The green investments and competitiveness of the Italian manufacturing system[1]

Received
13th June 2016
Revised
12th October 2016
Accepted
15th February 2017

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Abstract

Purpose of the paper: *This paper aims to verify whether investments in climate change mitigation and adaptation would result in sectoral gains in relation to the way in which resources are allocated and used, thus potentially contributing to the competitiveness of Italian manufacturing firms.*

Methodology: *We carried out an econometric analysis on a data set drawn from the annual Istat Structural Business Statistics (SBS) with specific reference to manufacturing sectors based on their size class during the middle years of the economic crisis (2009-2012).*

Findings: *We find that expenditures in climate change mitigation and adaptation have positive and significant effects on business performance in terms of labour productivity over the whole period considered.*

Research limits: *Some limitations apply to this study. The relationship between investments in environmental technologies and different measures of economic performance should be explored, possibly from a comparative perspective. Additional research is also needed to explore firm-level environmental behaviours in order to bring out potential heterogeneity and difference in economic performances.*

Practical implications: *Our results are in line with the hypothesis that firms having environmental concerns and devoting substantial resources to green technologies may also improve their economic performance and competitiveness. Evidence from this study also indicates that there is great potential in adopting more proactive environmental strategies other than compliance-driven ones. From this perspective, the so-called Paris Agreement creates huge market opportunities at a global level.*

Originality of the paper: *Several studies have recently attempted to assess the effects of the decarbonisation process on business performance and industrial competitiveness. This paper brings new insights into the economic effects of environmental activities and green management by focusing on the relationship between investments in green technologies and productivity, still regarded as the foundation of industrial competitiveness.*

Key words: green technologies; investments; productivity; manufacturing industry; environmental policies

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[1] Disclaimer:
The views expressed in the article are those of the authors and not of the institutions they are affiliated with.
Acknowledgements:
We thank Fabio Di Sebastiano and Paolo Perciballi for their assistance in the database building and econometric analysis.

1. Introduction

Several studies have recently attempted to assess the effects of the decarbonisation process on business performance and industrial competitiveness. The persisting economic crisis has further widened the divergence between those who identify environmental protection as a burden, particularly for the manufacturing sector, and those who, by contrast, envisage major opportunities for future growth precisely in more sustainable economic processes (Rodrik, 2014).

While the adoption of environmental management in the organizational and production process has increasingly become a strategic issue within the current competitive scenario (Ki-Hoon, 2009), there are no clear-cut conclusions concerning the nature of the relationship between environmental proactivity and economic performances.

As a matter of fact, global investments in the so-called green sectors have increased exponentially, signalling an expanding commitment in environmental protection, although mainly as a result of the support policies that are implemented, to different extents, in many countries. Looking at renewable energies, often considered as a good proxy of overall trends, global expenditures in environmental sustainability have increased more than fivefold between 2004 and 2014, going from only 45.1 billion to 270.2 billion U.S. dollars, with an average annual growth of 20% (Frankfurt School-UNEP, Bloomberg New Energy Finance, 2015). This is a much more marked increase compared to the totality of the investments, which grew by about 7% in annual average over the same period (IMF, 2015). The economic crisis has only partially hindered the described trend, which is instead bound to strengthen further over the next decades insofar as the new agreement negotiated in the Paris Climate Conference (COP21) to contain the increase of global warming under 2°C will be effectively put into place.

Full assessment of the economic effects of green investments is complex (Iraldo *et al.*, 2011). From a theoretical point of view, the existence of a potential conflict between environmental sustainability and economic, as well as financial, performances has been progressively called into question on company, sectoral or national levels (Jaffe *et al.* 2003; Rodrik, 2014). Following the seminal contributions of Porter (1991) and Porter and van der Linde (1995), attention has mostly been paid to the economic consequences of environmental regulation and the effectiveness of the different regulatory instruments that can be potentially introduced (Koźluk and Zipperer, 2013; Dechezleprêtre and Sato, 2014). More recently, managerial studies founded on a resource based view framework contributed to shift the focus on the competitive benefits of green management and firms environmental conducts, regardless of whether or not they were the outcomes of specific obligation (Hart, 1995; Hart and Dowell, 2011; Pane Haden *et al.*, 2009; Costantini and Mazzanti, 2012). Indeed, improvements in environmental performance can be the results of a complex set of motivations that are not mutually exclusive, ranging from standard financial considerations to compliance and domestic law and regulation, or from ethical and social concerns to marketing policies. When beyond-compliance behavior is taken into account, the subsequent effects can be rather different both at a firm and industry level. Potential competitive advantages can stem from a more efficient use of resources, future cost savings, gains in productivity, the opening of new market opportunities, reduced cost of compliance, etc. (Ambec and Lanoie, 2008). Results from empirical literature are however inconclusive in validating or confuting theoretical considerations (Albrizio *et al.*, 2014). Therefore, there is still space for further in-depth analysis, especially in understanding the effects of investments in green technologies on productivity, still regarded as the basis of industrial competitiveness.

For the purpose of bringing new insights into the economic effects of environmental activities, the present article contributes to the empirical investigation of the relationship among investments at an industry level to improve the environmental performances and resource productivity of Italian manufacturing firms. More specifically, the aim is to verify whether investments in climate change mitigation and adaptation would result in sectoral gains in terms of the way resources are allocated and used, thus potentially contributing to firms' competitiveness; if there is a specific role in the productivity gains of green investments compared to other types of investments; whether improvements in productivity are eventually related to technologies that are adopted by firms; and, finally, if those gains rest on the structural characteristics of industries, such as average firm size and energy and raw material intensity, rather than specific environmental policies in combating climate change. Indeed, the industry still remains a key level of analysis for scholars since literature has emphasised that the ability of firms to benefit from green management differs across sectors since they are strongly influenced by specific features of the production process and relative international pressure on the optimization of the use of natural resources, as well as the existence of market-based environmental policies (Koźluk and Zipperer, 2013; Albrizio *et al.*, 2014). Our focus is on investments in green technologies, considered as a proxy of the commitment to green management and to potential improvements in environmental performances (Albrizio *et al.*, 2014). According to Eurostat's definition, green investments are expenditures «resulting from actions and activities which have as their prime objective the prevention, reduction and elimination of pollution and any other degradation of the environment». As is known, in green technologies, the literature distinguishes between integrated technologies (ITs) and end-of-pipe technologies (EOPTs). Although both have the aim of limiting polluting emissions, ITs reduce emissions prima facie by modifying the polluters' production process and/or by adopting cleaner production methods, while EOPTs curb emissions by implementing add-on measures such as anti-pollution devices (Frondel *et al.*, 2007). As ITs generally include the development of new products and/or new production processes, they are considered potentially more advantageous from an economic, as well as an environmental, point of view (Antonietti and Marzucchi, 2013).

The rest of the paper is organised as follows. Section 2 sets the theoretical background to the linkages between green investments and economic performance, with particular reference to productivity. Section 3 presents the empirical analysis carried out on national statistical data and discusses the results. Section 4 looks at managerial implications and concludes.

2. Relationship between investments in green technologies and productivity: theoretical background

The analysis of the relationship between investments in green technologies and productivity is traditionally placed within the wider theoretical debate about the effectiveness of environmental policies and their impact on the competitiveness of firms, industrial sectors and national economies. It is an extremely prolific body of research that was progressively enriched over the last few years as a consequence of the increasing need of a better understanding of the economic effects of environmental policies (Jaffe *et al.*, 1995; Lanoie *et al.* 2008; Morelli and Meleo, 2013; Ambec *et al.*, 2013; Iraldo *et al.*, 2011; Koźluk and Zipperer, 2013; Dechezleprêtre and Sato, 2014; Albrizio *et al.*, 2014).

Even if extremely wide, there are at least two main threads from which theory and insights might be woven.

The first starts from the idea that an investment that is capable of improving productivity will always be made, irrespective of whether it has an environmental purpose or not (Jaffe *et al.*, 1995). Since environmental regulations are promoted to internalise a (negative) externality, their introduction inevitably determines an increase in the cost of the inputs, a reduction in the range of technologies that can be potentially adopted by firms and a deduction of financial resources to more profitable investments (Ambec *et al.*, 2013). Therefore, the expected economic impacts are negative, or neutral at most. As a consequence, an investment in climate change mitigation and adaptation could not be carried out by firms without any specific obligation, no matter if it is imposed by environmental standards, or market based instruments, such as taxes, subsidies, or authorisations (Dechezleprêtre and Sato, 2014; Rubashkina *et al.*, 2014). It is recognised, however, that the overall impact might be different between firm, industry and national level (Iraldo *et al.*, 2011; Koźluk e Zipperer, 2013).

An alternative theoretical point of view rests on the belief that environmental regulation, on the contrary, could reinforce the competitive position of firms, enhancing their performance (Porter, 1991; Porter and van der Linde, 1995). Under the condition that the environmental policies are well designed and properly implemented, the expected effect in terms of productivity will therefore be positive (Lanoie *et al.*, 2008; Brännlund and Lundgren, 2009). Productivity growth would be the effect of the benefits derived from the push towards innovation and technological change that environmental regulation is able to stimulate, whose extent would be such as to overcompensate inevitable compliance costs (Porter and van der Linde, 1995; Frondel *et al.*, 2007). The potential advantages would go beyond that, both with reference to the single firm - more efficient use of resources, access to new markets, increase in product value and differentiation, etc. - and looking at the economic system as a whole - growth in competitiveness, increase in employment, etc. (Ambec and Lanoie, 2008). The solidity of the so-called Porter hypothesis has been, as is well known, a matter of intense debate with an increasing number of contributions trying to empirically settle the theoretical controversy (Ambec *et al.*, 2013; Rubashkina *et al.*, 2014). So far, evidence at firm, industry and aggregate levels does not allow definitive conclusions to be drawn (Jaffe and Palmer, 1997; Costantini and Mazzantini, 2012; Antonietti and Marzucchi, 2014).

Focusing on industry studies dealing more directly with effects in terms of productivity and in particular with the role of firms' investments in green technologies, literature has mainly focused on more polluting sectors and those characterised by more stringent environmental regulations (Koźluk and Zipperer, 2013). Besides, investments in green technologies have been mainly regarded as a proxy of the impact of environmental regulation on firms' strategies (Gray and Shadbegian, 1998; Lanoie *et al.* 2008).

Hamamoto (2006) highlights an increase in investments in research and development, used as a proxy of the innovating activity, connected to a subsequent productivity growth that tends to progressively decrease in five sectors of the Japanese industry with a high environmental impact. A positive impact of environmental regulation on innovative and productive activities is also noticed by Yang *et al.* (2012) with reference to various sectors of the manufacturing industry in Taiwan, whereas Lanoie *et al.* (2008), in focusing on Canadian manufacturing industry, demonstrate that the positive effect on productivity of a stricter environmental regulation is actually delayed due to initial compliance costs, and is generally stronger in the sectors that are most exposed to international competition. Comparing US and Mexican food industry and still using the frequency of environmental inspections as an explanatory variable, Alpay *et al.* (2002) find a null effect on the productivity of the expenditures made for the control and the reduction of pollution in the US, and a positive impact in Mexico. Rubashkina *et al.* (2014) analyse the impact on a European level of environmental regulation on the economic performance of manufacturing sectors, highlighting how stricter policies stimulate innovative activity (with the number of patents as a proxy) but do not seem to affect growth levels and rates of the total factor productivity. Chen e Golley (2014) estimate a lower growth of the total factor productivity in emission-intensive sectors characterised by a high capital/labour ratio, a higher presence of public enterprises and a lower percentage of small enterprises. Albrizio *et al.* (2014) estimate the effects of a stricter environmental regulation at firm, industry and national levels on OECD countries. On a macroeconomic level, the initial negative effect determined by a greater rigidity of the environmental regulation seems to be compensated by a subsequent productivity growth with a negligible net impact over the medium term. On an industry level, the productivity effect would be rather positive in the short term, but less and less relevant when gradually drifting away from the technological frontier and from the most technologically advanced industries; finally, the positive impact would be extremely restricted at a firm level, affecting only a third of the considered firms, while it is even negative for lower productivity firms. In addition, larger firms could eventually benefit more from environmental policies changes due to a more rapid adoption of technologies, the opportunity to better exploit new markets' opportunities, and to externalise and outsource abroad at least part of the production.

More recently, investment decisions in climate change mitigation and adaptation have started to be analysed in the light of the firm's overall strategy without limiting itself to the compliance to environmental regulations (Antonietti and Marzucchi, 2014). Growing concerns about climate change, together with the persisting economic crisis, have provided a further boost towards strategies of investments in technologies capable of improving environmental performances as well as re-launching productivity dynamics and growth (OECD, 2015).

In this perspective, many studies have emphasised the distinction between EOPTs and ITs. Analysing the determinants of firms' investments, Frondel *et al.* (2007) show that investment in EOPTs is determined at least in part by environmental regulations, while the adoption of ITs can reflect more complex reasons and depends, among other things, on market factors. The role of ITs, however, remains difficult to assess, as they should be placed among the firms' wider investment strategies (Klassen, 2000). With reference to a sample of Italian manufacturing industries, Antonietti and Marzucchi (2013) show that the firms that have invested in environmental technologies and in a more efficient use of raw materials have experimented an improvement of the export capacity, especially in countries that adopt stricter environmental legislation. In one of the few studies that explicitly consider the possibility that green technologies can be the result of reasons that differ from the obligations imposed by environmental regulations, Antonietti and Marzucchi (2014) highlight a positive impact of investments in ITs only for firms characterised by lower levels of productivity. However, positive responses seem to be limited to the investments in ITs that aim at the reduction of the consumption of raw materials.

3. Empirical analysis

3.1 Data

The empirical analysis of the relationship between green investments and industrial productivity is based on a data set drawn from the Structural Business Statistics (SBS) annual statistics by Istat, the Italian National Institute of Statistics.

The data refer to all manufacturing sectors, with the exception of the manufacturing of tobacco products, according to the Nace Rev.2 classification at a 2-digit level and to different enterprise size classes, defined in terms of the number of persons employed (fewer than 10 employees, 10-19; 20-49; 50-249; 250 and more). As known, SBS describe the structure, activity, competitiveness and performance of economic activities across the European Union (Istat, 2014). Table A.1 reports the breakdown of Italian manufacturing firms by sector and size class. We estimate some missing data that was not published for determined sector/size classes by Istat for confidentiality reasons but was needed to compute specific variables by means of the application of direct or indirect methods, starting from information derived from other sources of administrative or statistic nature and through the construction of specific parameters.

Focusing on industry-level data has several advantages for the purposes of our study. First, they are designed to be representative of the entire universe of manufacturing activities, thus providing a more comprehensive view on firms' investment trends in the last few years and on their economic effects. It should be noted that investments have been largely hindered by economic crises with high variability among sectors. According to Istat (2014), overall investments by Italian manufacturing firms have declined on average by 6% per year over the 2010-2012 period, while investments in environmental protection, amounting to 2.5 billion euros, proved to be substantially flat in the same period and largely concentrated in large enterprises. In this regards, SBS also provide detailed information on the amount of investments made by Italian firms in environmental protection, which are distinct from other business purposes (such as construction, machinery and equipment, transport vehicles , etc.). Moreover, investments in environmental protection are further classified as investments in EOPTs and ITs, allowing to take into account their potential different effects in business performances (Istat, 2013; Frondel *et al.*, 2007). In the 2009-2012 period, about 69% of green investments by Italian manufacturing firms have been directed to EOPTs. However, while this latter has decreased annually by 8% in the last few years of the economic crisis, investments in ITs have shown an average annual increase of 17% in the same period. Finally, the Istat survey builds a set of data for a greater understanding, at least in monetary terms, of the linkages between production activities and resource consumption, including the use of raw materials and energy inputs.

3.2 Empirical strategy

Consistent with recent empirical studies on industry-level data (Issoufou and Ouattara, 2011; Costantini and Mazzanti, 2012; Antonietti and Marzucchi, 2014; Dognay *et al.*, 2014), we test the research hypothesis by employing an OLS regression.

The effects of investments on economic performance is carried out using two different empirical specifications, where labour productivity at a sectorial level is the dependent variable used as a measure of performance and expressed in terms of real gross value added per hour worked[2].

In the first specification, labour productivity is expressed in absolute values. For this reason, this specification can be defined *structural*, since it aims to test whether investments made by manufacturing firms in the last few years contribute in explaining the current level of sectorial labour productivity.

Analytically, the estimated equation is the following:

$$LP_{ijt_f} = \beta_0 + \beta_1 ARInvG_{ijt_0-t_f} + \beta_x \boldsymbol{I}_{ijt_0-t_f} + \beta_x \boldsymbol{X}_{ijt_0} + \beta_z \boldsymbol{Z_{ij}} \quad [1]$$

In equation [1], LP represents the level of labour productivity in the last year (2012), calculated with reference to each sector *i* Nace Rev.2 (2-digit) and size class *j*, while t_0 represents the first year of the considered time horizon (2009) and t_f represents the last year (2012).

[2] The data on gross value added were opportunely deflated using deflators derived from National economic accounts.

To control for the inherently lagged impacts of investments on economic performance, the investment variable is measured in terms of accumulation rate, that is the ratio of investments to gross value added in the 2009-2012 period (*ARInvG*)[3]. It should be noted that, according to Confindustria (2015), Italian managers usually set the longest acceptable payback period for investments in environmental protection technologies at four or five years. Moreover, the accumulation rate allows them to also control for the high variability of firms' investments, especially in time series analyses. This is particularly true for investments in green technologies that suffer from government decisions on support schemes in addition to other broad macroeconomic determinants such as global risks, economic climate, investors' expectations, and so on.

Vector I includes, within the limits that such a classification inevitably entails, a further categorization of the investments which is aimed at verifying the linkages between expenditures in environmental protection and other capital investments (such as investments in buildings, machinery and equipment, furniture and other equipment, transport vehicles, other assets, patents[4]). Especially when ITs are considered, the decision to invest in environmental protection can only be hardly analysed independently from the overall business objectives of the firms (Klassen, 2000).

Finally, vector X indicates a set of variables, considered at the initial year t_0 of the period (2009), which are used as proxies of the sectorial weight of environmental protection and natural resources issues on investment decisions at a managerial level. More in detail, they refer primarily to resource intensity, which is a measure of efficiency of resource use and is calculated as the value of expenditure in raw materials per unit of product, and to energy intensity, that is the value of expenditure in energy inputs per unit of product. Although rather imprecise, it is expected that the greater value of such indicators, also related to the cost of fossil fuels, may either be a signal of larger future productivity gains deriving from investments in resource efficiency or create competitiveness concerns, especially when their products are traded internationally, due to comparative higher investment costs, to increase environmental sustainability (Eyraud *et al.*, 2011). In contrast, to not completely ignore industry-level differences in environmental mandatory regulations, we include a variable reflecting if the sector is covered by the European Union Emissions Trading Scheme (EU-ETS) in our regressions. As is known, the EU-ETS is the cornerstone of the EU's strategy to limit or reduce greenhouse gas emissions and it covers, above certain capacity thresholds, power stations and other combustion plants, oil refineries, coke ovens, as well as iron and steel plants

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3 Analytically, the accumulation rate (ARInv) is calculated as follows:

$$ARInvG_{t_0-t_f} = \frac{\sum_t Inv_{ijt}}{\sum_t VA_{ijt}}$$

where *t* varies from t_0 to t_f for $t_0 = 2009$ and $t_f = 2012$, *Inv* represents the nominal investment spending in green technologies and *VA* the sectorial gross value added of NACE 2-digit sector *i* and size class *j*.

4 Consistently, Istat survey does not take into consideration green investments as an independent category, but as a sub-classification of the different types of capital investments that are traditionally considered.

and factories making cement, glass, lime, bricks, ceramics, pulp, paper and board[5]. The way environmental mandatory regulations affect economic efficiency and business performance remains a highly controversial issue on an empirical level (Borghesi *et al.*, 2014).

Lastly, vector Z includes control variables related to the particular sector and size class in terms of employment and production. To take into account for endogeneity, we also include the level of productivity at the initial time t_0.

The second empirical specification uses the time variation of labour productivity, ΔLP, comparing the average level of the 2011-12 biennium with the average level of the 2009-10 biennium. This specification can be labelled as dynamic, because it seeks to test the effect of investments in green technologies on labour productivity trends. Analytically, the estimated equation is the following:

$$\Delta LP_{ijt_f} = \beta_0 + \beta_1 ARInvG_{ijt_0-t_f} + \beta_x \boldsymbol{I}_{ijt_0-t_f} + \beta_x \boldsymbol{X}_{ijt_0} + \beta_z \boldsymbol{Z_{ij}} \quad [2]$$

In analogy with specification [1], ARInvG represents the accumulation rate of investments in green technologies; vector I represents the corresponding accumulation rate of investments in buildings, machinery and equipment, furniture and other equipment, transport vehicles , other assets and patents. Vector X is the vector of control variables (production value, employment, energy and raw material intensity and labour productivity), always considered at the initial year t_0; finally, vector Z includes dummy variables referring to the sector and size class in terms of persons employed.

The analysis in dynamic terms of the relationship between investments in green technologies and productivity can provide additional information. In this respect, it has been considered appropriate to further subdivide the investments into green technologies, distinguishing between investments in EOPTs and in ITs.

Tables A.2 and A.3 present the variables used in the econometric analysis and some descriptive statistics. Table A.4 reports the correlation matrix among the variables.

3.3 Results

Overall, the results show that investments in green technologies have a strong impact on labour productivity of manufacturing sectors both in structural terms (specification 1) and in dynamic terms (specification 2).

In the attempt to check for the robustness of the estimates, for each specification, Model A only considers variables related to firms investments; Model B includes the variables related to energy and raw material intensity; Model C includes the variable *ets* reflecting if the sector is covered by the EU-ETS; finally, considering that *ets* and energy intensity variables are highly correlated[6], model D includes only *ets* without considering energy intensity. The dataset comprises 115 records.

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5 The EU-ETS sectors correspond to NACE Rev.2 divisions 17, 19, 23, 24 and 25 (Ecorys, 2009).

6 The four considered EU-ETS sectors are among the first five sectors with high energy intensity.

The positive relationship between investments in green technologies and the way resources are allocated and used, as measured by labour productivity, is robust and meaningful to all the different models tested within each specification. Sectors with higher investments in climate change mitigation and adaptation during the economic crisis have thus experimented improvements in labour productivity. Tables 1 and 2 report the results of the econometric analysis.

Conversely, we find that other capital investments, such as investments in buildings, machinery and equipment, furniture and other equipment, transport vehicles, other assets, and patents do not have the same significant effects on labour productivity. This evidence may be explained in light of the observed trend of fixed investments, which strongly declined during the economic crisis. However, many investments made by firms have multiple purposes (Istat, 2014).

It remains difficult to analyse the interaction between green investments and other capital investments because of the intrinsic problem to isolate and measure the differential contribution of green technologies in terms of the improvement of economic performance (Leiter *et al.*, 2009). This is especially true for investments in machinery and equipment which should theoretically represent the asset category more closely related to the accumulation process and the potential adoption of new technologies in sectors other than manufacturing. Indeed, we estimate a positive effect of investments in machinery and equipment on labour productivity in the dynamic specification. Perhaps more complex variables that consider the interaction between different investments are needed in order to capture this effect. Contrary to what was expected (Chen e Golley, 2014), the results show the absence of a significant relationship between labour productivity and the resource- or energy-intensive nature of single sectors both in the structural and dynamic specifications. In other words, such a result indicates that different values of raw materials and energy expenditures per unit of product are not directly linked to labour productivity. This, in turn, suggests caution in considering them as indicators of related opportunities of manufacturing sectors by improving their efficiency through environmental expenditures.

Among the structural characteristics, we find a positive and significant relationship with the size of the firm at least in the structural specification. More in detail, the estimated coefficients increases along with the enterprise size class, together with an increase in significance. This may point to the existence of some sort of "scale factor" related to the amount of made investments, with greater benefits in terms of resource productivity that would be realized once certain expenditure thresholds are exceeded. Albrizio *et al.* (2014) have argued that the adoption of environmentally friendly practices are associated with larger financial and human resources and that larger firms have better opportunities to benefit from environmental activities.

Tab. 1: Effects of green investments on productivity. Structural specification

	(A)	(B)	(C)	(D)
ARInvG09-12	190.200*** (2.993)	185.196*** (3.427)	185.196*** (3.427)	169.476*** (3.208)
ARInvConstr09-12	33.896 (1.475)	50.109** (2.535)	50.109** (2.535)	55.426*** (2.857)
ARInvMachEquip09-12	-21.498 (-1.274)	-3.408 (-0.218)	-3.408 (-0.218)	-12.234 (-0.869)
ARInvFurnOEquip09-12	-94.747 (-1.326)	-1.856 (-0.030)	-1.856 (-0.030)	-5.871 (-0.096)
ARInvTransp09-12	-245.481* (-1.719)	-184.428 (-1.556)	-184.428 (-1.556)	-180.132 (-1.514)
ARInvOthers09-12	106.202 (0.461)	164.714 (0.831)	164.714 (0.831)	230.544 (1.200)
ARInvPat09-12	6.236 (0.055)	-73.552 (-0.773)	-73.552 (-0.773)	-68.050 (-0.713)
LP09	0.360*** (3.569)	0.474*** (5.303)	0.474*** (5.303)	0.436*** (5.156)
ProdN09	0.000 (-1.006)	0.000 (0.367)	0.000 (0.367)	0.000 (0.613)
EmplT09	0.000 (0.695)	0.000 (-0.260)	0.000 (-0.260)	0.000 (-0.539)
Energy_prodN		-36.989 (-1.276)	-36.989 (-1.276)	
RawMat _prodN		1.379 (1.636)	1.379 (1.636)	0.306*** (6.028)
size10-19 dummy	0.488 (0.158)	1.029 (0.398)	1.029 (0.398)	1.485 (0.577)
size 20-49 dummy	4.304 (1.266)	4.242 (1.488)	4.242 (1.488)	4.841 (1.715)
size 50-249 dummy	7.597* (1.726)	7.589** (2.081)	7.589** (2.081)	7.935 (2.174)
size 250+ dummy	16.215*** (3.216)	14.136*** (3.379)	14.136*** (3.379)	14.457 (3.449)
sect dummy	Yes	Yes	Yes	Yes
ets dummy			6.246* (1.880)	5.731* (1.731)
Observations	115	115	115	115
R^2	0.931	0.954	0.954	0.953
F	29.167	41.485	41.485	42.218
p-value	0.000	0.000	0.000	0.000

Note: t-statistics in parenthesis; *** p<0.01, ** p<0.05, * p<0.1

Source: own elaboration

However, this result is to be expected, given that the preponderant share of expenditure in green investments during the economic crisis period is ascribable to large firms, while micro and small enterprises maintain a very moderate level of expenditure and accumulation rate. It should be noted that, conversely, there is not a clear and marked positive effect of the variable *ets* in the dynamic specification.

Tab. 2: Effects of green investments on productivity. Dynamic specification

	(A)	(B)	(C)	(D)
ARInvG09-12	3.637** (1.453)	3.851*** (1.407)	3.851*** (1.407)	3.313** (1.352)
ARInvConstr09-12	-0.902* (0.497)	-0.719 (0.474)	-0.719 (0.474)	-0.608 (0.468)
ARInvMachEquip09-12	1.460*** (0.377)	1.750*** (0.381)	1.750*** (0.381)	1.551*** (0.351)
ARInvFurnOEquip09-12	3.838** (1.562)	5.100*** (1.479)	5.100*** (1.479)	4.996*** (1.484)
ARInvTransp09-12	-6.731** (3.088)	-6.939** (2.875)	-6.939** (2.875)	-6.489** (2.868)
ARInvOthers09-12	-3.865 (4.929)	-2.849 (4.762)	-2.849 (4.762)	-1.275 (4.630)
ARInvPat09-12	-1.343 (2.421)	-2.180 (2.248)	-2.180 (2.248)	-2.170 (2.258)
LPm0910	-0.006** (0.003)	-0.006** (0.003)	-0.006** (0.003)	-0.006** (0.003)
ProdNm0910	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
EmplTm0910	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Energy_prodNm0910		-1.231 (0.939)	-1.231 (0.939)	
RawMat_prodNm0910		0.044 (0.027)	0.044 (0.027)	0.009*** (0.002)
size 10-19 dummy	-0.081 (0.067)	-0.070 (0.062)	-0.070 (0.062)	-0.061 (0.062)
size20-49 dummy	-0.078 (0.075)	-0.077 (0.071)	-0.077 (0.071)	-0.060 (0.070)
size 50-249 dummy	0.014 (0.098)	0.021 (0.092)	0.021 (0.092)	0.036 (0.092)
size 250+ dummy	0.116 (0.115)	0.101 (0.107)	0.101 (0.107)	0.115 (0.107)
sect dummy	Yes	Yes	Yes	Yes
ets dummy			0.057 (0.081)	0.046 (0.081)
Observations	115	115	115	115
R^2	0.611	0.676	0.692	0.510
F	3.399	4.176	4.176	4.203
p-value	0.000	0.000	0.000	0.000

Note: t-statistics in parenthesis; *** p<0.01, ** p<0.05, * p<0.1

Source: own elaboration

Confirming Jaraité and Di Maria (2012), we find a positive correlation between the inclusion of sectors in EU-ETS and the level of labour productivity. This result provides interesting empirical insights on the debate on the effectiveness of environmental policies and the economic consequences of beyond-compliance behaviours (Koźluk and Zipperer, 2013; Albrizio *et al.*, 2014). Indeed, such a result offers support to Porter's argument that strict environmental regulation may lead to improvements in the productivity with which resources are used (Frondel *et al.*, 2007; Lanoie *et al.*, 2008; Brännlund and Lundgren, 2009; Albrizio *et al.*, 2014). Furthermore, once the variable related to energy intensity is eliminated from the model due to its high correlation with the *ets* variable, the latter still has a positive effect on labour productivity, although it slightly decreases. The described evidence could also be the reflection of investment strategies combining the need to conform to environmental laws and regulations with more advanced environmental management to improve resource productivity and hence competitiveness.

The outcomes of the separate regressions on ITs and EOPTs are shown respectively in Tables 3 and 4. We find that both investments in ITs and EOPTs have a positive effect on labour productivity. It should be noted that ITs generally show a higher intensity of effect, although with a lower significance of relationship (always at 10% except for the model reported in Column D in Table 4). This confirms the argument that ITs are potentially more advantageous - from an economic as well as environmental point of view - than EOPTs (Frondel *et al.*, 2007), although the specific role of ITs on business performances remains difficult to assess (Klassen, 2000).

Tab. 3: Effects of green investments EOPTs on productivity. Dynamic specification

	(A)	(B)	(C)	(D)
ARInvGeop09-12	4.403** (1.726)	4.653*** (1.652)	4.653*** (1.652)	4.113** (1.600)
ARInvConstr09-12	-0.893* (0.496)	-0.700 (0.472)	-0.700 (0.472)	-0.596 (0.466)
ARInvMachEquip09-12	1.470*** (0.376)	1.751*** (0.380)	1.751*** (0.380)	1.561*** (0.349)
ARInvFurnOEquip09-12	3.779** (1.559)	5.047*** (1.475)	5.047*** (1.475)	4.957*** (1.479)
ARInvTransp09-12	-6.518** (3.091)	-6.682** (2.872)	-6.682** (2.872)	-6.273** (2.864)
ARInvOthers09-12	-3.846 (4.922)	-2.716 (4.741)	-2.716 (4.741)	-1.250 (4.612)
ARInvPat09-12	-1.406 (2.416)	-2.253 (2.240)	-2.253 (2.240)	-2.229 (2.249)
LPm0910	-0.006** (0.003)	-0.005* (0.003)	-0.005* (0.003)	-0.006** (0.003)
ProdNm0910	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
EmplTm0910	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Energy_prodNm0910		-1.162 (0.928)	-1.162 (0.928)	
RawMat_prodNm0910		0.042 (0.027)	0.042 (0.027)	0.009*** (0.002)
size 10-19 dummy	-0.079 (0.067)	-0.067 (0.062)	-0.067 (0.062)	-0.058 (0.062)
size20-49 dummy	-0.076 (0.075)	-0.073 (0.071)	-0.073 (0.071)	-0.057 (0.070)
size 50-249 dummy	0.016 (0.098)	0.025 (0.092)	0.025 (0.092)	0.040 (0.091)
size 250+ dummy	0.117 (0.115)	0.103 (0.107)	0.103 (0.107)	0.118 (0.106)
sect dummy	Yes	Yes	Yes	Yes
ets dummy				0.041 (0.091)
Observations	115	115	115	115
R^2	0.612	0.678	0.678	0.671
F	3.415	4.208	4.208	4.248
p-value	0.000	0.000	0.000	0.000

Note: t-statistics in parenthesis; *** p<0.01, ** p<0.05, * p<0.1

Source: own elaboration

The positive effects of EOPTs on labour productivity contrast with the findings of Antonietti and Marzucchi (2013) and, in general, with the view that, as green investment adoption is often the outcome of behaviours of mere compliance to environmental regulations, they inevitably cause additional costs, which in turn erode a firm's global competitiveness (Ambec *et al.*, 2013). Such a result is of particular interest, since EOPTs represent more than two-thirds of total investments in the environmental protection of Italian manufacturing firms.

Tab. 4: Effects of green investments in ITs on productivity. Dynamic specification

	(A)	(B)	(C)	(D)
ARInvGtech09-12	12.359* (7.189)	12.267* (7.209)	12.267* (7.209)	9.504 (6.754)
ARInvConstr09-12	-0.945* (0.506)	-0.754 (0.489)	-0.754 (0.489)	-0.649 (0.480)
ARInvMachEquip09-12	1.436*** (0.385)	1.700*** (0.391)	1.700*** (0.391)	1.533*** (0.360)
ARInvFurnOEquip09-12	3.933** (1.600)	5.160*** (1.527)	5.160*** (1.527)	5.042*** (1.525)
ARInvTransp09-12	-7.580** (3.144)	-7.757** (2.970)	-7.757** (2.970)	-7.231** (2.934)
ARInvOthers09-12	-3.610 (5.028)	-2.386 (4.916)	-2.386 (4.916)	-0.981 (4.748)
ARInvPat09-12	-1.300 (2.475)	-2.142 (2.320)	-2.142 (2.320)	-2.180 (2.322)
LPm0910	-0.006** (0.003)	-0.006** (0.003)	-0.006** (0.003)	-0.006** (0.003)
ProdNm0910	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
EmplTm0910	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Energy_prodNm0910		-1.073 (0.988)	-1.073 (0.988)	
RawMat_prodNm0910		0.040 (0.029)	0.040 (0.029)	0.009*** (0.002)
size 10-19 dummy	-0.099 (0.067)	-0.089 (0.064)	-0.089 (0.064)	-0.079 (0.063)
size 20-49 dummy	-0.100 (0.076)	-0.099 (0.072)	-0.099 (0.072)	-0.083 (0.071)
size 50-249 dummy	-0.016 (0.099)	-0.009 (0.093)	-0.009 (0.093)	0.005 (0.092)
size 250+ dummy	0.086 (0.116)	0.070 (0.109)	0.070 (0.109)	0.083 (0.108)
sect dummy	Yes	Yes	Yes	Yes
ets dummy			0.015 (0.084)	0.013 (0.084)
Observations	115	115	115	115
R^2	0.595	0.657	0.657	0.652
F	3.180	3.835	3.835	3.898
p-value	0.000	0.000	0.000	0.000

Note: t-statistics in parenthesis; *** p<0.01, ** p<0.05, * p<0.1

Source: own elaboration

4. Conclusions and managerial implications

The relationship between investments in green technologies and business performance has been hotly debated in the last few years. Understanding whether green management has any economic benefits has become even more relevant in light of the economic crisis, since environmental practices and supply-chain sustainability were often seen as a means to improve firms' competitive advantages.

This article relies on SBS data to provide further empirical evidence on the effects of investments in green technologies and on the way resources are allocated and used at an industry level, focusing in particular on Italian manufacturing sectors and on the central years of the economic crisis. Confirming the existing literature (Albrizio *et al.*, 2014), we find that expenditures in climate change mitigation and adaptation have positive and significant effects on business performance in terms of labour productivity over the whole period considered. Improvements in economic performance are not correlated with the raw materials and energy-intensive nature of single sectors, when used as indicators of the related dependency on natural resources and energy inputs at least in monetary terms. From a different point of view, this could imply that these factors are not necessarily penalising in the enhancement of competitiveness of the firm. We found that the inclusion of sectors in EU-ETS has a positive impact on labour productivity that is in line with the findings of previous research on Porter's hypothesis (Frondel *et al.*, 2007; Lanoie *et al.*, 2008; Brännlund and Lundgren, 2009; Albrizio *et al.*, 2014). Finally, there is also some support for the view that investments in EOPTs, even if merely aimed to meet legal requirements, may positively influence economic performances although at a sectoral level. Moreover, in confirming the existing literature (Antonietti and Marzucchi, 2013), we find new evidence in support of the positive impact of ITs.

From a managerial perspective, our results are in line with the hypothesis that firms having environmental concerns and devoting substantial resources to green technologies may also improve their economic performance and competitiveness (Antonietti and Marzucchi, 2013; Costantini and Mazzanti, 2012; Lanoie *et al.*, 2011). The positive effect on labour productivity may be the result of the reduction of inefficiencies caused by pollution as well as of savings in raw materials, water and energy usage deriving from green technologies. Since firms investing in green technologies are those with a greater propensity to innovate, and considering that a large amount of innovation is often embedded in these kind of investments, the latter also stimulate organisational learning and the development of human resources, such as to trigger a virtuous "green-innovation-skills" circle (Symbola Foundation, Unioncamere, 2016). After all, the relationship between green investments and productivity proves to be strong both in structural and in dynamic terms, confirming how such investments may lead to competitive advantages. Evidence from this study also indicate that there is great potential in adopting more proactive environmental strategies than compliance-driven ones. As observed, more than two-thirds of total expenditures in environmental protection has been devoted to EOPTs during the middle years of the economic crisis. Insofar as they often goes together with radically new products, product redesign, changes in production processes, etc., investments in ITs may promote efficiency and enhance the corporate image, competitive advantage and marketing exposure. After all, the entry into force of the so-called Paris Agreement intends to create huge market opportunities at a global level. This, in turn, suggests that fostering investments to improve environmental performance may bring fundamental early-mover advantages to companies.

Some limitations apply to this study and offer opportunities for further research. Firstly, the relationship between investments in environmental technologies and different measures of economic performance, such as total factor productivity, should be explored. Taking advantage of SBS data, the relationships that are suggested in this paper should be empirically tested in different countries to enable comparative studies. Additional research is also needed to explore firm-level environmental behaviours in order to bring out the potential heterogeneity and difference in economic performances. Finally, the analysis of cause-effect mechanisms between green investments and economic performances would require a longer time horizon than the one available here.

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Appendix

Tab. A.1: Italian manufacturing firms by sector and size class (2012)

	number of enterprises		distribution by size class			
	absolute values	% of total	small	medium	large	Total
10.food products	55,100	13.2	98.6	1.2	0.2	100.0
11.beverages	2,891	0.7	96.5	2.9	0.5	100.0
13.textiles	15,291	3.7	97.2	2.5	0.3	100.0
14.wearing apparel	32,376	7.8	98.8	1.1	0.2	100.0
15.leather and related products	15,692	3.8	97.9	1.9	0.2	100.0
16.wood and products made out of wood and cork	31,720	7.6	99.5	0.5	0.0	100.0
17.paper and paper products	4,054	1.0	93.9	5.5	0.6	100.0
18.printing and reproduction of recorded media	16,289	3.9	99.0	0.9	0.1	100.0
19.coke and refined petroleum products	320	0.1	87.8	7.5	4.7	100.0
20.chemicals and chemical products	4,436	1.1	90.4	8.3	1.4	100.0
21.basic pharmaceutical products and pharmaceutical preparations	464	0.1	58.6	28.0	13.4	100.0
22.rubber and plastic products	10,588	2.5	93.5	5.9	0.6	100.0
23.other non-metallic mineral products	21,420	5.1	97.8	1.8	0.3	100.0
24.basic metals	3,811	0.9	89.1	9.2	1.8	100.0
25.fabricated metal products, except machinery and equipment	69,528	16.7	98.1	1.8	0.1	100.0
26.computer, electronic and optical products	5,520	1.3	94.3	4.8	0.9	100.0
27.electrical equipment	8,971	2.1	94.9	4.2	0.8	100.0
28.machinery and equipment n.e.c.	23,685	5.7	93.3	5.9	0.8	100.0
29.motor vehicles, trailers and semi-trailers	2,326	0.6	86.8	9.4	3.9	100.0
30.other transport equipment	2,638	0.6	93.7	4.7	1.5	100.0
31.manufacture of furniture	19,332	4.6	98.0	1.8	0.2	100.0
32.other manufacturing	30,883	7.4	99.3	0.6	0.1	100.0
33.repair and installation of machinery and equipment	39,967	9.6	99.3	0.6	0.0	100.0
Total manufacturing	417,302	100.0	97.6	2.1	0.3	100.0

Source: own elaboration on Istat data

Tab. A.2: Variable definitions

Variables	Name	Calculation
LP	Labour productivity (level)	Ratio of real value added to number of hours worked (VAreal/H)
ΔLP	Labour productivity (change)	Change medium level 2011-12/medium level 2009-10 (Yt / Yt-1)
ARInvG	Accumulation Rate – total Green Investment	Ratio of total Green Investment to value added (InvG/VA)
ARInvGeop	Accumulation Rate – Green Investment end of pipe	Ratio of Green Investment end of pipe to value added (InvGeop/VA)
ARInvGtech	Accumulation Rate – Green Investment integrated technology	Ratio of Green integrated technology Investment to value added (InvGtech/VA)
ARInvConstr	Accumulation Rate –Investment in Costruction, buildings and structures	Ratio of Investment in Construction, buildings and structures to value added (InvCostr/VA)
ARInvMachEquip	Accumulation Rate –Investment in Machinery and Equipment	Ratio of Investment in Machinery and Equipment to value added (InvMachEquip/VA)
ARInvFurnOEquip	Accumulation Rate –Investment in Furniture and Other Equipment	Ratio of Investment in Furniture and Other Equipment to value added (InvFornOEquip/VA)
ARInvTransp	Accumulation Rate –Investment in Transport vehicles	Ratio of Investment in Transport vehicle to value added (InvTransp/VA)
ARInvOthers	Accumulation Rate –Investment in Other tangible goods	Ratio of Investment in Other tangible goods to value added (InvOther/VA)
TAInvPat	Accumulation Rate –Investment in concessions, Patents, licences, trade marks and similar rights	Ratio of Investment in concessions, Patents, licences, trade marks and similar rights to value added (InvPat/VA)
ProdN	Production value in nominal terms	
EmplT	Total number of persons employed	
Energy_prodN	Energy input per unit of product	Ratio of purchases of energy products to production value (Energy/prodN)
RawMat_prodN	Raw materials input per unit of product	Ratio of purchases of raw materials to production value (RawMat/prodN)
sect	Economic sectors 2digit Nace Rev.2	dummy
size	Size class of persons employed	dummy

Source: own elaboration

Tab. A3: Summary statistics

	Mean	S.D.	Min	Max
LP_{12}	33.7484	17.3346	9.2773	93.2358
ΔLP	1.1117	0.1570	0.5296	1.7019
$ARInvG_{09-12}$	0.0034	0.0111	0.0000	0.1042
$ARInvGeop_{09-12}$	0.0023	0.0093	0.0000	0.0892
$ARInvGtech_{09-12}$	0.0011	0.0023	0.0000	0.0150
$ARInvConstr_{09-12}$	0.0365	0.0351	0.0007	0.2664
$ARInvMachEquip_{09-12}$	0.0754	0.0542	0.0039	0.4168
$ARInvFurnOEquip_{09-12}$	0.0130	0.0123	0.0003	0.0739
$ARInvTransp_{09-12}$	0.0104	0.0114	0.0001	0.0533
$ARInvOthers_{09-12}$	0.0039	0.0039	0.0000	0.0225
$ARInvPat_{09-12}$	0.0055	0.0078	0.0000	0.0450
$ProdN_{09}$	6,836,979	7,350,573	134,571	34,401,017
$EmplT_{09}$	35,520	34,004	459	183,952
$Energy\_prodN_{09}$	0.0388	0.1587	0.0039	1.7145
$RawMat\_prodN_{09}$	0.9469	5.4587	0.2011	58.9647

Source: own elaboration.

Tab. A4: Correlation matrix

	LP_{12}	ΔLP	ARInv G_{09-12}	ARInv $Geop_{09-12}$	ARInv $Gtech_{09-12}$	ARInv $Constr_{09-12}$	ARInvMach $Equip_{09-12}$	ARInvForn $OEquip_{09-12}$	ARInv $Transp_{09-12}$	ARInv $Others_{09-12}$	$ARInvPat0_{9-12}$	$Prod_{N09}$	$EmplT_{09}$	Energy_ $prodN_{09}$	RawMat_ $prodN_{09}$
LP_{12}	1.000	0.114	0.393**	0.382**	0.341**	-0.025	0.009	-0.434**	-0.603**	0.279**	0.211*	0.254**	-0.144	0.326**	0.324**
ΔLP	0.114	1.000	-0.013	-0.034	-0.040	-0.038	0.027	0.024	-0.125	0.062	-0.022	0.039	0.019	0.223*	0.217]
$ARInvG_{09-12}$	0.393**	-0.013	1.000	0.993**	0.826**	-0.057	0.311**	-0.180	-0.132	0.167	-0.024	0.164	-0.097	0.094	0.072
$ARInvGeop_{09-12}$	0.382**	-0.034	0.993**	1.000	0.778**	-0.060	0.299**	-0.165	-0.128	0.159	-0.005	0.156	-0.091	0.067	0.046
$ARInvGtech_{09-12}$	0.341**	-0.040	0.826**	0.778**	1.000	0.002	0.320**	-0.187*	-0.112	0.196*	-0.095	0.104	-0.136	0.190*	0.164
$ARInvConstr_{09-12}$	-0.025	-0.038	-0.057	-0.060	0.002	1.000	0.309**	0.387**	0.240**	-0.168	0.224*	-0.205*	-0.157	-0.050	-0.039
$ARInvMachEquip_{09-12}$	0.009	0.027	0.311**	0.299**	0.320**	0.309**	1.000	0.100	0.240**	-0.057	-0.004	-0.026	-0.140	-0.013	-0.039
$ARInvFurnOEquip_{09-12}$	-0.434**	0.024	-0.180	-0.165	-0.187*	0.387**	0.100	1.000	0.581**	-0.298**	0.085	-0.302**	-0.076	-0.103	-0.090
$ARInvTransp_{09-12}$	-0.603**	-0.125	-0.132	-0.128	-0.112	0.240**	0.240**	0.581**	1.000	-0.214*	-0.008	-0.223*	0.143	-0.078	-0.082
$ARInvOthers_{09-12}$	0.279**	0.062	0.167	0.159	0.196*	-0.168	-0.057	-0.298**	-0.214*	1.000	0.094	0,215*	0.028	0.026	0.024
$ARInvPat_{09-12}$	0.211*	-0.022	-0.024	-0.005	-0.095	0.224*	-0.004	0.085	-0.008	0.094	1.000	-0.141	-0.222*	-0.034	-0.031
$ProdN_{09}$	0.254**	0.039	0.164	0.156	0.104	-0.205*	-0.026	-0.302**	-0.223*	0.215*	-0.141	1.000	0.760**	-0.087	-0.085
$EmplT_{09}$	-0.144	0.019	-0.097	-0.091	-0.136	-0.157	-0.140	-0.076	0.143	0.028	-0.222*	0.760**	1.000	-0.068	-0.066
$Energy\_prodN_{09}$	0.326**	0.223*	0.094	0.067	0.190*	-0.050	-0.013	-0.103	-0.078	0.026	-0.034	-0.087	-0.068	1.000	0.997**
$RawMat\_prodN_{09}$	0.324**	0.217*	0.072	0.046	0.164	-0.039	-0.039	-0.090	-0.082	0.024	-0.031	-0.085	-0.066	0.997**	1.000

** Correlation values are significant at the 0,05 level; ** Correlation values are significant at the 0,01 level.*

Source: own elaboration

Academic or professional position and contacts

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sinergie
italian journal of management

ISSN 0393-5108
DOI 10.7433/s102.2017.11
pp. 141-163

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