission's review of the impact of the Single Market in the EU (CEC, 1998). This study provides information at the 3-digit level of the NACE classification of whether trade is affected by technical regulations including environmental rules. Trade data according to the NACE classification were obtained from the COMEXT database.[11] Trade was then aggregated into one broad group, consisting of all sectors were differences in environmental regulations constrain trade flows according to this classification in CEC, 1998. The 3-digit sectors that we selected are reported in Table 1.

[10] Comext only reports trade for Belgium and Luxembourg treated as one.

[11] The NACE is the industrial classification used by the Statistical Office of the European Communities (Eurostat). A detailed definition of the classification is presented in CEC (1998).

Table 1: Sectors subject to the harmonization of environmental regulations

110-140	Mining and Quarrying	321-328	Machines and equipment
151-152	Extr. & prod.of nuclear materials	342	Manuf. of electrical mach.
244	Man. of art. Asbestos	343	Electr. Appar.for ind. use
245	Work. of stones & non-met. prod.	347	Manuf. electr. Lamps
247	Manuf. of glass & glassware	351	Manuf. motor vehicles
251-259	Chem, petrochem., pharmac.	363	Man. of cycles, motor cycles
314	Structural metal products	411-419	Food products
315	Boilers, reservoirs, tanks	471-472	pulp and paper
316	Heating appliances	481-482	Rubber products

In order to calculate the compliance cost with the harmonization of EU environmental regulations, we use an indicator of the economic resources spent on environmental protection. We are aware that this is not an entire cost in alignment with the harmonization of environmental standards since we are not including institutional and administrative costs; however, for the purpose of our study, the costs that we are capturing are directly related to the production process as well as those costs that serve to abate the pollution stemming from the production process as a result of their compliance with EU environmental standards. We rely on two sources. Wherever possible, we use data on the 'industry expenditure on environmental protection' from EUROSTAT. When the data are unavailable, we fill in missing observations with comparables from the various statistical institutes. The environmental protection expenditure is classified in different activities according to the Single European Standard Statistical Classification of Environmental Protection Activities (CEPA) broken down in the following groups: water & soil, industrial pollution, air, noise, nature and forestry protection, as well as chemical substances and genetically modified organisms.

To this data set, we add a number of other variables that are necessary to estimate the gravity model. Distance between countries is measured as the great circle distance between the national capitals. We add production in total manufacturing and GDP (constant) from EUROSTAT. When production data were unavailable, we fill in missing observations from the OECD statistical compendium. When all else fails, missing data, then, are approximated by applying a trend of the gross rate of value-added (in quantity).

Finally, this paper also requires data on innovation measures. This data is taken from the OECD statistical compendium. R&D expenditure performed by firms (GERD) and government funding of R&D expenditure performed by firms (BERD) is expressed in constant USD and were converted to the EURO using the exchange rate listed in the IMF 'Financial Statistics'. For a number of countries; R&D expenditure data are not available for the full period 1990-1998, in which case, an estimated equation relating R&D expenditures to output was used to predict the missing R&D expenditure data.

5 Results

5.1 Model 1

Using data for 21 countries between 1995 and 1998, we pool the cross-section data over time because the extra time-series observations result in more accurate estimates compared to the use of cross-section data to estimate gravity models. One reason is that using panel data allows for a better control for the effects of missing or unobserved trade determinants, which are otherwise captured by the error term (Egger, 2000). Consequently, we also introduce time effects, which are jointly significant using the F-test.[12] In order to deal with the presence of heteroscedasticity, we

[12] The general interpretation of the time estimates can reflect many interpretations. In gravity, these factors are generally not treated as random and are usually interpreted as the overall business cycle, the general development

use the approach proposed by Harvey (1976) where the square of the weight (σ^2) is constructed as the exponential function of the predicted ln $\hat{e}ij^2$. All the variables in the regression are than weighted by the inverse of the variance in order to avoid inefficient estimates in the presence of heteroscedasticity.[13]

We also use instrumental variables since production and exports are most likely jointly determined in equilibrium (Harrigan, 1996). In order to deal adequately with this problem, several endowment measures are used as instruments.[14] The set of instruments are (1) the log of capital stock from the current and previous year, (2) the log of skilled labor (the total number of persons employed who are engaged in the productive activity of a given industrial branch) from the current and previous year and (3) current population.

The basic results for total bilateral trade flows using different specifications of the gravity equation (1) are reported in Table 2. We proceeded as follows. In column 1, we augmented the basic gravity equation with the compliance cost variable (ADAPTi) but excluding the domestic and foreign spillover variables in order to obtain a set of base results. In column (2), we added the domestic R&D spillover variable, in addition to the standard variables of the first estimation, while in column (3) we added both the domestic and foreign R&D spillovers. In column (4), we employ the same gravity specification from column (2) but we let interact a EU (if $country_i = EU\ else\ 0$)

of openness, or amongst others, the process of globalization. Note: in the gravity specification of column 1, Table 1, the F-test did not reject the hypothesis that these time effects are jointly zero.

[13] See Judge et al. (1979). By applying the Breusch-Pagan test for the OLS estimate using the gravity specification of column 2, Table 1, yields a chi-square of 137.9 (p-value=0.000). We consequently carried out a series of Breusch-Pagan tests for several country groups (ranked by their GDP) as well different versions of the gravity specifications (GDP weights, quadratic transformations) but the null hypothesis of homoscedasticity was rejected in most cases. The Breusch-Pagan test statistic using the Harvey procedure substantially reduced heteroscedasticity with a Breusch-Pagan test statistic of 17.5.

[14] The gravity literature uses population as an instrument, but many authors conclude that this does not modify the overall fit of the regression.

and CEEC (if $country_i = CEEC\ else\ 0$) dummies with both the domestic spillover variable and the cost compliance variables.

In line with the gravity literature, the overall fit is good (R2=0.83, 0.84) and all the variables of the basic regression have the expected sign. It is evident that both the R&D spillover effect and the compliance cost are significant in general.[15] When we take these effects jointly, we see that the R&D intensity has a significant and positive impact on the trade performance of countries and therefore reduces the compliance costs that countries face upon exporting abroad. Using the same specification of column (2), we also compute the correlation between the R&D intensity and the compliance cost. We find an economic and statistical significant correlation coefficient of -.55. In column (3), when we introduce the foreign R&D intensities, this jointly effect of all three variables is even more pronounced. However the magnitude of the R&D intensity are considerable larger than those from studies that also include international R&D spillovers. In column (4), we allow for separate coefficients to be estimated for both the R&D intensity and the compliance cost for CEEC and EU countries. In the case of the effect of the compliance cost on exports, this elasticity is much higher for our selected CEEC countries in the sample. Although, these results are consistent with expectations, it is evident that some degree of variation exists across country groups.

[15] When we introduce simultaneously the R&D intensity interacting with the compliance cost, this generated variable is not significant anymore. We introduced them separately since it not only gives a better overall fit but also a better precision to the compliance cost according to the t-statistics. (not reported in the table).

Table 2: Gravity model for trade in sectors subject to harmonized environmental regulations

	1	2	3	4
Ln $PROD_i$	1.02**(0.01)	0.97**(0.02)	0.97**(0.01)	0.94**(0.01)
Ln $PROD_j$	0.92**(0.01)	0.93**(0.01)	0.92**(0.01)	0.94**(0.02)
Ln D_{ij}	−0.95**(0.04)	−0.90**(0.04)	−0.84**(0.05)	−0.90**(0.04)
Adjacency	0.31**(0.09)	0.32**(0.09)	0.37**(0.09)	0.31**(0.09)
Language	0.26**(0.14)	0.33**(0.13)	0.35**(0.13)	0.25**(0.13)
Ln $SPILL_i$		0.70**(0.01)	0.72**(0.01)	
Ln $SPILL_j$			0.22**(0.06)	
Ln $ADAPT_i$	−0.13**(0.03)	−0.34**(0.03)	−0.34**(0.03)	
$D^{EU} *$ Ln $SPILL_i$				0.54**(0.08)
$D^{CEEC} *$ Ln $SPILL_i$				0.35**(0.10)
$D^{EU} *$ Ln $ADAPT_i$				−0.14**(0.05)
$D^{CEEC} *$ Ln $ADAPT_i$				−0.48**(0.11)
Year 96	0.03(0.06)	−0.03(0.06)	−0.12**(0.06)	−0.01**(0.06)
Year 97	0.001(0.06)	−0.12**(0.06)	−0.16**(0.06)	−0.07(0.06)
Year 98	−0.01(0.06)	−0.12**(0.06)	−0.17**(0.06)	−0.17**(0.06)
Intercept	−2.50(0.54)	0.50(0.62)	0.99*(0.63)	−0.13(0.66)
R^2	0.83	0.84	0.84	0.84
Estimation Method	WLS-IV	WLS-IV	WLS-IV	WLS-IV
Observations	1400	1400	1400	1400

Notes : Standard errors are reported in parentheses.

** denotes significance at 1 percent and * denotes significance at 5 percent

5.2 Model 2

In line with Levy (1990), this model is estimated by a maximum likelihood procedure allowing all variables to be Box-Cox transformed for each sample [16] The transformation of which maximizes the likelihood is solved for (lambda) values between 0 and 1 with 0.005 increments. The results are reported in table 3.

Table 3: The impact of government subsidies on firms' R&D

	CEEC		EU
GovR&Di	0.003**(0.002)		0.002**(0.0008)
PRODj	0.016**(0.003)		0.05**(0.02)
GovR&Di*CZ	0.007**(0.001)	GovR&Di*IT	0.002(0.001)
GovR&Di*PO	0.001(0.0009)	GovR&Di*SP	0.003**(0.001)
GovR&Di*RO	−0.008**(0.002)	GovR&Di*FR	0.005**(0.0001)
GovR&Di*SR	−0.007**(0.003)	GovR&Di*GE	0.002(0.001)
GovR&Di*SL	−0.011**(0.003)	GovR&Di*UK	0.003**(0.001)
Intercept	11.47**(0.31)		21.02**(4.76)
λ	0.21		0.28
R^2	0.88		0.98
Estimation Method	Box-Cox		Box-Cox
Observations	60		66

Notes : Standard errors are reported in parentheses.

** denotes significance at 1 percent and * denotes significance at 5 percent

[16] In a simple production function, Levy (1990) models a non-linear relationship between a firm's R&D and government funded R&D.

The impact of government involvement in the area of R&D activities is likely to differ across countries, we; therefore, added country-specific dummies interacting with the Box-Cox Gov R&D. Results are reported in table 2. The overall picture reveals that the impact of government-funded R&D within the two country-group samples somewhat differ across countries . Clearly, for the EU countries, this is positive for each country. While the contribution of government-funded R&D for Romania, the Slovak republic and Slovenia is negative, this effect is positive for Poland, the Czech Republic and Hungary. We will return to this issue in the next section.

6 Conclusions with Policy Implications for Applicant Countries in Central and Eastern Europe

A first aspect we have examined is that the effect of R&D spillovers in reducing the compliance cost varies. Supported by our empirical results, it is suggested that, being a EU member appears to allow countries to significantly overcome the compliance cost that is generated by the harmonization of environmental standards. But, there remain substantial problems within the EU in completing the "environmental acquis" since our results suggest that the negative impact of the compliance cost on EU trade is significant. Since compliance costs in some sense measure an industry's response to regulation, high compliance costs could indicate an ineffective response. This raises two issues A first issue regarding the post-enlargement situation and in particular, the impact that enlargement will have on the harmonization process. Clearly, the efforts of the existing members to effectively implement the alignment of EU environmental regulations must increase in the context of enlargement since the accession of new members will substantially increase the pressures on the internal market and stretch the abilities to ensure compliance with harmonized directives. Within the EU, environmental regulations and directives are growing steadily in number and scopes, but the environment continue to be under great stress due to the economic growth and consumption of natural resources and energy. Impact assessments published by the European Environmental Agency indicate that the situation is deteriorating in parallel with the growth in number of environmental regulations being adopted (EEA, 1999). The enlargement will certainly improve environmental conditions and capabilities for the CEEC countries, but there are also potential negative sides to an enlargement process. Problems related to the enforcement and implementation of environmental regulations in the EU will probably be repeated in Central and Eastern Europe, if not enough resources are invested to bring up the capacity to implement the alignment process with EU environmental regulations within EU countries. But these investments will certainly be a heavy burden on both the EU and CEEC countries. Thus, there is a risk that the political prestige invested in the enlargement process will impose costs on the environment, and that in the end what matters for the accession countries is growth, which may be prioritized at the cost of the environment. In that sense, the environment might come under even further pressure and the gap might continue to grow.

The second but more crucial issue emanating from this empirical finding is that even though differences between the CEEC and EU countries are great in terms of complying with the EU environmental policy, the capacity to implement the acquis seems to be a greater challenges to enlargement. Our results suggest that the R&D capacity, measured in R&D spillovers is relatively weak in CEEC countries. Our data on the level R&D intensity (measured in relation to production) reveals that with the exception of Poland and Czech Republic, all other CEEC countries have the lowest level. The process of transition can be attributed to this obvious weakness. For example, the sharp shock model encourages "short term-term economics" in company planning, whereas R&D requires long-term perspectives (Grabner, 1992, p.219). CEC (1995) reports that reduced public expenditure, as part of the stabilization program, is leading to a decline in R&D. Williams et al. (1998) note that the demand for traditional company-level research has declined in favor of imported technology, a substitution that has been encouraged by appreciation in the real exchange rate in the early transition. As we have mentioned in the introduction, it is suggested that high R&D intensity increases the capacity and flexibility of production facilities. Since we are utilizing information on the sectorial incidence of environmental EU regulations (through mandated directives), embodied in our trade data, we expect that high levels of R&D expenditure will facilitate the development of new technologies/products in response to environmental regulations, lower productions costs and improve trade performance. In general, however, given the high cost of relative compliance cost of meeting the acquis, the relatively weak R&D capacity raises the question as to how the CEEC countries will properly take care of (sustain) their 'obligation' to enforce the implementation of EU environmental regulations?

To help answer this central question, it is important to note that, on the positive side, empirical evidence (Porter, 1991; Jaffe and Palmer, 1996, Ashford et al. 1985) suggest that increasing the stringency of environmental regulations stimulate incentive for firms to develop new and less costly ways of reducing pollution, or potentially, entire new methods of production that eliminate particular types of emissions and reduce cost of production. In this study, we found a negative relationship between R&D spillovers and the compliance cost supporting this hypothesis; however, an increasing concern is the economic inequity between the CEEC and current EU countries stemming from the capacity of complying with environmental regulations.

This bring us to the second aspect of the paper; namely, that solutions involving government intervention by direct support in terms of R&D subsidies are not themselves sufficient to provide solutions to the sustainability challenges. We have shown that the government can choose between a R&D tax or subsidy depending on the efficient use of R&D. So when the government commits to its R&D subsidy, it may distort R&D rivalry by helping some of them at the expense of others. This type of intervention should merely be considered as a 'soft package' and purely relying on financial loans, funds may not be sufficient: investments will continue to be planned and 'financial support' is limited[17]. Our empirical evidence shows, that paradoxically, public R&D subsidies to some CEEC firms 'crowd out' the private R&D investment. The capacity or capability for CEE firms to meet those challenges can be enhanced by increases in R&D knowledge or support from current EU firms (engineering consulting services, technical assistance, demonstration projects, training,) that have 'internalized' decades of environmental legislation[18]. This can be enhanced by a deliberate creation of networks or strategic alliances but in reality, such willingness requires a climate, which is not necessarily confined to a technological regime, a geographical area and the reliance of the more liberal forms of R&D modernization on firms' economic self-interest. The role of the regulator (European Commission) should not only be limited to a 'creating directives' and 'monitoring progress' but to coordinate a more substantive development/transformation process where firms' interests collide with public endeavors. Since we have shown that R&D investments are a proper response to environmental regulations, to the regulator, this suggests that a more creative use of law is a more promising strategic instrument for achieving the sustainable demands in the CEEC.

[17] Extra-budgetary environmental funds are in the process of being formed in nearly every CEEC country and are operated under the auspices of the national Ministry of Environment. The financial support by the European Commission is in form of special pre-accession aid funds. However a recent trend in agricultural policy among the current EU member countries is to redirect the portion of the EU budget previously channeled in the form of farmer subsidies toward environmental allowances (Dziegielewska (1999)).

[18] Especially, the heavy, basic industries, which are also sometimes the most polluting, unsafe, and resource-intensive industries, may find it more difficult to meet environmental demands.

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