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Manello Alessandro

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Comparing green performances of Italian and German firms

Alessandro Manello

CNR-Ceris

National Research Council of Italy,
via Real Collegio, n. 30, 10024 Moncalieri (To), Italy

Tel.: +39 011 68 24 946
Mail: a.manello@ceris.cnr.it

ABSTRACT: This paper analyses the environmental efficiency of a sample of chemical firms located in Italy and Germany, which are included in the European Pollution Emission and Transfer Register (E-PRTR). The adoption of a common set of standards can open important way to compare economical and ecological performances of firms which must follow the same formal rule, but operating in different countries. The Directional Distance Function (DDF) approach is here applied to obtain global efficiency scores able to consider pollution in computations: emissions generally increase between 2004 and 2007, with a worse performance of Italian firms. Eco-efficiency indicators partially slim down that evidence considering both turnover and input usage, underlining a reduction of average inefficiencies over time. From a dynamic viewpoint empirical findings shows a most favourable trends in environmental TFP growth for German firms.

Keywords: Environmental Efficiency, Porter's Hypothesis, Chemical industry

JEL Codes: D24, O33, Q50, Q52.

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SUMMARY

INTRODUCTION

Environmental protection is nowadays a key point to be considered in all the industrial process, but in some cases it became one of the most important objective to be pursued by managers. New costs are imposed in order to respect regulatory constraint and they are so pervasive to influence at 360 degree all economical considerations regarding production decisions. In the case of mature industries, where margins are small and competitors numerous, new rules are the most powerful engine to stimulate green innovations and new investments (Fukasaku, 2005). Porter (1991) supposes the existence of win-win opportunities in the increasing stringency of environmental regulation, starting with the case of Japanese industry, able to grow more than US under more stringent rules. European Community during last decades is becoming one of the most important and active decision makers regarding environment: a set of rules is adopted, in order to guarantee an homogeneous level of life quality in all the member states. One of the most important action in this direction was the adoption of the so called IPPC (Integrated Pollution Prevention and Control) approach. This consist in a common regulation framework (directive, regulation or decision) with the aim of protecting environment and reducing emissions, stimulating technical innovation in some relevant sectors. The directive 1996/61/EC and the EC regulation 166/2006 create a system of preventive authorisation to pollute that could be obtained after the adoption of the so called BAT (Best Available Technique) to reduce emissions. Another important point was the creation of a public register, in the wake of US Toxic Release Inventory published in the late 80s, now called European Pollution Release and Transfer Register (E-PRTR) after the inclusion of pollutant transfer activity in 2006. This strategy correspond to the so called third wave of environmental policies based on reputation or better information disclosure, after a first phase of command-control methods corresponding to pollution standards and a second market-based step, when tradable permits and emission fees were the main instruments (Canon-de-Francia et al., 2008). Some doubts arise around the effectiveness of environmental reputation and in fact information availability by public register stimulate green performances if and only if data are effectively considered by public opinion and if green preferences are real in consumer choice (Caplam, 2003). Of course the adoption of BATs, which represent just an average environmental performances and also derives from a benefit-cost analysis, needs increasing investments on pollution abatement equipment, but also change in input-output mix, pollution prevention activity and process re-organisation. IPPC framework could then have different initial costs across industries and countries as well as among firms. Some primitive comparisons of regulatory costs have been proposed in order to understand the impact of the IPPC related policy REACH for new member states (Angherer et al., 2008), but only basing the analysis on direct abatement activity. Across Europe coexist different levels of environmental sensibility: traditionally, in Germany the informal pressure on polluting firms to green innovations is high, also thanks to the presence of strong green parties and higher sensibility of social society (Rio Gonzales, 2009). In southern countries, like Italy, this aspects are weaker, especially regarding some industrial sites placed in less developed areas. Among the nine industrial sectors subject to the IPPC normative, the chemical industry is probably the most important and is traditionally associated to dangerous emissions, both in air and water. It also plays a key role as an intermediate manufacturer for all other industrial sectors and it has all the characteristics of a mature industry. Europe is the first chemical producer with around the 25% of the total world production, and in this scenario, Germany and Italy are respectively the first and the third producers (Federchimica, 2010). Firms located in this two countries have common features with their national industrial structure, but also significant differences in term average firm’s size (Vitali, 2010). The adoption of a common set of standards can open important way to compare the economical and ecological performances of firms which must fulfil the same formal rule, but operating in different countries. Some interesting regional differences can arise between the two economical system (Fleishman et al., 2009). The informal regulation is proved to be a significant factor enhancing environmental performances in manufacturing (Cole et al., 2005) and the two economies traditionally show a different sensibility to the environment. The long run debate on the inclusion of undesirable outputs in efficiency and productivity estimates was positively sorted out with the concept of Directional Distance Function (DDF), introduced by Chambers et al. (1996) at theoretical level. The power of the tool lies in the possibility to modify the direction in which to search for the efficient counterpart of each firms enveloping the more stringent idea of input or output distance function. Many application arise especially in the environmental field both with micro and macro economical perspective.

Environmental frontiers are derived in many cases of firms operating in different sectors or countries, mainly considering greenhouse gas emissions. Stating with DDF concept, also the estimation of itertemporal frontiers, able to consider also pollution reductions, became a common feature. Without prices information, not available for undesirable outputs, the Malmquist-Luenberger (ML) indexes are widely applied to estimate more reliable and global TFP growth indexes. All the computations are built on the DDF assumptions and Empirical application are numerous both at firm and aggregate level. Chung et al. (1997) is the first application of ML estimate analyse a sample of pulp and paper firms operating in US, Weber and Domazlicky (2001) analyse the manufacturing sector in US including air pollution, Arocena and Waddams Price (2002) apply ML to the electricity generation sector in Spain, Nakano and Managi (2008) do the same for Japanese firms, Barros (2008) propose a ML estimation for hydroelectric generators in Portugal and finally Yu et al. (2008) estimates TFP growth in the air transportation sector considering noise as undesirable output. The most recent application of ML indexes are mainly focused on macro-economical trends. The main examples, recent and less recent are the following: Färe et al. (2001) about manufacturing sectors in US, Domazlicky and Weber (2004) on chemical 3-digit sectors, Yoruk and Zaim (2005) on OECD countries, Kumar (2006) to a group of countries, Kortelainen (2008) to UE member states, Zhou et al. (2010) to most polluting countries in term of greenhouse gas emissions, Kumar and Managi (2010a) estimates EKC on the basis of ML growth indexes and finally Zhang et al. (2011) to Chinese provincial regions. In this kind of application as well as in standard application of Malmquist indexes is not uncommon to observe a decomposition of the overall TFP growth in efficiency recovery and pure technical progress. From a theoretical and methodological viewpoint it is very difficult to justify technical regress, easily observed in empirical estimates in many previous cited papers, both in ML and standard Malmquist framework. In classical DEA a sequential concept of technology is introduced by Tulkens and Vander Eeckaut (1995) regarding standard technology assumption and radial distance in order to avoid implausible downward shift of the technical frontier. For an extensive discussion of sequential technology concept see Shestalova (2003) who also propose a comparison among standard Malmquist values and decomposition in respect to the sequential approach. Oh and Hesmati (2010) propose the first extension of sequential technology estimates to the directional distance function framework. The aim of the article is to provide, after applying a reliable estimation method, a set of eco-efficiency estimates for a group of firms located in Italy and Germany operating in the well identified sector of base chemicals. The existence and the impact of an informal or cultural pressure, specific for each country, is also considered among the determinants of the TFP changes and eco-efficiency scores. The remainder of this paper is organised as follows: section 1 formally presents the model, database's issues are explained in section 2 and empirical results are summarised in section 3. This analysis is briefly concluded in section 4.

1. ECO-EFFICIENCY: THE DIRECTIONAL DISTANCE FUNCTION APPROACH

1.1 Theoretical framework

A fully non parametric and deterministic framework is here adopted since the estimation of shadow prices is not a priority. The main advantages rely in not having to assume before a particular functional form of DDF: estimates are then free from misspecification problems. From the other hand stochastic noise is ignored and all the observed departure from the frontier is detected as inefficiency. In this section the main characteristics of a production process with undesirable outputs are formalised on the basis of a commonly accepted axiomatic framework. First of all undesirable are a sort of byproduct results, then a positive production of good output is not compatible with a zero production of them. Secondly reducing bad outputs with unchanged input bundles is only possible, from a technological perspective, by reducing good outputs volume. Some notation have to be introduced in order to clarify the points, . Let $x = (x_1,...x_N) \in R_+^N$ be a vector of inputs, $y = (y_1,...y_N) \in R_+^M$ a vector of good outputs and $b = (b_1,...b_N) \in R_+^N$.

The output set P(x) collects all the combinations of good and bad outputs that could be produced using each particular input vector x. Following Färe et al. (2007) the base chemical production process could be represented through some standard axioms satisfied by a generic polluting technology.

1. Inactivity. From a technical point of view the choose of remaining inactive is always possible.

2. Compactness. is compact, then for each finite input mix one could obtain a finite couple of vector.

3. Free disposability of inputs. As in standard technology representation, an increasing quantity of inputs allows to produce a fixed quantity of outputs. Inputs are freely disposable: each Decision Making Units (DMU) could always obtain the same amount of outputs by implying more inputs and this is technically feasible. These standard assumptions are always valid in modelling a production process. In presence of undesirable outputs one have to formalize the joint production idea and the cost of reducing, then two additional axioms need to be introduced:

4. Null jointness. It is impossible to observe positive amount of good outputs without observing also a positive amount of bad outputs, or in formulae

$$(y,b) \in P(x) \text{ and } b = 0 \Longrightarrow y = 0 \quad (1)$$

5. Weak disposability assumption on outputs. Each couple of vectors is assumed to be weakly disposable, then they cannot be freely reduced:

$$(y,b) \in P(x) \text{ and } 0 \le \alpha \le 1 \Longrightarrow (\alpha y, \alpha b) \in P(x) \quad (2)$$

In words only proportional contraction of both good and bad outputs are feasible (Färe et al., 1989), because the decrease on bad outputs could only be performed by reducing desirable outputs if one consider inputs as fixed. Free disposability is still valid on the subset of good outputs for which every reduction is technically feasible without costs and maintaining inputs constant.

$$(y,b) \in P(x) \text{ and } y' \le y \Longrightarrow (y',b) \in P(x) \quad (3)$$

The Directional Output Distance Function model (DODF), defined on the output set that meets previous axioms, gives the maximum feasible expansion of outputs in a pre-assigned direction maintaining inputs unchanged. The asymmetrical treatment of good and bad outputs is ensured by an appropriate choose of the directional vector (Chambers et al., 1998): g(y,-b) as is done in the wide majority of papers dealing with DDF, in order to get a β of immediate meaning. The objective is to reach a model able to discredit base chemical firms which increase pollution and to credit them for reductions; also each increase in good outputs have to improve measured efficiency. DDF allows to search for the efficient counterpart of each firms along non-radial projections, the DODF value represents the maximum feasible expansion of the outputs vector. DODF takes a value equal to 0 for efficient DMUs and increase with inefficiency. Its formal definition is given by the following expression:

$$\vec{D}_O^W(x,y,b;g_y,g_b) = \max\{\beta : (y,b) + (\beta g_y, \beta g_b) \in P(x)\} \quad (4)$$

where $g = (g_y, -g_b)$ is the directional vector.

The particular directional vector comes directly out from IPPC directive: a continuous reduction in bad outputs production have to be achieved in order to obtain authorisation to pollute, from the other hand managers want to increase good outputs.

1.2 Contemporaneous and sequential ML indexes

Following the results on sequential technology introduced by Tulkens and Vanden Eeckaut (1995) and the extension in the environmental field by Oh and Heshmati (2010) standard Malmquist-Luenberger indexes of TFP growth could be restated assuming a more reliable definition of technology based on a sequential view. The basic assumption is that in each all previous technological choices are still available. Describing the same concept, Shestalova (2003) concludes that the frontier at one time envelops all data points observed up to that time, eliminating by construction the problem of implausible downward frontier shifts sometimes obtained in empirical works. Starting with the contemporaneous output set assumed in standard ML setting:

$$P^t(x^t) = \{(y^t, b^t) \mid x^t \text{ can produce } (y^t, b^t)\},\ \text{with } t = 1, \dots T \tag{5}$$

To assume a sequential idea of technology, it is sufficient to take the superset of each single contemporaneous production possibility set defined over the five previous axioms. Changing the definition of technology, standard ML indexes could be re-defined on that sequential output set to obtain a sequential version of ML, named SML. The two formulation are very similar the big in each distance components recalls the fact that each distances is computed assuming the aforementioned sequential output set.

$$\bar{P}^t(x^t) = P^1(x^1) \bigcup P^2(x^2) \bigcup .. \bigcup P^t(x^t) \tag{6}$$

The ML index is built as the geometrical mean of two components - one based on technology at time t and one based on technology at time t+1 - which represent the ratio of the DODFs calculated on quantities at time t and t+1. In the same manner SML is the geometric mean of two distances ratios, but the reference technology envelop all previous observations.

$$SML_t^{t+1} = \left[\frac{(1+\vec{D}_S^t(x^t, y^t, b^t; g^t))}{(1+\vec{D}_S^t(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}))} \cdot \frac{(1+\vec{D}_S^{t+1}(x^t, y^t, b^t; g^t))}{(1+\vec{D}_S^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}))}\right]^{\frac{1}{2}} \tag{7}$$

An SML=1 indicate an absence of productivity growth between t and t+1, an increasing productivity emerges in case of SML>1, the converse indicate a deterioration in the firms' position. One of the main advantages of sequential approach rely in a more robust definition of the frontier, in a way less sensible to extemporaneous or implausible observations. The TFP might be divided in two parts: the former representing the efficiency gain over the time period (EFF), the latter accounting for technical progress in the production function of chemical products (TECH):

$$EFF_t^{t+1} = \frac{1+\vec{D}_S^t(x^t, y^t, b^t; g^t)}{1+\vec{D}_S^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1})} \tag{8}$$

$$TECH_t^{t+1} = \left[\frac{(1+\vec{D}_S^{t+1}(x^t, y^t, b^t; g^t))}{(1+\vec{D}_S^t(x^t, y^t, b^t; g^t))} \cdot \frac{(1+\vec{D}_S^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}))}{(1+\vec{D}_S^t(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}))}\right]^{\frac{1}{2}} \tag{9}$$

Given the assumption on sequential technology, the problem of implausible downward frontier shifts disappears, through a re-shaping implied by a different outputs set. An efficiency component EFF>1 shows a catching-up process based on technological diffusion and imitation: the observed distance from the frontier is decreasing over time indicating an increasing homogeneity of performances. Of course the reference piecewise linear frontier could change over time and this effect if picked by the other term.

The technical progress represents the share of TFP growth connected with new opportunities emerging from innovations. Short time periods are less easily interested by important technological shocks, then this component has limited impact often overcame by more reliable efficiency recovery. In general $ML_{t,t+1}$ is different to SML $_{t,t+1}$ due the different outputs set on which they are estimated, but if technology is well defined along all the periods without exceptions, ML and SML are equivalent.

$$P^t(x^t) \subset P^{t+1}(x^{t+1}) \forall t \quad \rightarrow \quad ML_{t,t+1} = SML_{t,t+1} \tag{10}$$

1.3 Computation of distances and regulatory impacts

All the required distances to obtain and decompose SML indexes should be obtained, in a deterministic settings, through the solution of 4 linear programs for each firm. Two of them, reported in 11 and 12, involve only contemporaneous output sets and, the other two explore sequential features.

$$\begin{aligned} \overrightarrow{D}^t_S(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}) &= \max \beta \\ Y^{\tau}_t z^{\tau} &\geq y^k_{t+1} + \beta y^k_{t+1} \\ B^{\tau}_t z^{\tau} &= b^k_{t+1} - \beta b^k_{t+1} \\ X^{\tau}_t z^{\tau} &\leq x^k_{t+1} \\ z^{\tau}_k \geq 0, k = 1, ..K, \tau &= 1, ...t \end{aligned}$$

(11)

$$\begin{aligned} \overrightarrow{D}^{t+1}_S(x^t, y^t, b^t; g^t_y, g^t_b) &= \max \beta \\ Y^{\tau}_{t+1} z^{\tau} &\geq y^k_t + \beta y^k_t, \\ B^{\tau}_{t+1} z^{\tau} &= b^k_t - \beta b^k_t, \\ X^{\tau}_{t+1} z^{\tau} &\leq x^k_t \\ z^{\tau}_k \geq 0, k = 1, ..K, \tau &= 1, ...t+1 \end{aligned}$$

(12)

Return to scale are assumed to be constant as it is done in the majority of environmental application of DDF, especially when intertemporal frontier have to be estimated reliable TFP growth estimates could be derived only in case of CRS (Färe and Grosskopf, 1996). The equality constraint applied on bad outputs reveals the weak disposability assumption and influence both efficiency levels and potential TFP growth. In the present work both the case of regulated and unregulated scenario are considered, getting estimates of regulatory constraints from the comparison of efficiency score obtained by firms under the hypothesis of weak and free disposability of bad outputs. Following Picazo-Tadeo and Prior (2009) the difference in the estimated DDF for each firm under the two set of assumption could be used as a proxy of the cost to comply to environmental rules:

$$RI = \overrightarrow{D}^F_0(x^k, y^k, b^k; y^k) - \overrightarrow{D}^W_0(x^k, y^k, b^k; y^k)$$

(13)

Where superscripts F and W indicate respectively Free and Weak disposability on bad outputs. From a computational viewpoint, the equality in the linear programs relative to bad outputs are replaced by inequalities with the same direction of good outputs constraints. Of course assuming free disposability on bad outputs, is equivalent to exclude them from computation, then also affecting TFP dynamics. Both efficiency recovery and technical progress may change in an unclear way: literature on TFP growth often compare ML indexes with standard Malmquist, but there is no clear evidence on the direction of bias. The previous literature underlines how theoretically both-sign biases are consistent with the model when bad outputs are missing. However, previous empirical findings, such Chung et al. (1997) or Weber and Domazlicky (2001), often reveal a negative bias on the estimated TFP growth if bad outputs are ignored. The situation is still more uncertain around SML. Here a simple way to compare results is presented, focusing on the observed role for each component in determining final differences.

$$(1 - \frac{SML^F_{t,t+1}}{SML^W_{t,t+1}}) = (1 - \frac{EFF^F_{t,t+1}}{EFF^W_{t,t+1}}) + (1 - \frac{TECH^F_{t,t+1}}{TECH^W_{t,t+1}})$$

(14)

Decomposing each index by subtracting 1, the total variation between SML under weak and free disposability of pollution could be seen as algebraic summation of the change in the efficiency recovery and technical progress under the two assumptions. Positive sign for components indicate an upward bias under free disposability, negative observations show an underestimated effect.

2. DATA

Environmental data comes from the European Pollution Release and Transfer Register (E-PRTR), a public register published on-line by the European Environment Agency (EEA). This steps is part of the so called third wave of environmental regulation(Canon- de-Francia et al. 2008) that is based on information disclosure. An European Pollution and Emission register is introduced with directive 1996/61/EC, but it became real only after 2000; with the regulation 166/2006 EC its application has been enlarged and also transfer activity is traced. E-PRTR is relatively young in comparison with US the Toxic Release Inventory born in 1986 and then it is still less investigated. All firms operating in 9 particular sectors must declare emissions if a double thresholds, on production capacity and emissions level, is overcome. In this paper only data for firms included in the point number 4, Chemical industry, are used. A certain homogeneity in firms activities is directly guaranteed by law: regulation CE 166/2006 provides a list of equipment and production capacity included in the register. Of course no information are provided about the share of that activities on the global turnover, but thanks to big dimensions required for each equipment, one could assume a significant contribute in total firm's production.

Table A1 in the appendix shows in detail each specific activity for which emission are available in the chemical sector. General information, release means (air, water or soil), methods of measurement, particular installation and emission quantities must be declared in E-PRTR. The level of information is very fine: data must be delivered for each production plant and for each of 91 chemicals that are listed in the directive. Data release starts with 2001 observation, then 2004 and the last available is 2007. This last 2 data are here used and all emissions coming from air, water and soil are considered, but after an aggregation procedure to avoid convergence problems in computations of LP. Firstly emissions from each plants are aggregated by firm, then they are summed up over release means using the following weighting scheme derived by the UE normative. For each substance the law assign a threshold, specific for each release means, that if overcame create the obligation to declare pollution in the E-PRTR. Applying the idea of damage function (Färe et al., 2007), the inverse of allowed thresholds is assumed as an indicator of the toxicity level relative to each substance (Canon-de-Francia et al., 2008). The implicit idea is that the higher is the threshold the lower is the associated dangerousness for public health. The resulting indicators of environmental impact are computed for each release means and then summed in a global indicator. In notation:

$$EEI = \sum_{j=1}^{3} \sum_{g=1}^{91} d_{gj} q_{gj} \tag{15}$$

Where d_g=1/T , g indexes pollutants, j indexes release means, k indexes firms, T represents thresholds relative to each pollutant and is the total quantity released. The approach of including composite indicators of health risk is already applied by Färe et al. (2006), where two human risk-adjusted indexes of pesticide leaching and runoff are used as bad outputs to be minimised in a deterministic linear model.

Table 1: Descriptive statistics of Input and Output variables (2007)

Variable	mean	min	max	sd
Inputs (1000s of constant euros 2004)				
Assets	119,236	51.7	1,401,390	247,045
Intermediate Goods	314,558	1,830.20	2,787,152	516,628
Labour costs	64,315	138.4	758,782	124,795
Good Output (1000s of constant euros 2004)				
Turnover	526,922	9,100.40	3,721,139	805,998
Bad Output (environmental impact index)				
EEI	72.24	1.02	469.87	121.82

Table 2: Total and relative emission levels

	Average EII		EII/Turnover (mlns)	
	2004	2007	2004	2007
GERMANY	68.61	56.59	0.258	0.163
ITALY	44.96	86.53	0.307	0.985
Total sample	56.2	72.2	0.284	0.593

Economical data come from Amadeus on-line database, by Bureau Van Djick, that collects balance-sheets of European firms which are forced to lay their accounts. Of course physical data on production and inputs are not available, then economical proxies are taken from balance sheets information. Good output is replaced by total production value (Y), given by the total turnover, net of inventory changes. Capital stock (K) is measured as the net value of tangible fixed asset included while Labour (L) is proxied by the total labour costs to partially include both quantity and quality of human resources. Intermediate goods (M) are obtained by the sum of raw material costs (net to inventory change) and costs of services. Table 1 shows descriptive statistics for inputs and outputs, all variable are expressed in Euros at constant 2004 prices and deflated using sector specific deflators from OECD[1]. Differences in prices levels among countries, which could be easily ignored in case of physical quantity, matters when values are considered, because the underlying real quantities can differ significantly. Germany and Italy are exactly in such situation: a PPP actualisation is applied here in addition to constant prices transformation of all variables. Some problems arise for some individual data due to Mergers and Acquisition or transformation process, but to partially control for data inconsistency firms showing an abnormal growth rate on inputs and outputs are excluded[2]. Secondly are only considered firms with unchanged business name and complete balance sheet data in both period. Finally each firm must declare emission in both period: this condition is potentially very restrictive because it exclude all virtuous firms able to reduce emissions under the thresholds. The latter point is a possible, but unusual process and in many cases is related to dismissing plant, then adopted restrictions guarantee more reliable environmental and economical data. Given the difficulties to collect complete data from balance sheets and the numerous restriction the number of analysed firms is only 44 , 23 from Italy and 21 from Germany. However the sample is able to represent more than 23 billion of total production, around 10% of the total sector turnover. The Gross Output deflator is applied to Y, the intermediate input deflator is applied to actualise M and L, and the deflator for Gross Fixed Capital is used for K. Firms included in E-PRTR for which is possible to collect complete economical data are respectively 79 and 70 regarding 2004 and 2007, but only 44 are observed in both period.

Starting from the aim of the present study, focused on looking at the productivity trend in presence of bad outputs, the analysis is restricted to firms showing emissions in both the time periods. In this way data are also cleaned by mergers and acquisition problems, because in many cases the exit from E-PRTR is an outcome of a reorganisation phase that normally leads to a new name for the firm.

Observing the emission levels from each firms give an intuition of the attention payed by firms in protecting environment. Average and relative

[1] All deflators are relative to manufacturing sector and data came from OECD Stan Database for Structural Analysis PPP indexes relative to 2004 and 2007 comes from OECD Stan.

[2] This is the case of the biggest Italian produced of polymers and resins, Polimeri Europa SPA, part of the Eni Group, excluded by the analysis because only 2007 economical data are reliable. In the period 2004 and 2007 Polimeri Europa receive all profitable activities by Syndial and by other firms of Eni. In 2004 the financial situation reveal a transition phase where all human resources were already transferred to Polimeri Europa but not jet industrial activities. Then from 2004 and 2007 the firms show an increase of revenues from 5 million to around 7 billion, with a similar trend in fixed capital

Environmental Impact Indicators are reported in table 2 and show an increase of pollution between 2004 and 2007, both in absolute and relative term. Italian firms, which initially declared less emissions than their German counterparts, give a negative image of their efforts in protecting environment, showing a strong increase in EEI. Expanding production in a phase of growth imply an increase of pollution especially if the emission level is low mainly for an under-utilisation of equipment.

The Italian picture looks similar: emissions observed in 2007 are in line with the turnover path, the opposite in respect to German firms able to simultaneously increasing production an limited pollution.

The difficulties of Italy in protecting environment are clarified in the last two column of table 2 where a relative measure of environmental impact is computed. The level of declared emission per million of turnover is more than doubled over three years, without any changes in the reporting procedure. The observed path is totally due to Italian firms which increase threefold their index, despite a more limited increases of turnover. From the analysis of purely environmental performances German firms show more reliable efforts in limiting pollution, but this position could be reached at the expenses of total factor productivity. The estimation of DDF models and SML indexes try to answer at remaining open issues.

3. RESULTS

3.1 Environmental efficiency evidence

The set of linear programs, both assuming weak and free disposability of pollution are written and solved using R. Computed efficiency score in the observed regulated scenario are reported in table 3, CRS are assumed according to linear programs in previous section. Before results interpretation, it should be underlined that efficiency is a relative concept and then what comes from estimation is the position of each firm in respect to the best of the sample in a specific time period. The mean efficiency values appear really different over the two time period considered: the distance from the frontier is higher in 2004 and decrease over time, highlighting strong recovery of eco-efficiency. The mean performances of Italian and German firms are similar in 2004 and also in 2007, non-parametric Kruscal-Wallis test rejects the hypothesis of differences between the two groups in both periods. Of course some small differences arises, but only in 2007: Italian firms appear to be more eco-efficient of theirs German counterpart.

That evidence from table 3 seems to contradict purely ecological performances reported in table 2, but estimated DDF values also consider inputs and good outputs in assessing scores. The values of β represent the feasible expansion of good output and reduction of bad outputs in each time periods.

Table 3: Computed efficiency scores , weak disposability assumed

	2004			2007		
Country	mean	sd	Pr(β = 0)	mean	sd	Pr(β = 0)
GERMANY	0.85	0.24	5%	0.25	0.25	28%
ITALY	0.85	0.26	4%	0.22	0.22	26%
Total sample	0.85	0.24	4.5%	0.24	0.24	27%

High average values for DDF suggest the coexistence of very heterogeneous firms: a limited number of eco-efficient firms drives the frontier probably thanks to their ability to anticipate regulation and reducing their emission or production capacity under legal limits. Also when free disposability on outputs is assumed conclusions on Italian firms position do not change. From one hand data gathering partially drives this point: when a firm invests for greener equipment and specialised labour force, a decrease in the value of both Assets and Labour costs is really unusual. Labour costs are higher in Germany, due to higher salary standards, but also investments in Pollution Abatement Control are probably higher. German firms could appear more inefficient due to an higher, but costly attention to environmental footprints; reading together table 3 and 4 gives exactly this picture. The higher general inefficiency level directly comes from the small probability of lying on the frontier in 2004 in respect to 2007, another way to say some firms very eco-efficient, corresponding to a First in Class situation, operate together with less advanced realities.

The first introduction of E-PRTR was in 2001, not so far and probably some problem in the adoption of BAT still emerges in 2004. Wide margins for potential contemporaneous increases of turnover and joint contraction of undesirable outputs are underlined by average DDF values higher than 50%.

During the three years period many opportunities are caught and the situation appears more homogeneous at the end. The average distance form the frontier decreases drastically, but good possibilities to enhance green performances still remain also in 2007. Also in this case turnover could be expanded and emission reduced of around 20% if the best technology is adopted by all the observed sample. A less restrictive view of Porter's hypothesis proposed by Murty and Kumar (2003), suggest that a decreasing eco-inefficiencies over time could be seen as a first generic evidence in support.

3.2 Productivity dynamics

Only comparing efficiency levels over time, on the basis of a not fixed frontier does not allow to infer about real path of growth, then SML indexes are estimated on the bases of theoretical steps depicted in previous section. Table 5 shows results for the 2 subgroup of interest and the whole sample, applying geometric mean instead of arithmetic, in line with the index nature of SML indicators. Values bigger than 1 indicate an observed TFP growth while an indicator smaller than 1 shows a regress in the level of observed TFP.

Considering the path under weak disposability gives results more similar to purely ecological performances showed in table 4 Italian firms suffer a negative growth of global productivity around -1%, in line with increasing emissions. On the contrary German firms show a growth around 7% in three years, mainly driven by a catching-up effect, as it is showed by the substantial contribute of the EFF component of SML indexes. In Italy chemical firms are loosing efficiency during the period, while their performances are sustained by higher frontier swift compared with the German case. The total number of firms showing a negative TFP growth is 22 over the 2004-07, 13 from Italy and 9 from Germany.

Table 4: Sequential Malmquist-Lunberger indexes under weak and free disposability

	Weak Disposability			Free Disposability		
	SML_W	EFF_W	$TECH_W$	SML_F	EFF_F	$TECH_F$
Italy	0.99	0.97	1.01	1.02	0.96	1.06
Germany	1.06	1.06	1.00	0.95	0.92	1.03
Total sample	1.02	1.01	1.00	0.99	0.94	1.05

Table 5: Change in sequential TFP indexes due to regulation

	$\Delta_W{}^F$SML	$\Delta_W{}^F$EFF	$\Delta_W{}^F$TECH
Germany	-10.8%	-13.5%	3.1%
Italy	3.7%	-1.4%	5.2%
Total sample	-3.4%	-7.4%	4.2%
H_0 : $INDEX_W$=$INDEX_F$			
Mann-Whitney U test	Not rejected	Not rejected	Rejected
Paired-sample T test	Not rejected	Not rejected	Rejected

Computation of SML under the assumption of free disposability allows to derive conclusion about the effectiveness of productivity enhancement without considering pollution.

A priory expectations suggest that if a firm invest more in green assets or greener inputs, Table 5 shows the magnitude of the difference between the two set of assumption by taking the ratio of SML indexes under free and weak disposability hypothesis subtracting 1. Positive sigh in the indicate that the productivity growth is higher when free disposability is assumed. Non-parametric Mann-Whithney test and parametric matched pair test are performed on the ratios: the two set of estimated SML are considered different only if the hypothesis of equality to 1 is rejected. In the parametric version of the test, geometric mean are applied and thanks to ratios could be computed without losing information: in the case of geometric mean negative values are excluded by computation, given that the sample is unique, the matched procedure is based on differences, equal to zero under. Here this hypothesis on differences is replaced by an hypothesis on a ratio, equal to 1.

In the total sample and in the two subsamples, parametric and non parametric tests are performed in order to verify if SML are different under regulated and unregulated scenarios in the second part of table 5. The tests are run for each component of SML and they show high accordance in rejecting the hypothesis of equality only for the technical progress component. SML are not statistical different under the two hypothesis on bad outputs nor the efficient component (EFF) in which they could be decomposed.

On the contrary the frontier shift component is different and it is reasonable: disposability assumption directly influences the output set and then frontier's shape. The magnitude of this effect is so small that in the end final computed SML does not change significantly.

4. CONCLUSION AND DISCUSSION

This paper is probably the first attempt to investigate eco-efficiency assessment at international level, using productivity indexes corrected for the presence of pollution. Directional distance function approach, a well known methodology to get reliable global efficiency indicators, has been applied to a sample of Italian and German firms operating in very specific field, the base chemical sectors, for the period 2004-2007. Emission data, coming from the European register E-PRTR, are aggregated in order to create a global index of environmental impact used as bad output in efficiency computation based on a deterministic linear programming. Two eco-efficient frontiers are obtained for the two observation years and through the application of sequential Malmquist-Luenberger, reliable TFP growth indexes are calculated for all analysed firms in both period. Comparing the obtained estimates with outcomes of an hypothetical unregulated situation, a rough proxy of regulation implicit costs is derived. The results show that the efficiency scores are not so different between Italian and German firms, partially overturning the evidence from emission analysis. For both the groups average inefficiency strongly decrease from 2004 to 2007, identifying the imitation effect as the stronger component of TFP growth. In term of productivity growth, German firms shows a better performance in comparison with their Italian counterpart, allowing to reduce significantly their impact on environment.

APPENDIX

Table A1 shows in detail each specific activity for which emission are available in the chemical sector

4. Chemical industry

(a) Chemical installations for the production on an industrial scale of basic organic chemicals, such as:

(i) Simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic)

(ii) Oxygen-containing hydrocarbons such as alcohols, aldehydes, ketones, carboxylic acids, esters, acetates, ethers,peroxides, epoxy resins

(iii) Sulphurous hydrocarbons

(iv) Nitrogenous hydrocarbons such as amines, amides, nitrous compounds, nitro compounds or nitrate compounds, nitriles, cyanates, isocyanates

(v) Phosphorus-containing hydrocarbons

(vi) Halogenic hydrocarbons

(vii) Organometallic compounds

(viii) Basic plastic materials (polymers, synthetic fibres and cellulose-based fibres)

(ix) Synthetic rubbers

(x) Dyes and pigments

(xi) Surface-active agents and surfactants

(b) Chemical installations for the production on an industrial scale of basic inorganic chemicals, such as:

(i) Gases, such as ammonia, chlorine or hydrogen chloride, fluorine or hydrogen fluoride carbon oxides, sulphur compounds, nitrogen oxides, hydrogen, sulphur dioxide, carbonyl chloride

(ii) Acids, such as chromic acid, hydrofluoric acid, phosphoric acid, nitric acid, hydrochloric acid, sulphuric acid, oleum, sulphurous acids

(iii) Bases, such as ammonium hydroxide, potassium hydroxide, sodium hydroxide

(iv) Salts, such as ammonium chloride, potassium chlorate, potassium carbonate, sodium carbonate, perborate, silver nitrate

(v) Non-metals, metal oxides or other inorganic compounds such as calcium carbide, silicon, silicon carbide

(c) Chemical installations for the production on an industrial scale of phosphorous-, nitrogen- or potassium-based fertilizers (simple or compound fertilisers)

(d) Chemical installations for the production on an industrial scale of basic plant health products and of biocides

(e) Installations using a chemical or biological process for the production on an industrial scale of basic pharmaceutical products

(f) Installations for the production on an industrial scale of explosives and pyrotechnic products

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