Green investment strategies and export performance: A firm-level investigation

Roberto Antonietti*, Alberto Marzucchi†

Abstract

In this paper we empirically investigate the relationship between investments in environmentally-oriented equipment and firms' export performance. Drawing on Porter hypothesis and firm heterogeneity theory, we adopt a structural model where first we estimate the impact of green investment strategies on the level of productive efficiency (TFP), and second we assess whether induced productivity influences the extensive and intensive margin of exports. Relying on a rich firm-level dataset on Italian manufacturing, our results show that firms with higher productivity, induced among other factors by green investment involving environmental protection and reduction in the use of raw materials, have increased commitment to, and profits from, exports, especially towards countries adopting a more stringent environmental regulatory framework. Our evidence provides a 'green investment-based' explanation for the link between TFP-heterogeneity and trade.

JEL Codes: Q55; Q56; F14; F18

Keywords: exports; firm heterogeneity; green investment strategy; Total Factor Productivity

* Corresponding Author. Department of Economics and Management "Marco Fanno", University of Padova, via del Santo 33, 35123 Padova, Italy. Email: roberto.antonietti@unipd.it
† Department of International Economics, Institutions and Development (DISEIS), Catholic University of Milan (Italy) and INGENIO (CSIC-UPV), Valencia (Spain). Email: alberto.marzucchi@unicatt.it

1. Introduction

Debate on the effect of environmental protection on economic performance has increased in recent decades. In contrast to conventional wisdom that environmental goals are incompatible with greater competitiveness, there is a strand of work that promotes the idea of economic and environmental performance going hand in hand (Porter, 1991; Porter and van der Linde, 1995). This perspective, often described as the Porter Hypothesis (PH) challenges the idea of a trade-off between social benefit and private costs and reconsiders the notion of environmental protection being a burden for industry. Focusing in particular on environmental regulation, Porter and van der Linde (1995: 98) claim that: “properly designed environmental standards can trigger innovation that may partially or more than fully offset the cost of complying with them”. Other contributions provide refinements to the PH (strong, weak, narrow, narrowly-strong), considering the possible relations between regulation, innovation and competitiveness (Jaffe and Palmer, 1997; Costantini and Mazzanti, 2012).

Within the PH framework, the relation between environmental regulation, environmental protection and economic competitiveness has been investigated in several empirical studies (for a review see Iraldo et al., 2011). Although they do not reach consensus, they consider different types of effects including the impacts on productivity and international competitiveness. With respect to productivity, early (see the review by Jaffe et al., 1995) and more recent analyses (Gray and Shadbegian, 2003; Shadbegian and Gray, 2005; Broberg et al., 2010) point to modest, non-significant or even negative effects of environmental regulation, while a number of other recent studies finds at least partial support for PH. This support spans over different industries and geographical contexts, like: oil refineries in the U.S. (Berman and Bui, 2001); Mexican food processing industry (Alpay et al., 2002); offshore oil and gas industry in the Gulf of Mexico (Managi et al., 2005); heavily polluting manufacturing sectors in Japan (Hamamoto, 2006); manufacturing sectors in Quebec (Lanoie et al., 2008) and Taiwan (Yang et al., 2012).

As for the relation between environmental regulation and international competitiveness, evidence of a positive effect of the former on exporting activities comes from analyses of: export dynamics of EU15 countries (Costantini and Mazzanti, 2012), export flows in from 21 OECD countries of technologies for the energy sector (Costantini and Crespi, 2008), and export performance by US environmental products manufacturers (Becker and Shadbegian, 2008).

Despite the increasing empirical evidence, we believe that the literature on the PH has two shortcomings. The first and more general limitation is that the focus is all on the economic effects of environmental regulations,[1] without considering that environmental investments may be driven by a broader set of factors. Especially in contexts characterized by weak regulatory frameworks, other key determinants emerge: these pertain to endogenous and profit-oriented strategies of the firm (Ghisetti and Quatraro, 2013) which refer to Corporate Social Responsibility (CSR) actions (see the review by Lee, 2008) and also intertwine CSR with business performance (e.g. Porter and Kramer, 2006, 2011; Portney, 2008; Nidumolu et al., 2009).[2]

Environmental practices may aim either at reducing the costs or increasing revenues. As for the increase in the revenues, environmental investment can allow the firm to enter specific markets, differentiate products and sell in-house developed environmental technology (e.g. for pollution control). As for the costs reduction, environmental investment can decrease the cost related to litigations, fines and the risks associated with relations with external stakeholders (e.g. government, industry, NGOs, bankers, media, ecological groups and association, trade unions). Furthermore, adopting environmental practices can directly reduce the cost of materials and energy use, capital assets (e.g. by easing access to green or ethical

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[1] With some exceptions (Hamamoto, 2006; Managi et al., 2005), PH-related studies largely use pollution abatement capital investment or operating costs to proxy for environmental regulation strategies.

[2] Managerial literature has pointed also to the relevance of other factors that affect the engagement in environmental practices, like: managerial environmental concerns (Eiadat et al., 2008); dynamic capabilities related to proactive environmental strategies (Martin-Tapia et al., 2010); organizational design and managerial attitudes (Sharma, 2000); customer-supplier relationships (Andersson et al., 1999).

mutual funds), and labour inputs (e.g. by enhancing loyalty and commitment) (Ambec and Lanoie, 2008). In this perspective, environmental investment can clearly result in higher economic performances and effects may emerge on the productivity and international competitiveness of the firm.

Taking stock from this framework, we do not focus on the effect of environmental regulation, but consider the impact of *green investment strategies* (GIS), targeted specifically at reducing the environmental impact of production. We start from the idea that GIS should not be seen as isolated from other business and production strategies, but as part of the firm's entire investment portfolio (Porter and van der Linde, 1995) and linked to investments in other manufacturing technologies (Klassen, 2000).

The second gap addressed by this paper is the absence of a clear microeconomic foundation for the relationship between environmental protection and firms' international competitiveness. In this context, we study whether investing in new capital assets to reduce the environmental impact of production increases firms' export performance. Our main point here is that this relationship cannot be studied through the estimation of reduced-form models. We posit that GIS indirectly influence firms' export performance by improving first their technical efficiency. This hypothesis calls for a structural modelling approach.

To support our hypothesis, we borrow from 'firm heterogeneity' theory (Bernard and Jensen, 1999, 2004; Melitz, 2003; Helpman et al., 2004; Bernard et al., 2007; Melitz and Ottaviano, 2008). Its key prediction is that only firms with high levels of total factor productivity (TFP) – the main source of firm heterogeneity – can engage in international activities, being able to face the sunk costs involved in acquiring information on foreign markets, establishing distribution channels, and so on. However, the sources of these productivity *premia* are seldom explained, leaving these differences among firms being the result of a random draw (Castellani and Zanfei, 2007; Castellani and Giovannetti, 2010). Recent papers try to shed some light on the sources of firm heterogeneity, and attempt to identify the drivers of different modes of internationalization. These studies show that international firms are more innovative (Costantini and Melitz, 2008; Atkeson and Burnstein, 2010; Bustos, 2011; Burnstein and Melitz, 2013), have superior organizational and managerial practices (Bloom and van Reenen, 2007), and benefit from better market access (Lileeva and Trefler, 2010), product diversification (Bernard et al., 2011) or agglomeration economies (Antonietti and Cainelli, 2011a; Rodriguez-Pose et al., 2013).

In the present paper, we argue that, in addition to factors already elicited by these studies, environmentally-oriented investments are a source of firm heterogeneity and also impact indirectly on the internationalization of firms by affecting their productivity levels. Controlling for confounding factors, we would expect firms with fixed investments aimed at mitigating the environmental impact of production to show higher levels of technical efficiency (i.e. through their impact on TFP) and, thus, to show greater international competitiveness (in terms of export propensity and intensity).[3]

We add a further point to the analysis of the relation between GIS and firm international competitiveness. Investments aimed at reducing the environmental impact are expected to trigger the introduction of sustainable methods and products, thus enabling the firm to overcome trade barriers imposed to non-sustainable producers (Rugman et al., 1998; Cainelli et al., 2012). Hence, we do expect the productivity enhancement generated by GIS to affect more the capability of firms to penetrate markets with stricter environmental regulations and standards. We address this issue by scrutinizing whether the GIS effect –via TFP – is higher for firms exporting in areas with higher levels of environmental regulation stringency, with respect to firms exporting in areas with less stringent regulations.

[3] Actually, firm heterogeneity theory discriminate between the choice to produce goods at home and sell them abroad (through exports) and the choice to fully produce and sell goods abroad (through foreign direct investments, FDI). Unfortunately, due to the very limited amount of firms investing abroad (only 7 in our sample), we focus only on export decisions. The relationship between GIS and FDI will be object of future research.

The reminder of the paper is organized as follows. Section 2 describes the empirical methodology and econometric model; Section 3 presents the dataset; Section 4 discusses the estimation results; Section 5 concludes and proposes some policy implications.

2. Empirical methodology

Our structural model is based on two equations. The first concerns the relationship between GIS (i.e. investment in equipment and machinery targeted at reducing the environmental impact of production) and the level of productive efficiency, measured by TFP. In this equation, we also control for potential endogeneity, by using credit sources as instruments. We use the prediction from this equation to model the incidence of induced TFP on the firm's export performance. Thus, we test for both the direct and the indirect impact of GIS adoption on the firm's international competitiveness. In particular, we investigate whether a strategy aimed at reducing the environmental impact of production is *per se* sufficient to influence the firm's export choice and performance, or whether a mixed investment strategy is better. In a mixed investment, environmental objectives are tied to other types of objectives such as product quality and quantity improvements, introduction of new products, reductions in the use of raw materials and of labour inputs.

Figure 1 provides a graphical representation of our model, which borrows some elements from the so called 'Green CDM model' (Crépon et al., 1998; Marin, 2012; van Leeuween and Mohnen, 2013). The upper part describes the relationship between GIS and productivity (TFP). The latter is calculated as a residual of a production function with capital and labour as the main inputs, and then estimated including traditional input variables such as R&D and human capital. The lower part block illustrates the relationship between productivity (i.e. TFP-heterogeneity) and export performance. The underlying idea is that GIS do not *directly* affect the decision to commit to exports, as it seems to emerge in the recent literature on environment and international trade (e.g. Martin-Tapìa et al., 2010; Costantini and Mazzanti, 2012; Elliot and Zhou, 2013). Rather, we would suggest that this effect is *indirect*, and passes through the first-stage effect of GIS on TFP. Thus, we propose a ‘green investment-based' explanation of the link between firm heterogeneity and international competitiveness, which better explains why more ‘environment-friendly’ firms should also be more willing to sell their products abroad.

[FIGURE 1 around here]

2.1. The productivity equation

As a first step in our structural model, we assess the relationship between GIS and productivity. We start by estimating a Cobb Douglas production function using labour and capital as inputs. TFP is computed as the residual (*a*) from equation 1, where *y* is the log of value added (deflated by a 2-digit price index), *l* is the labour cost (deflated by a wage index) and *k* is net tangible assets (deflated by a capital price index). In order to reduce the simultaneity bias between inputs and output, TFP is estimated using the semi-parametric method provided by Levinsohn and Petrin (2003), which uses raw materials and the cost of services (all deflated by proper price indexes) as instruments:

$$(1)\quad y_{it} = \beta_L l_{it} + \beta_K k_{it} + a_{it}\,.$$

Since TFP level cannot be measured in meaningful units, we compute firm-specific TFP as the averages of exponential transformations of $\hat{a}_{it}$ divided by the industry means. These scaled values are then log-transformed. Hereafter, our TFP measures will refer to relative measures of how firm-specific TFPs differ from the industry mean in the year considered.

Subsequently, we regress the term *a* on two vectors of variables that are supposed to influence firm efficiency, as in equation 2:

(2) $a_{it} = \gamma_Z \mathbf{Z}_{it-1} + \gamma_I \mathbf{I}_{it-1} + \varepsilon_{it}$.

For the first vector (**Z**), we consider two dummies for the firm's belonging to a business group as either *Group leader* or *Group affiliate* (using firms as both leader and affiliate as the reference point), and a size variable (*Size*) given by the log average number of employees in 2001-2003. We also include the level of human capital (*HC*) measured by the (log) average 2001-2003 share of white collar workers (i.e. top and middle managers, executives and clerks). Innovation capabilities are captured by the log of total 2001-03 R&D expenditure (*R&D*) and its squared term ($R\&D^2$). Finally, we include series of industry and NUTS-1 area dummies to control for industry- and region-specific effects.

The second vector (**I**) includes variables measuring fixed investment strategies related to the purchase of new machinery and equipment over the period 2001-2003 and targeted to a series of specific objects. These variables are created as follows. First, we take the variable measuring total fixed investments in 2001-03 ($Log\_investments_{2001\text{-}03}$), properly deflated by a business investment price index, and log-transformed. Then, we interact it with a series of dummy variables which capture the objectives of these investments. The questionnaire asked firms to rank the importance (high, medium, low) of seven targets of their investment: (i) improving the quality of existing products (*prodimprov*); (ii) increasing the amount of production of existing products (*incrprod*); (iii) producing new products (*newprod*); (iv) lowering the environmental impact (*environment*); (v) lowering the use of raw materials (*lessraw*); (vi) reducing the employment of labour inputs (*lessemp*); (vii) and other objectives (*other*). For each option, we define a dummy equal to 1 if the firm assigned *high* importance to the specific goal.[4] The rationale for the creation of these interacted investment variables is the need to capture both the objectives of firm investment and the corresponding amount in Euros.

[4] In unreported estimates we used 7 alternative dummies which also included the *medium importance* option. The results were not significantly different.

Only creating continuous variables we will be able to estimate the investment elasticity of TFP. Table 1 shows the sample distribution of the seven dummy variables.

[TABLE 1 around here]

At the end of this process we have seven (log-transformed) continuous variables: *Log_prodimprov*, *Log_incrprod*, *Log_newprod*, *Log_environment*, *Log_lessraw*, *Log_lessemp* and *Log_other*.[5] Among these, *Log_environment* is the one directly measuring the firm's GIS.

[TABLE 2A around here]

[TABLE 2B around here]

Since firms can pursue more than one objective (see Table 1), our investment variables overlap. Tables 2a and 2b show that this does not seem to be an issue for our empirical analysis since the level of pairwise correlation remains low.[6] In order to capture the existence of potential interactions between the aforementioned GIS variable and the other six investment strategy variables, we include a series of interaction effects where $Log\_nvestments_{2001\text{-}03}$ multiplies six dummies, which are equal to 1 when the firm assigns high importance to the *simultaneous* pursuit of environmental goals and one of other six objectives. This results in six new GIS variables: *Log_prodimprov*env*, *Log_incrprod*env*, *Log_newprod*env*, *Log_lessraw*env*, *Log_lessemp*env,* and *Log_other*env*. Appendix Table A1 presents some descriptive statistics for these variables.

[5] Appendix Table A1 shows the sample statistics for log fixed investments.

[6] Table 1 shows also that only a small fraction of firms (around 14% on average) declared pursuing only a single objective when investing in new machinery and equipment. Most firms adopt a mixed investment strategy involving more than one objective.

We also want to distinguish the effects of 'end-of-pipe' and 'cleaner production' technologies. The former refer to solutions that do not directly alter the production process (e.g. pollution control technology, or technology reducing GHG and liquid emissions, like filters, separators, scrubbers and so on), but are designed to reduce environmental impact in order to comply with standards and regulation. The latter are designed to reduce waste and emissions by integrating the production process, and substituting for, or improving, existing technologies with the addition of cleaner ones (Frondel et al., 2007)[7].

To this aim, in addition to the six interacted GIS variables that integrate reduction of environmental impact with changes in production and methods, we include *Log_environment_only*, which captures an investment strategy aimed solely at reducing the environmental impact.

Equation 2 is estimated by Ordinary Least Squares (OLS) and the coefficients γ_I are considered as the elasticity of TFP with respect to the corresponding investment strategy types. Although measuring TFP in 2004 and the explanatory variables in 2001-03 should avoid potential simultaneity bias, the impact of fixed investments on TFP may be due to unobserved factors that *ex ante* make more productive firms self-select into investment in capital assets (including environmental ones). If this is the case, the OLS coefficients would be biased. We address this issue by using a two-stage least square (2SLS) approach. Since we cannot assign a specific instrument for each type of investment, we choose to instrument the broader $Log\_investments_{2001\text{-}03}$ variable, from which all the other (log) investment variables are generated.

As instruments, we use four dummy variables measuring the ways by which firms finance their fixed investments. These credit sources include: self-financing, the use of bank credit (either in the short and in the medium-long run), the use of public subsidies or tax reliefs, and the use of venture capital. The identification strategy implied by our approach is that,

[7] Examples of clean production technology range from raw material conversion/low-pollution devices to waste reduction and eco-conservation equipment and services.

conditional on the other controls included in equation 2, the financial instruments used by the firm do not have any impact on the TFP other than through the level of gross fixed investments[8].

2.2. The export performance equation

After estimating equation 2, we extract the predicted value of TFP and use it as a regressor in an export performance equation[9], where the dependent variable is measured as the ratio of export sales over total sales (*EXP_SALES*). Since this variable is observed only in a subset of firms, a potential self-selection effect may arise and bias standard OLS coefficients. Since not all firms are exporters, we re-specify the export performance equation in terms of a generalized Tobit model (hereafter Heckit) through two equations: the first accounts for the propensity to export (measured by the dummy *EXP*) (equation 3.1); the second accounts for export performance (equation 3.2), which we linearize through a logit transformation *LOGIT_EXP*=ln[*EXP_SALES*/(1-*EXP_SALES*)][10]:

$$(3.1)\ EXP_i = \alpha_0^1 + \alpha_{TFP}^1 TFP_i^{PRED} + \alpha_{GIS}^1 GIS_i + \alpha_X^1 \mathbf{X}_i + \alpha_Z Z_i + \varepsilon_i$$

$$(3.2)\ LOGIT\_EXP_i = \alpha_0^2 + \alpha_{TFP}^2 TFP_i^{PRED} + \alpha_{GIS}^2 GIS_i + \alpha_X^2 \mathbf{X}_i + \varepsilon_i\,.$$

X is a vector including a common subset of the covariates included in Equation 2, such as industry and area dummies, and total R&D expenditure in 2001-03, augmented by a dummy

[8] This assumption is confirmed when looking at the pairwise correlation between the four instruments, log investments and TFP. While the correlation between instruments and investments is always significant at 1% level, the correlation with firm-level TFP is always not statistically significant.

[9] We also properly correct the standard errors through a bootstrapping method.

[10] As a robustness check, we also re-estimate equation 3.2 taking *EXP_SALES* in its original proportional form (i.e. bounded between 0 and 1 and with a left-skewed distribution) and using a fractional logit model (Papke and Wooldridge, 1996). In this way, we do not separate export decision from export intensity, but we estimate a single export performance equation, where the zero values are considered as being generated by the same process as all the other proportions. Results remain the same.

measuring foreign ownership (*MNE*).[11] A positive and statistically significant coefficient of α_{TFP} is a sign of the indirect effect of GIS on firm export propensity and intensity. In order to control for GIS having also a direct effect on both *EXP* and *LOGIT_EXP*, we still include significant GIS variables (as emerging from the estimates of Equation 2), and test for the statistically significance of the coefficient α_{GIS}. A statistically significant α_{GIS} would mean that GIS also have a direct effect on firm export performance; a non-significant α_{GIS} and a significant α_{TFP} would be proof that GIS affect firm exports only indirectly, through induced TFP. In addition, we include in equation 3.1 the variable *Z,* which represents an exclusion restriction that makes the Heckit estimates robustly identified. This variable should generate a non-trivial effect on the probability to export, without being related to export intensity. A variable that meets these conditions is the export intensity of the NUTS 3 region (i.e. province) where the firm is located. We compute it as the 1999-2003 average (log) value of exports in province *p* with respect to the national average. Firms located in export-intensive regions should find the access to foreign markets easier, due to the sharing of hard and soft information on international opportunities, partners and competitors, and on best practices, and thanks to the availability of regional facilities, local expertise, public agencies and institutions for the internationalization of firms. Export intensity, instead, does not necessarily depend on firm location: rather, it is affected by firm-specific productive efficiency and technological capability.[12]

[11] In order to meet all the identification conditions, we consider here only a subset of the explanatory variables included in Equation 1. In unreported estimates, we also extended the set of covariates to firm size and group membership: they are never statistically significant, but they are highly correlated with predicted TFP. Here we report the most parsimonious specification of the Heckit model. Variables included in the export equations are also in line with previous studies on the export performance of Italian manufacturing firms (see, among others: Basile, 2001; Sterlacchini, 2001).

[12] Data on yearly regional export values are provided by ISTAT (*Sistemi di Indicatori Territoriali*): http://sitis.istat.it. Our assumption is confirmed by the pairwise correlation between variables: the one with export propensity is 0.18 (significant at 5% level) while the one with export intensity is 0.02 and not statistically significant.

A potential source of reverse causality may affect our estimates, i.e. through the feedback productivity impact of exports, as predicted by the *learning by exporting* hypothesis (Clerides et al., 1998; Salomon and Shaver, 2005; De Loecker, 2007; Wagner, 2007; Lileeva and Trefler, 2010). In this respect, the use of predicted TFP values helps reduce this risk. Although the cross-sectional nature of our data does not allow us to completely eliminate this problem, we can mitigate it by taking *EXP* and *LOGIT_EXP* in year 2006 and TFP in year 2004. In addition, TFP_{2004} is regressed on variables measured in the previous three years (2001-2003). We think that a three-year lag between the two covariates should avoid the possibility that firms become more productive because of engagement into export.[13]

A final analysis on the relationship between GIS and export performance concerns the identification of the regions of export destination. Investments in green technology can be done to penetrate countries and foreign markets where the stringency of environmental regulation is higher (Rugman et al., 1998; Cainelli et al., 2012). We test whether the productivity enhancement generated by GIS affects more the capability of firms to export in markets with stricter environmental regulations and standards. We estimate seven separate probit models in which, as a dependent variables, we use a series of dummies equal to 1 if, in 2006, the firm exported, respectively, in one of the following seven macro-regions: (1) EU-15; (2) other European countries (including Russia and Turkey); (3) Africa; (4) Asia; (5) North America (USA, Canada and Mexico); (6) Latin America; (7) Oceania.[14]

[13] Using the IX Unicredit Survey on manufacturing firms (2001-2003), Antonietti and Cainelli (2011b) show that, where present, the reverse effect of exports on productivity is much lower than the opposite effect. In its survey on exports and productivity, Wagner (2007) reports strong evidence in favor of the self-selection mechanism across a wide range of countries, whereas he does not find any clear evidence of learning by exporting.

[14] Unfortunately, our dataset does not provide any specific information on the single country of export destination. We pooled exports in countries entered the EU after 2004 with exports in other European countries and exports in Russia in order to keep a sufficient amount of observations for the probit estimate. For the same reason we also pooled exports in Asia (excluding China) with exports in China. Among macro-regions, EU-15 and North America (US and Canada) represent the main destinations of Italian exports in 2004-06 (ICE-ISTAT, 2006).

Information on the stringency of environmental regulations is obtained from the 2005-2006 Executive Opinion Survey managed by the World Economic Forum – The Global Competitiveness and Benchmarking Network.[15] According to these data, Oceania, EU-15 and North-America represent the most stringent areas in terms of environmental regulation, whereas Latin America and Africa the laxer ones. Therefore, we do expect to observe the highest impact of induced TFP when Italian firms export to Oceania, EU-15 and North American countries, and the lowest impact when exports are directed to Latin America and Africa.

3. Data

To extract our data we merge the IX and X surveys of manufacturing firms conducted by Unicredit bank (formerly Capitalia and Mediocredito Centrale) covering the period 2001-06. The two surveys provide information on representative samples of 4,289 and 5,137 Italian manufacturing firms respectively. Firms with more than 500 employees are fully represented; firms with 11-500 employees are selected on the basis of macro-region of location, employment size and sector of economic activity. The survey responses provide information on firms' innovative activities, labour force composition and internationalization, and market relationships between firms, banks, customers and competitors.

After merging the two datasets, we dropped firms with missing values for the variables of interest, or those with inconsistencies or negative values for value added, labour costs or capital. The final sample consists of 851 firms.[16] Table 3 shows the structure of the sample

[15] In the survey business executives are asked to rate on a 7-point Likert scale (where 0 stands for "very lax" and 7 for "among the world most stringent") the stringency of their country's environmental regulations. Out of the 124 country-level scores we computed the average stringency scores for seven macro-areas (Africa: 3.28; Asia: 3.72; EU-15: 5.78; Latin America: 3.50; Oceania: 5.96; other European countries and Russia: 4.14; North America: 5.05).

[16] Unfortunately we cannot apply panel data techniques because export data are not available on a yearly basis and because the way firms were asked to rank investment objectives differs between the IX and X survey.

with respect to employment size, macro-area of firm location, and Pavitt industry, compared to the original sample extracted from the IX Survey (2001-03). Table 3 shows that, with respect to the original sample, the merging slightly increases the number of medium and large firms located in the North-Centre of Italy and in the scale intensive and specialized supplier industries. Among the firms in our sample 75% are exporters, as in the 2001-2003 sample, with an average share of export sales of 47%.

[TABLE 3 around here]

Table 4 shows the different levels of productivity (value added and TFP) corresponding to the different investment objectives and export status. We note that, in general terms, investing in new capital assets is associated with a 1.6% average productivity *premium* compared to a loss of almost 7% for not investing at all. In looking at the single investment strategies, we observe that the highest productivity *premia*, both in 2004 and in 2004-2006, are for investments to reduce the use of raw materials and for investments to reduce the environmental impact of production. All other types of investment are associated with a lower level of productivity. Finally, exporting firms exhibit a +2.3% increase in 2004 productivity with respect to the industry mean. Non exporting ones are characterized by a productivity loss (-5%) in 2004, whereas in 2004-06 exporting firms registered a lower productivity loss with respect to domestic ones.

[TABLE 4 around here]

4. Estimation results

Table 5 reports the estimates of our productivity equation: the first-stage in our 'GIS-productivity-export' model.

[TABLE 5 around here]

Column 1 reports the estimation results for the model which considers TFP_{2004} as the dependent variable and, as independent variables, the controls and the seven log-transformed variables of fixed investments. Column 2 reports the same results when the TFP is measured as an average over 2004-2006. Other things being equal, productivity is improved by being a group leader, by increasing employment size, by the share of skilled personnel and by R&D, although only after achievement of a critical mass of investment. Columns 1 and 2 also show that only investments aimed at reducing the use of raw materials significantly affect firm TFP, with an elasticity around 0.006, whereas environment-oriented investments *per se* do not show any significant effect.

As a further specification, we interact the environment-oriented investments with the other types of investment to investigate the impact of more detailed GIS. The results in Column 3 show that TFP is positively affected by investment strategies aimed at reducing both the environmental impact of production *and* the use of raw materials, whereas the other interacted variables are never significant. In this case, the estimated elasticity is 0.008. From these results we can conclude that, if investments are targeted at reducing only the environmental impact of production (e.g. through adopting an end-of-pipe or a pollution control technology), there is no improvement in firm productive efficiency. Improvements to production efficiency emerge only if the firm invests in cleaner production technologies (Frondel et al., 2007) aimed at *simultaneously* reducing environmental impact and use of raw materials.

Finally, Column 4 shows the results for the endogeneity test. As previously explained, we re-estimated the TFP equation including the controls and the general $Log\_investments_{2001\text{-}03}$ variable only, and we test for the endogeneity of this latter variable using, as instruments, four credit source dummies. Results show that the four instruments are highly significant predictors of the level of investments. In addition, the F test is well above the rule-of-thumb value of 10 and the Stock and Yogo minimum eigenvalue statistic is well above the critical value (16.4) for not rejecting the null hypothesis of weak instrument at the 10% level. The problem of over-identification is also rejected by the Hansen J test statistic. Finally, and most important, the robustified Durbin-Watson-Hu test does not reject the null hypothesis of exogeneity of $Log\_investments_{2001\text{-}03}$, so we can consider it to be exogenous.

From the specifications in Columns 3 we extract the predicted value of TFP, and we use it as the main regressor in the export equations. Table 6 shows the corresponding Heckit results.

[TABLE 6 around here]

All our estimates confirm that predicted TFP positively affects both the propensity to export, and its intensity. In particular, we find that a 10% increase in induced TFP is related to a 2.13% increase in the probability to export, and, once entered foreign markets, to a 8.32% increase in the logit share of export sales. On the contrary, we find no evidence of a direct effect of GIS, being the estimated coefficient of *Log_lessraw*env* not statistically significant. Interestingly, we also find that, while the likelihood to export is positively affected by location in export-intensive regions, export performance is driven by R&D and foreign ownership.

Finally, Table 7 shows the probit results for exports of Italian firms in the seven macro-regions described in Section 2.2. We note that the estimated coefficient of predicted TFP is always statistically significant, a clear sign that the 'green' firm-heterogeneity hypothesis holds regardless of the export destination. As expected, we also find that the TFP marginal effect is higher when the firm exports to markets characterized by stricter environmental regulation: the Spearman's rank correlation between the TFP marginal effects and the average degree of environmental regulation stringency is strong (ρ=0.86, p-value=0.014). Exports to highly regulated macro-regions (e.g. EU-15 and North America) tend to benefit more from the GISenhanced productivity gains than exports to less regulated macro-regions (e.g. Latin America and Africa).[17]

[TABLE 7 around here]

From all these results we can characterize the effect of GIS on the export performance of firms as follows. First, it has an effect only if capital assets are aimed at reducing both the environmental impact of production and the use of raw materials. Second, it cannot be properly identified by estimating reduced-form models, it requires a structural modelling approach in which the first stage represents the effect of GIS on productivity. From the international trade perspective, investments in cleaner production technologies can be considered as an additional source of firm heterogeneity together with human capital and R&D, which allows firms to overcome the sunk costs of internationalization. Finally, the area of destination matters in determining the strength of the GIS-TFP-export relationship: GIS-induced productivity gains are particularly relevant for entering strictly regulated foreign markets.

5. Conclusions

Investment in environmental practices may be the result of a large set of factors and motivations, not only regulation (Ghisetti and Quatraro, 2013). These further motivations may be related to costs reduction or revenues increase (Ambec and Lanoie, 2008) and eventually lead to increasing business performances. Developing from these points, this paper empirically investigated whether green investment strategies (i.e. investments in machinery and equipment aimed at reducing the environmental impact of production) influence firms' productivity and international competitiveness.

[17] Oceania represents an exception: despite the strictest environmental regulation, the marginal effect of predicted TFP is not the highest. This may be due to the large transport costs required for exporting goods in that region, that may decrease the importance of GIS as a predictor for the propensity to export there.

Using the firm heterogeneity framework, we estimated a two-stage structural model for a sample of Italian manufacturing firms, that assumed that green investment strategies indirectly impact on firms' export performance, by improving the level of productive efficiency (TFP). Our results show that investing in end-of-pipe technology does not have any productivity effects. However, an environmental investment strategy that integrates environmental protection with reduction in the use of raw materials allows firms to increase their TFP. Having achieved higher productive efficiency allows firms to enter foreign markets and increase their export performance. Such a green investment strategy is found to be particularly suitable to enhance a sustainable technological change that enables firms to penetrate markets characterized by stricter environmental regulations and standards.

From an environmental policy point of view, we have provided additional empirical support for the strong version of the Porter hypothesis. Our evidence shows that, when the mediating role of technical change is properly accounted for, environmental protection can positively affect international competitiveness. In particular, our results contribute to the development of 'properly designed' policy actions, which are a major factor in the Porter hypothesis: the sequence is that supporting the adoption of cleaner production technologies, rather than simply end-of-pipe technologies, can increase firms' internal efficiency and, consequently, their international competitiveness. This means that policies should be directed at avoiding or reducing negative environmental externalities and also at increasing efficiency of use of raw materials.

From an international trade perspective, the paper provides a 'green innovation'-based explanation for the relationship between productivity and trade. In particular, we found that, in addition to R&D and human capital, integrated environmental technologies can determine firm TFP-heterogeneity. We find that more internationalized firms are also more productive and efficient, and this efficiency derives from investment in new capital equipment which integrates a lower environmental impact and reduced raw materials inputs. However, we show also that, in order to properly consider the effect of green investment strategies on firm internationalization entry choices, a structural modelling approach is better than a reduced-form model.

Finally, note that the cross-sectional and survey nature of our data does not allow for generalization of our results. Therefore, our estimated coefficients may be slightly overestimated since they are representative of the case of medium and large firms located in the North of Italy. Future research should focus on more representative longitudinal data, which would better account for endogeneity.

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FIGURES AND TABLES

Figure 1 – The structural model between GIS, productivity and internationalization

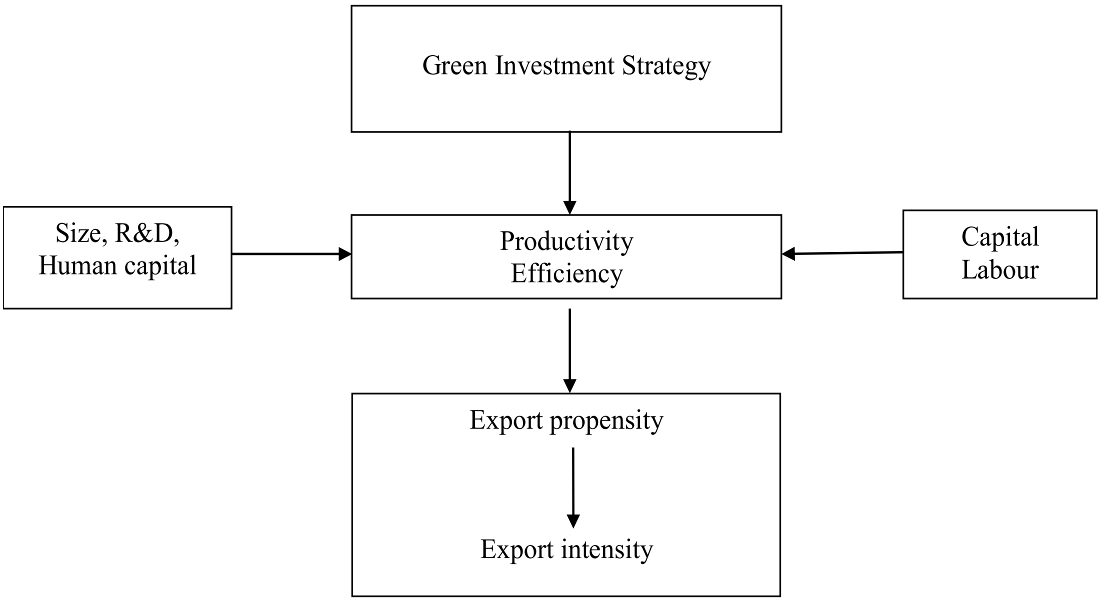

Table 1. Investment strategies: sample distribution

Object	%(*)	N. (total)	N. (only)	Only/Total
1. Product quality improvement	61.1	476	97	20.38
2. Increasing existing production	42.2	329	32	9.72
3. Introduction of new products	28.5	222	32	14.41
4. Lower environmental impact	21.2	165	16	9.70
5. Less raw materials	9.6	75	2	2.67
6. Less employment	16.7	130	11	8.46
7. Other	8.3	65	62	95.38

Note: (*) % is computed with respect to firms declaring to invest in new machinery and equipment. N. (total) refers to the number of firms declaring to pursue that specific object, irrespective to the existence of the other six objects. N. (only) refers to firms declaring to pursue exclusively that single object. Only/Total is the ratio between N.(only) and N.(total).

Table 2a. Correlation among investment strategies: dummy variables

	1	2	3	4	5	6	7
1. Product quality improvement	1						
2. Increasing existing production	0.3207***	1					
3. Introduction of new products	0.1823***	0.1273***	1				
4. Lower environmental impact	0.2198***	0.1173***	0.0945***	1			
5. Lower use of raw materials	0.1674***	0.1788***	0.0891***	0.1935***	1		
6. Employment reduction	0.1203***	0.1794***	0.0676**	0.0479	0.2828***	1	
7. Other	-0.0656*	-0.0012	0.0206	0.0044	0.0667*	0.0255	1

Table 2b. Correlation among investment strategies: log values

	1	2	3	4	5	6	7
1. Log_prodimprov	1						
2. Log_incrprod	0.3666***	1					
3. Log_newprod	0.2218***	0.1545***	1				
4. Log_environment	0.2549***	0.1794***	0.1323***	1			
5. Log_lessraw	0.2105***	0.1955***	0.1173***	0.2185***	1		
6. Log_lessemp	0.1719***	0.2018***	0.1105***	0.0773**	0.2943***	1	
7. Log_other	0.2661***	0.3526***	0.5396***	0.2753***	0.3286***	0.0973***	1

Table 3. Descriptive statistics

Employment size	**2001-03**	**2001-06**
11-20	22.1	10.7
21-50	29.6	23.7
51-250	36.9	50.8
251-500	5.3	6.9
500+	6.1	7.9
Area		
North West	35.9	36.6
North East	30.2	32.7
Centre	17.6	18.3
South	16.3	12.5
Pavitt industry		
Supplier dominated	51.9	48.2
Scale intensive	16.8	18.2
Specialized supplier	26.7	31.4
Science based	4.6	2.5
Export status		
Exporting	74.72	75.09
Non-exporting	25.28	24.91
Export intensity (% export sales, exporters only)	40.09	46.88

Table 4. Investment strategies and export, log value added and Total Factor Productivity

Objects	N	$LogVA_{2004}$	$LogVA_{04\text{-}06}$	TFP_{2004}	$TFP_{2004\text{-}06}$
$Investments_{2001\text{-}03}$ (no)	72	14.80	14.79	-0.067	-0.092
$Investments_{2001\text{-}03}$ (yes)	779	15.28	15.27	0.016	-0.012
Product improvement	476	15.24	15.25	0.009	-0.009
Increasing production	329	15.24	15.24	0.014	-0.006
New product	222	15.34	15.34	0.010	-0.012
Lower environmental impact	165	15.44	15.43	0.050	0.025
Lower environmental impact (only)	22	15.54	15.56	0.028	0.037
Less raw materials	75	15.71	15.70	0.112	0.077
Less employment	130	15.25	15.22	-0.011	-0.047
Other	65	15.16	15.13	0.071	0.022
Exporting	639	15.31	15.31	0.023	-0.008
Non exporting	212	14.90	14.90	-0.050	-0.069

Table 5. The impact of investment strategies on TFP

	(1) TFP_{2004}	(2) $TFP_{2004\text{-}06}$	(3) TFP_{2004}	(4) TFP_{2004}
Log_environment	0.0014	0.0021		
	(0.0021)	(0.0020)		
Log_ prodimprov	0.0003	0.0018		
	(0.0019)	(0.0019)		
Log_incrprod	0.0004	0.0018		
	(0.0018)	(0.0018)		
Log_newprod	-0.0010	-0.0009		
	(0.0020)	(0.0019)		
Log_lessraw	0.0058**	0.0053*		
	(0.0028)	(0.0028)		
Log_lessemp	-0.0021	-0.0035		
	(0.0023)	(0.0024)		
Log_other	0.0032	0.0021		
	(0.0036)	(0.0038)		
Log_environment_only			0.0015	
			(0.0029)	
Log_prodimprov*env			-0.0021	
			(0.0028)	
Log_incrprod*env			0.0009	
			(0.0029)	
Log_newprod*env			-0.0005	
			(0.0029)	
Log_lessraw*env			0.0075**	
			(0.0037)	
Log_lessemp*env			0.0021	
			(0.0045)	
Log_other*env			0.0094	
			(0.0098)	
$Log\_investment_{2001\text{-}03}$				0.0049**
				(0.002)
Group leader	0.154**	0.061	0.163**	0.064
	(0.061)	(0.064)	(0.062)	(0.064)
Group affiliate	-0.050*	-0.046*	-0.053*	-0.041
	(0.028)	(0.028)	(0.027)	(0.027)
Size	0.149***	0.128***	0.149***	0.122***
	(0.016)	(0.017)	(0.014)	(0.017)
HC	0.310***	0.343***	0.321***	0.346***
	(0.101)	(0.103)	(0.107)	(0.100)
R&D	-0.026**	-0.018	-0.027**	-0.022*
	(0.011)	(0.012)	(0.011)	(0.011)
$R\&D^2$	0.002**	0.001	0.002**	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
Industry dummies	Yes	Yes	Yes	Yes
Area dummies	Yes	Yes	Yes	Yes
N	851	851	851	851
R^2	0.285	0.214	0.286	0.281
Instrument#1: self-financing				*3.002****
Instrument#2: bank credit				*2.062****
Instrument#3: public subsidies				*1.213****
Instrument#4: venture capital				*1.543****
1st stage adj. R^2				0.294
Robust F				29.10
DWH endogeneity test				0.060
(p-value)				(0.807)
Min. eigenvalue				39.45
Hansen J test (p-value)				0.171

Notes: cluster (at firm level) robust standard errors in parentheses. * Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 6. TFP-heterogeneity, GIS and export performance, Heckit estimate

	(1) Selection	(2) Logit-export
TFP^{PRED}	0.683***	1.433***
	(0.266)	(0.434)
dy/dx	*0.213****	*0.832****
	(0.072)	*(0.265)*
Log_lessraw*env	-0.004	-0.039
	(0.016)	(0.025)
MNE_{2003}	-0.064	0.687***
	(0.174)	(0.259)
R&D	0.009	0.027**
	(0.008)	(0.014)
EXPORT_NUTS3	1.168**	
	(0.518)	
Industry dummies	Yes	Yes
Area dummies	Yes	Yes
Num. obs.	851	639
rho	0.879***	
lambda	1.941***	

Notes: bootstrapped standard errors in parentheses. *dy/dx* refers to marginal effects at the mean of the dependent variable. Estimates also include a constant term. * Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 7. TFP-heterogeneity, GIS and the export choice by geographical area, probit estimates

Area	β_{TFP_PRED}	dy/dx	Pseudo R^2	HL test (p-value)	% corr. class.
EU-15	0.738***	0.250***	0.071	0.111	71.08
	(0.271)	(0.089)			
Other European	0.535**	0.154**	0.059	0.168	77.20
	(0.248)	(0.072)			
Africa	0.500*	0.059*	0.056	0.442	93.07
	(0.290)	(0.39)			
Asia	0.741**	0.127**	0.210	0.321	89.54
	(0.289)	(0.050)			
North America	1.218***	0.349***	0.087	0.213	77.38
	(0.240)	(0.067)			
Latin America	0.935**	0.110**	0.087	0.150	92.42
	(0.384)	(0.050)			
Oceania	1.638***	0.167***	0.084	0.699	93.84
	(0.279)	(0.030)			

Note: boostrapped standard errors in parentheses. HL refers to Hosmer and Lemeshow goodness of fit test. Estimates also include GIS, MNE_{2003}, R&D, industry and area dummies, and a constant term. * Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Appendix

Table A1. Green investment strategies: sample statistics, in Euros

	Mean	Median	Min	Max	St. dev.
Log investments (total)	4,220,807	775,303	0	2.46e+08	1.40e+07
Log investments (>0)	4,880,308	1,018,888	1,755.03	2.46e+08	1.49e+07
Log_prodimprov	5,184,668	1,170,017	1,755.03	2.46e+08	1.75e+07
Log_incrprod	5,148,031	1,209,401	5850,08	1.24e+08	1.48e+07
Log_newprod	4,867,045	1,170,017	12,718.9	9.90e+07	1.11e+07
Log_environment	9,294,235	1,462,521	1755,03	2.46e+08	2.62e+07
Log_lessraw	8,908,155	1,209,736	40,241.5	2.46e+08	3.11e+07
Log_lessemp	3,618,975	1,006,528	40,241.5	1.00e+08	9,952,640
Log_other	323,537	0	0	9.90e+07	3,752,292
Log_environment_only	94,015.4	0	0	2.49e+07	1,226,167
Log_prodimprov*env	9,304,000	1,413,611	1755,03	2.46e+08	2.86e+07
Log_incrprod*env	1.03e+07	1,809,491	40241,5	1.05e+08	2,32e+07
Log_newprod*env	9,230,975	1,632,408	48,458.1	9.90e+07	1.76e+07
Log_lessraw*env	1.54e+07	1,407,939	40241.5	2.46e+08	4.58e+07
Log_lessemp*env	7,980,829	2,101,340	40,241.5	1.00e+08	1.87e+07
Log_other*env	185,465	0	0	9.90e+07	3,567,779