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REGULAR ARTICLE

Eco-innovation, firms' employment growth, and the mediating role of export activities

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Abstract

This paper analyses the growth-enhancing effect of different types of innovative activities, i.e. standard-innovation and eco-innovation, by focusing on the potential role of exports in mediating the innovation-growth nexus. The empirical study is carried out on a representative sample of Italian firms built by integrating data from the Italian CIS-Community Innovation Survey with the ASIA-FRAME database of the Italian National Statistical Office (ISTAT), which reports information on export values and employment dynamics. The econometric analysis applies a two-step counterfactual analysis and a Structural Equations Model (SEM). Results show that export activities, spurred by engagement in innovation efforts, represent a powerful transmission channel through which innovation displays its effect on firms' employment growth. Moreover, results highlight the existence of some heterogeneity in the capacity of different types of innovation activities (i.e., standard-innovation vs. eco-innovation) to leverage the export channel in fostering firms' employment growth. In particular, the empirical evidence has identified a strong indirect export-mediated impact for Efficiency-improving Eco-innovation. On the contrary, the direct effect of innovation on employment appears to be prevalent in the case of Pollution Reducing Eco-innovation.

Keywords Eco-innovation · Export-mediated effect · Innovation-growth nexus

JEL Classification Q52 · Q55 · L25

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1 Introduction[1]

The relationship between innovation and employment growth has been extensively analysed by the literature. Previous studies mainly conclude for the existence of a positive link between innovative activities and job creation (Pianta & Vivarelli, 2003; Vivarelli, 2013, 2014; Calvino & Virgillito, 2018; Ugur et al., 2018; Montobbio et al., 2023; Arenas Díaz et al., 2024).

Innovation has been found to display a positive effect on employment dynamics across different types of sub-samples and empirical methodologies, although this effect on employment may crucially depends on different conditions. These include the type of industries, countries, economic cycle and methodology considered in the analysis (Arenas Díaz et al., 2024). Moreover, the moderating role of age and size in shaping the conditions under which firms increase their dimension out of their innovative efforts has been found to be relevant (Coad & Rao, 2008; Coad et al., 2016; Colombelli et al., 2013; Flachenecker et al., 2020; Mazzucato & Parris, 2015).

In order to better understand the influence of innovative activities on firms' employment dynamics, previous literature has also highlighted another important distinction to be considered, i.e. the difference between *Standard Innovation* (SI) and *Eco-Innovation* (EI) (see for instance Pfeiffer & Rennings, 2001; Horbach & Rennings, 2013; Leoncini et al., 2019; Colombelli et al., 2021). In particular, in this paper we define EIs as those innovations that have environmental benefits, i.e. a new or improved product or process of an enterprise that reduces negative environmental impacts, compared to the enterprise's previous products or processes, and that has been made available to potential users or brought into use (EUROSTAT, 2024).[2]

With respect to SI, EIs represent a major technological effort to be pursued by firms, for which specific experience and capabilities are required (Horbach, 2008; Rennings et al., 2006; De Marchi, 2012). This is mainly due to the intrinsic complexity of green innovations, which may be carried out only by combining a variety of dedicated knowledge and competences (Ghisetti et al., 2016; Caravella and Crespi, 2020). This aspect appears to be particularly relevant in the case of a specific type of EIs, i.e. Efficiency-improving Innovations (EFI), since they have the double aim of reducing pollution and improving efficiency performance. This dual focus involves more complex and significant investment activities, requiring substantial effort in terms of financial and technological capabilities. This contrasts with innovative activities primarily driven by the need to comply with environmental regulations and focused on pollution-reducing (PR) objectives. These are typically achieved through incremental innovations that involve lower technical risk and require less investment effort. (Horbach, 2008; Veugelers, 2012; De Marchi & Grandinetti, 2013; Caravella & Crespi, 2020; Fernandez et al., 2024).

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[2] In contrast to such definition of EIs we classify as Standard Innovation (SI) all other innovations that do not have environmental benefits.

With respect to SI, the literature on the employment effect of EIs is more limited, and very few studies have examined their impact by accounting for the heterogeneity in the types and objectives of different EI activities (Caravella and Crespi, 2022; Fernandez et al., 2024). However, considering such distinctions is relevant because the specific characteristics of different EI modes make the investigation of the relationship between innovation and employment growth even less straightforward than in the case of SI. In this regard, research has shown that without adequate cognitive, technological, and financial capabilities to leverage the economic potential of environmental innovation, firms risk failing to expand their business, and consequently, their productive capacity and employment base. (Cainelli et al., 2011). In contrast, when adequate resources and capabilities are put in place, firms are more likely to succeed in the extraction of value from eco-innovation-related competitive strategies and consequently boost their growth potential. This, for instance, might explain why smaller and younger firms have been found to be less capable of leveraging eco-innovation to grow (Caravella and Crespi, 2022). These results are consistent with those obtained by Fernandez et al. (2024), who showed an employment growth premium for firms engaging in energy efficiency eco-innovations, which, as previously recalled, display a higher level of complexity with respect to those simply aimed at pollution reduction.

The aim of this paper is to contribute to the relatively scarce literature on the varied effects of different innovation activities, with a particular focus on distinct types of EIs, by highlighting the influence of different types of innovations on export activities and by taking into account the influence that these latter may exert on employment growth. In particular, we argue that, while prior research has primarily concentrated on the direct impact of various innovation activities on employment growth, a certain variability in the total effect might be influenced by the differing intensities of mediated effects that these innovation efforts induce on other drivers of employment growth. Among these, we argue that those related to international competitiveness and export performance are of particular importance. This is due to the varying impacts that specific innovative activities can have on cost reduction and competitiveness, and consequently on export growth, which in turn can influence the labor compensation effect associated with increased demand (Calvino & Virgillito, 2018; Vivarelli, 2014).

Previous research has largely explored the relationship between innovation and export performance from various perspectives, confirming the positive effect exerted by the former to the latter (see, for instance, Wakelin, 1998; Dosi et al., 2015; Ganotakis and Love, 2011; Grazzi et al., 2021). However, the contributions that have jointly investigated the relationships between the three dimensions (i.e., innovation, export, and growth performances) are more limited (Bogliacino et al., 2017; Love & Roper, 2015). Among these, the distinction between standard innovation and different types of eco-innovations has not been previously addressed.

In this paper, the mediating role played by exports in explaining the relationship between innovation and employment growth across different types of innovative activities is investigated through an empirical analysis based on a representative sample of Italian firms constructed by integrating the 7th wave of the Italian CIS – Community Innovation Survey with the ASIA-FRAME database of the Italian

National Statistical Office (ISTAT), which provides information on export values and employment dynamics. The econometric analysis is conducted by applying a two-step counterfactual analysis, estimating (*i*) the causal impact of the idiosyncratic effect of innovation on export, and (*ii*) the predictive power of such effect over firms' employment growth. We corroborate our analysis through a path analysis in Structural Equations Models (SEM) enabling a thorough investigation of the relationships between our focal variables and highlighting the statistical relevance of mediating effects among them.

The main findings demonstrate a positive impact of innovation on firms' employment growth through exports, with eco-innovation playing a key role. In particular, the empirical evidence suggests that firms that undertake more complex and knowledge-intensive innovation processes, such as those associated with EFI EIs, have larger mediated effect through export activities in enhancing their growth performance. In the case of PR EIs results showed a positive direct relationship between innovative activities and employment growth. However, even though PR EIs are able to stimulate export activities, this type of EIs do not display a positive mediated effect on employment via export. The remainder of the paper is structured as it follows. The next section reviews the reference literature and sets out the research hypotheses; Sect. 3 describes the data and provides the empirical framework and methodology. Results are discussed in Sect. 4. Finally, Sect. 5 provides the conclusions and policy implications of the analysis.

2 Background literature and research hypotheses

The empirical debate on the direct employment growth-enhancing effects of innovation at the firm level is a long-standing one. In particular, the microeconometric literature tends to support the existence of a positive relationship between innovation and employment growth, especially when R&D or product innovation are adopted as proxies of innovative activity and mostly when high-technology sectors are considered in the analyses (Calvino & Virgillito, 2018; Montobbio et al., 2023; Vivarelli, 2014). These results suggest that firms that actively engage in innovative practices not only enhance their competitiveness, but also position themselves for long-term growth by improving, among other things, their competitive advantages, market positioning, production efficiencies, cost savings, and adaptation capacities in response to market dynamics.

Innovative activities can also indirectly sustain firms' growth through the export channel since innovation plays a significant role in shaping firms' competitive advantages (Guarascio & Pianta, 2017; Antonelli & Feder, 2021; Benfratello et al., 2022; Fassio, 2022; Brancati et al., 2022). In this respect, relative to their non-innovative peers, innovators tend to be more prone towards international market openness, encouraged by higher profit expectations arising from exporting market novelties (Castellani and Zanfei, 2006). Innovative firms are more likely to better afford the cost associated with exporting activities thanks to the 'extra-returns' from innovation outcomes (Calvino & Virgillito, 2018; Pianta & Vivarelli, 2003; Vivarelli, 2013, 2014). Moreover, exporting experience has been found to be relevant to

guaranteeing stability in innovation activities and, hence, fostering innovation persistence (Andersson & Lööf, 2009; Antonelli et al., 2012; Lööf et al., 2015; Tomàs-Porres et al., 2023). Finally, innovators are provided with superior capabilities, which may translate into better knowledge of markets and higher capacities to fully exploit the growth potential of exporting activities (Agostino et al., 2015).

Building on these considerations, we define the following research hypothesis:

Hp1 *The employment growth-enhancing effect of innovation is positively mediated by export dynamics*.

By recognising, however, that innovation cannot be considered a homogeneous activity, we claim that the mediating role of export may differ with respect to the different types of innovation strategies put in place by firms. In this regard, a fundamental distinction exists between SI and EI, with the latter encompassing innovations primarily aimed at reducing environmental pressure from economic activities (Caravella & Crespi, 2020; Marzucchi & Montresor, 2017). In particular, EIs are developed within a less mastered technological space characterised by a higher degree of complexity (Barbieri et al., 2020; Carrillo-Hermosilla et al., 2010; Ghisetti et al., 2015). For these reasons, to be developed and effectively turned into economic outcomes, EI requires more tangible and intangible resources, especially those reliant on persistent R&D, cooperation-based activities, and external knowledge sources (De Marchi & Grandinetti, 2013; Fabrizi et al., 2018). Such a peculiarity suggests that, when successfully developed, the export premium of technological progress could be superior in the specific case of EIs, given the more complex innovation trajectory and the stronger linkage between innovation and international performance (Lieberman & Montgomery, 1988; Tellis & Golder, 1996). Such an argument also finds support in the bulk of managerial studies devoted to understanding the nexus between innovation and export by differentiating the former across different degrees of 'innovativeness' used as a proxy of complexity. According to Barney (2000), firms carrying out highly innovative strategies benefit from at least three types of competitive advantages over their non- (or less) innovative competitors. First, the higher the level of 'innovativeness', the higher the value of differentiation and diversification strategies and, therefore, the greater the effects on international success (Contractor et al., 2007; Kim & Park, 2010). Second, the higher the level of 'innovativeness', the more difficult it becomes for competitors to imitate (Lages et al., 2009; Schilke, 2014), especially for companies operating in international markets (Lu & Beamish, 2004). Third, the higher the level of 'innovativeness', the stronger the possibility of shaping market demand by directly influencing consumers' tastes and preferences (Tellis et al., 2009).

Hence, while more efforts and capabilities might be needed to develop EIs, when these are properly introduced, they could be particularly effective in shaping the export performance of companies and, in this way, in magnifying the growth potential of innovative activities.

Based on these arguments, and considering the different potential impacts of SI and EI on export dynamics, we define the second research hypothesis as follows:

Hp2 *The strength of the mediating role of exports on the employment growth-enhancing effect on innovation is influenced by the type of innovation* (*Standard or Eco-innovation*).

So far, the limited empirical research on the impact of eco-innovation on employment has not shown fully conclusive results. In particular, a positive impact on employment of eco-innovation, due to the prevailing effect associated with the creation of new markets that require more jobs has been identified by previous empirical literature. Nevertheless, results are still heterogeneous. On the one hand, the introduction of innovations increases the productivity of the firms leading to a negative impact on employment since the increase in productivity determines a reduction of labour and costs. On the other hand, the compensation effect due to increase in demand induced by the reduction of costs and prices could stimulate labour demand (Calvino & Virgillito, 2018; Díaz et al., 2020; Vivarelli, 2014). In this respect, the empirical literature has obtained results that are not entirely conclusive on whether the higher level of production would compensate for the labour losses or not.

According to Fernandez et al. (2024), one possible explanation for these mixed results is that the effects of eco-innovations on employment could vary depending on a set of factors including the specific type of innovation and its related environmental goal (Aldieri et al., 2019a; Caravella and Crespi, 2022), the skill levels of workers (Aldieri et al., 2019b; Burger et al., 2019) and the type of industries classified by environmental impact (Kunapatarawong & Martínez-Ros, 2016).

In this paper we argue that another factor that might explain the heterogeneity in the results emerging from previous literature relates to the varied impact that different types of EIs might have on export performance.

In this respect, recent analyses show that the adoption of more sustainable production processes and/or products improves the international competitiveness of enterprises. The main reason is the growing worldwide demand for goods and services provided with eco-requirements concerning safety and environmental standards (Chai, 2023; García-Quevedo et al., 2020; Lewandowska, 2020; Martínez-Ros & Merino, 2023; Meneto & Siedschlag, 2020). Yet, we may also expect substantial heterogeneity in the strength of the export mediating role on growth channelled by the different aims of EIs, i.e., EFI EIs or novelties merely aimed at PR objectives. Such a classification has been extensively used in the analysis of the determinants and the effects of green innovations since statistical surveys have started to provide detailed data on different eco-innovation strategies (see, among others, Horbach, 2008, 2016; Veugelers, 2012; Horbach et al., 2012). In a nutshell, PR refers to innovations, mainly driven by environmental regulation stringency, that allow for a reduction of negative externalities (in terms of air, soil, water, noise pollution, and dangerous materials) without providing substantial input-saving advantages at process and/or product levels. On the contrary, the achievement of green purposes by EFI EIs is pursued through a decrease in materials and/or energy input per unit of output, leading to efficiency gains (Caravella & Crespi, 2020). Moreover, these innovation activities are typically associated with a high incidence of specialized and highly qualified employees, which

require advanced knowledge management strategies to recruit and manage internal cognitive resources (Horbach, 2008).

This implies that, compared to the former (PR), the realisation of the latter (EFI) takes place through more radical and complex innovative processes that imply a higher degree of risk but also, potentially, larger changes and impact on firms' business activities and economic performances.

In this context, one may expect the mediating role of export to vary according to the specific aim of environmental innovation carried out by companies. In particular, we expect that EFI EIs not only allow firms to comply with international environmental regulations, but also enable firms to achieve significant cost reductions and changes in business activities that can positively affect their competitiveness and further enhance their growth potential via the export channel.

Against this background, we refine the previous hypothesis by introducing an additional one stating that:

Hp3 *The strength of the mediating role of exports on the growth-enhancing potential of Eco-innovation depends on its aim and is larger for Efficiency-improving than Pollution-reducing innovation*.

3 Data, empirical framework and methodology

To investigate our research hypotheses, we employ 5283 Italian firm-level data observations from two different sources. The first is the 7th wave of the Italian CIS—Community Innovation Survey, which provides key information on specific aspects of innovation processes undertaken during the three-year period 2012–2014, while also distinguishing between standard and specific categories of eco-innovation (Table 1). Operationally, we define *Eco-innovation* as encompassing all firms whose innovations result in one or more beneficial environmental impacts. The survey identifies ten distinct types of environmental benefits at both process and product level, including activities aimed at reducing input use per unit, as well as innovations involving the substitution of material with less harmful alternative.[3] The results reveal that 1772 firms, representing just over one-third of the total sample, introduced at least one environmental innovation over the three-year period. To further classify the types of eco-innovation, we distinguish between EFI EIs and PR EIs. This classification is based on an aggregation of the four clusters of environmental innovators identified by Caravella and Crespi (2020) drawing on the same dataset. Specifically, pollution-reducing and recycling innovations are grouped under PR EIs, as these activities primarily aim to mitigate negative externalities (e.g., air, soil, water, and noise pollution, as well as the use of hazardous materials) without significantly reducing production costs. This category includes 1071 firms. The remaining

[3] Due to the limited number of observations—which would have been particularly problematic when distinguishing between different types of EIs—we have not differentiated between product and process innovation.

Table 1 Innovating firms* (2012–2014)

			Freq	Perc
No			2517	47.64
Yes	Standard-innovation		994	18.61
	Eco-innovation		1772	32.60
		Efficiency-improving	701	
		Pollution-reducing	1071	
Total			5283	100

*Manufacturing firms with a minimum of 10 employees (smaller firms are not included in the dataset main sources)

701 eco-innovators fall under the EFI EIs category, comprising firms that innovate along an input-saving technological trajectory, reducing material or energy consumption per unit of output.

The second is the ASIA-FRAME database of the Italian National Statistical Office (ISTAT), which reports information on export values and employment dynamics for the period 2012–2018. We focus on manufacturing firms with at least 10 employees for two key reasons. First, the Community Innovation Survey excludes firms with fewer than 10 employees. Secondly, we concentrate on manufacturing industries because previous research indicates that innovation activities might differ substantially between manufacturing and service industries, requiring specific analysis (Gallouj & Savona, 2009). This distinction appears to be particularly relevant when evaluating different types of eco-innovation (Jové-Llopis & Segarra-Blasco, 2020).

The conceptual framework used for the empirical analysis is sketched in Fig. 1. Precisely, we focus on the link between innovation and a firm's employment growth, assuming that *Innovation* exerts either a direct or an indirect (i.e., *Export*-mediated) effect on *Growth*. Thus, our aim is to disentangle and measure these effects. The temporal structure, with the *Innovation* variable measured from 2012 to 2014, *Export* dynamics assessed between 2014 and 2016, and employment *Growth* evaluated from 2016 to 2018, is designed to eliminate issues related to feedback loops.

Table 2 describes the model's focal variables as well as the set of controls we use in the empirical analyses.

To develop our empirical strategy, we apply a two-step counterfactual analysis. This approach estimates the impact of the idiosyncratic effect of *Innovation* on *Export* and its influence on firms' employment *Growth*. Initially, we investigate how *Innovation* causally influences *Export*. Upon confirming this effect, we use it as a predictor for firms' employment *Growth*. If a significant and positive coefficient is detected, it indicates the presence of an *Export*-mediated effect of *Innovation* on *Growth*.

Thus, following Cerulli et al. (2016) and Cerulli and Potì (2012), in the first step, we estimate the firm-level idiosyncratic causal effects by the conditional Average Treatment Effect (ATE(**x**)), representing the causal counterfactual effect of *Innovation* on *Export*. In the second step, we use the ATE(**x**) as a predictor of firms' *Growth*. In details, in the first step, we apply the Regression Adjustment (RA) approach, which is a parametric alternative to matching when one aims at measuring the impact of a

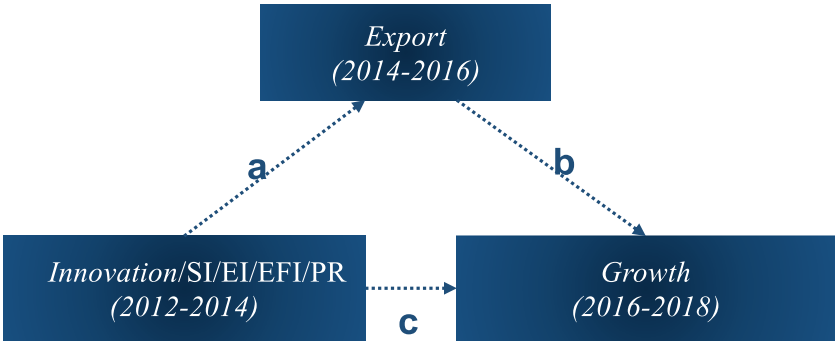

Fig. 1 Conceptual framework: the mediating role of *Export* dynamics in the link between *Innovation* and employment *Growth*

treatment on an outcome. Regression Adjustment is based on a treatment random coefficient model as outlined in Wooldridge (2010, 945–51). This model allows us to estimate, for each company, an idiosyncratic effect of *Innovation*, formally defined as the Average Treatment Effect conditional on a vector of covariates **x** (i.e., ATE(**x**)). On the contrary, in standard regression models, this effect cannot be estimated individually but only as a common (and thus singleton) parameter (typically, the ATE).

Under the assumption of selection on firm's observable characteristics $\mathbf{x}_i$, company *i*'s idiosyncratic average treatment effect for the outcome Y_i, i.e., *Export*, is:

$$ATE(x_i) = m_1(x_i) - m_0(x_i) \tag{1}$$

where $m_1(\mathbf{x}_i) = \mathrm{E}(Y_i \mid \mathbf{x}_i, D_i = 1)$ and $m_0(\mathbf{x}_i) = \mathrm{E}(Y_i \mid \mathbf{x}_i, D_i = 0)$, with D_i equal to the treatment variable. In our case, $D_i = 1$ for firms having introduced an innovation (or, alternatively, a standard/eco- innovation) in the time considered, and zero otherwise. The average effects (Average Treatment Effect, ATE; Average Treatment Effect on the Treated, ATET; and Average Treatment Effect on the Non-treated, ATENT) are estimated as follows:

$$\widehat{\mathrm{ATE}} = \frac{1}{N} \sum_{i=1}^{N} \left[\hat{m}_1(\mathbf{x}_i) - \hat{m}_0(\mathbf{x}_i) \right] \tag{2}$$

$$\widehat{\mathrm{ATET}} = \frac{1}{N_1} \sum_{i=1}^{N} D_i \cdot \left[\hat{m}_1(\mathbf{x}_i) - \hat{m}_0(\mathbf{x}_i) \right] \tag{3}$$

$$\widehat{\mathrm{ATENT}} = \frac{1}{N_0} \sum_{i=1}^{N} (1 - D_i) \cdot \left[\hat{m}_1(\mathbf{x}_i) - \hat{m}_0(\mathbf{x}_i) \right] \tag{4}$$

where the "hat" refers to a consistent estimator of $m_1(\mathbf{x})$ and $m_0(\mathbf{x})$, and N_1 and N_0 are respectively the number of treated and untreated units.

Table 2 Variables' description

Variables	Description	Source
Growth	The rate of growth of the number of employees between 2016–2018	ASIA-FRAME
Innovation (SI/EI/EFI/PR)	Dummy variable that assumes value of 1 if firm i has innovated between 2012–2014 and zero otherwise (process and product innovation). We also distinguish between Standard and Eco-innovation (SI/EI). Within Eco-innovation we further differentiate between Efficiency-improving (EFI) and Pollution-reducing (PR) Eco-innovation	CIS
Export	The rate of growth of exported turnover between 2014–2016	ASIA-FRAME
Employment level (initial)	Number of employees (log) at time 2016	ASIA-FRAME
Export level (initial)	The exported turnover (log) at time 2014	ASIA-FRAME
Size class	Categorical variable (1–3) at 2012 for small (10–49 employees), medium (50–249 employees) and large (> 250 employees) firms	ASIA-FRAME
High-tech industry	Dummy that takes value 1 for firms in high-tech sector and zero otherwise	CIS
Centre-North regions (NUTS2)	Dummy variable that takes value 1 when a firm is located in a northern or central region and zero otherwise	ASIA-FRAME
Energy intensive industry	Dummy that takes value 1 for firms in energy intensive sector and zero otherwise	CIS
Labour productivity	Productivity measured as the ratio (log) between the average (2012–2014) value added and average (2012–2014) number of employees	ASIA-FRAME
Age	Firm's age at time 2014	ASIA-FRAME
Part of a group	Dummy variable that takes value of 1 if a firm is part of a group and zero otherwise	CIS

Both $m_1(\mathbf{x})$ and $m_0(\mathbf{x})$ can be estimated either parametrically or non-parametrically, and the use of a parametric model (as a linear one) corresponds to the RA approach.

RA is well-suited to obtain the idiosyncratic (i.e., firm-specific) effect of the treatment as it directly estimates the conditional Average Treatment Effect on the Treated ATET($\mathbf{x}$). In particular, the analysis of the ATET($\mathbf{x}$) allows us to investigate the overall effect of the *Innovation* event on *Export* beyond the average effect that can be obtained by implementing standard techniques. Indeed, a single effect estimate might be poorly informative on the entire causal relationship between innovation activity and a firm's export performance.

As a second step, we use the estimated ATE($\mathbf{x}$) from the first step as a predictor of the firms' growth equation to evaluate if the idiosyncratic average treatment effect of *Innovation* on *Export* has some predictive power over firms' *Growth*. Thus, we run the following linear model:

$$Growth_i = \beta_{ATE}\widehat{ATE}(x_i) + \beta_W x_i + \varepsilon_I \tag{5}$$

where the firm's *Growth* is a function of the $\widehat{\text{ATE}}(\mathbf{x})$ and of the whole set of controls used in the first step (observable characteristics $\mathbf{x}_i$). If the estimate of β_{ATE} is positive and statistically significant, we can interpret this result as a confirmation of the mediating role of *Export* in the relationship between *Innovation* and *Growth,* since the causal (positive) effect of *Innovation* over *Export* explains firms' *Growth*. We run the above model considering innovation as a whole, separating *Standard-innovation* from *Eco-innovation* and disentangling *Eco-innovation* across *Efficiency-improving* (EFI) and *Pollution-reducing* (PR) innovation.

4 Results

Our key findings stem from the two-step counterfactual analysis previously described, using the Regression Adjustment (RA) method. Before presenting these results, we perform a heterogeneity analysis in the first step by investigating the conditional Average Treatment Effect on the Treated (ATET) units and providing an estimate of the ATET($\mathbf{x}$) distribution (see Fig. 2). Defined as the average effect on treated firms conditional on the pre-specified covariates $\mathbf{x}$, ATET($\mathbf{x}$) measures the firm-specific (average) effect of *Innovation* on *Export*. In this respect, plotting its (estimated) distribution is meaningful. Based on the law of iterated expectations, ATET($\mathbf{x}$) distributions are centered at ATET and can be interpreted as the distributions of firm-specific idiosyncratic (average) effects. Results show that the distribution is well bell-shaped for the general case (*panel a*) and for eco-innovators (*panel c*), with the distribution of eco-innovators presenting larger frequencies for positive values. On the contrary, the distribution of the effect for standard innovators (*panel b*) is bimodal and presents a share of frequencies with negative values. This evidence shows that the predominantly positive impact of *Innovation* on *Export* is primarily fueled by the contributions of *Eco-innovation*. In essence, the substantial influence on *Export* can be chiefly attributed to advancements and practices within the domain of *Eco-innovation*.

Following this, we explore the diversity of the impact on ATET(**x**) by determining the proportion of treated companies (innovators, standard innovators, and eco-innovators) that exhibit a positive *Innovation* effect on *Export*. This further underscores the favourable influence of *Eco-innovation* on *Export* outcomes. Indeed, it emerges that if a company pursues innovation, there's a 99.57% likelihood that it positively impacts *Export*. However, with *Standard-innovation*, the probability drops to 74.95%, whereas *Eco-innovation* increases it to 98.64%. Thus, *Eco-innovation* shows 23.7 percentage point higher likelihood of success in boosting exports compared to *Standard-innovation*, when compared to non-innovators.[4] If we than disentangle *Eco-innovation* into EFI and PR the percentages of treated firms experimenting a positive effect are respectively 97.86% and 85.99%, revealing the existence of some differentiated effect of EFI EIs with respect to PR EIs, and suggesting that it is the former that mainly contributes to the total effect displayed by *Eco-innovation*.

Table 3 reports the main results of the two-step counterfactual analysis in five distinct columns, distinguishing by type of innovation. We start by first analysing the distinction between *Innovation*, *Standard-innovation*, and *Eco-innovation*. In the first step, there's a clear and meaningful positive impact of the treatment (*Innovation*) on *Export*. This impact becomes more pronounced and statistically significant as we shift from *Standard-* to *Eco-innovation*, confirming a stronger influence of *Eco-innovation* on *Export* growth. In the second step, the estimate of ATE(**x**), representing the mediating effect, consistently maintains statistical significance. Particularly noteworthy is its substantial increase in the case of *Eco-innovation*. This suggests not just a greater influence of *Eco-innovation* on *Export* compared to *Standard-innovation* but also a significantly stronger effect of this influence on firms' employment *Growth*.

Overall, our main results confirm that the employment growth-enhancing effect of innovation is positively mediated by export dynamics (Hp1), suggesting that significant differences exist between SI e EI (Hp2), with a pivotal role played by *Eco-innovation* in enhancing firm's *Growth* through its impact on *Export*.

When we move to investigate EFI and PR EIs separately, the positive casual effect on *Export* in the first step is confirmed for both types of Eco-innovation, while in the second step we observe a positive sign only for EFI EIs. This result is consistent with our Hp3 and provides some additional information with respect to previous analyses (Fernandez et al., 2024).

In particular, results show that PR EIs positively affect export growth as they enable to comply with environmental regulations and to access foreign markets. However, the negative sign identified for PR EIs in the second step suggests that their mediated effects through export negatively impact firm size growth, specifically by slowing down employment growth with respect to non-innovators.

[4] In the broader context of *Innovation* (panel a), among 2,766 treated firms, 2,754 show a positive treatment effect (99.57%), while if one considers *Standard-innovation* (panel b), among 994 treated firms, 745 demonstrate a positive treatment effect (74.95%). In the domain of *Eco-innovation* (panel c), out of a total of 1,772 treated firms, approximately 1,748 (98.64%) exhibit a positive treatment effect. When we disentangle *Eco-innovation*, a positive effect is experienced by 686 out of 701 treated firms (97.86%) for EFI eco-innovators and by 921out of 1071 (85.99%) in the case of PR eco-innovators.

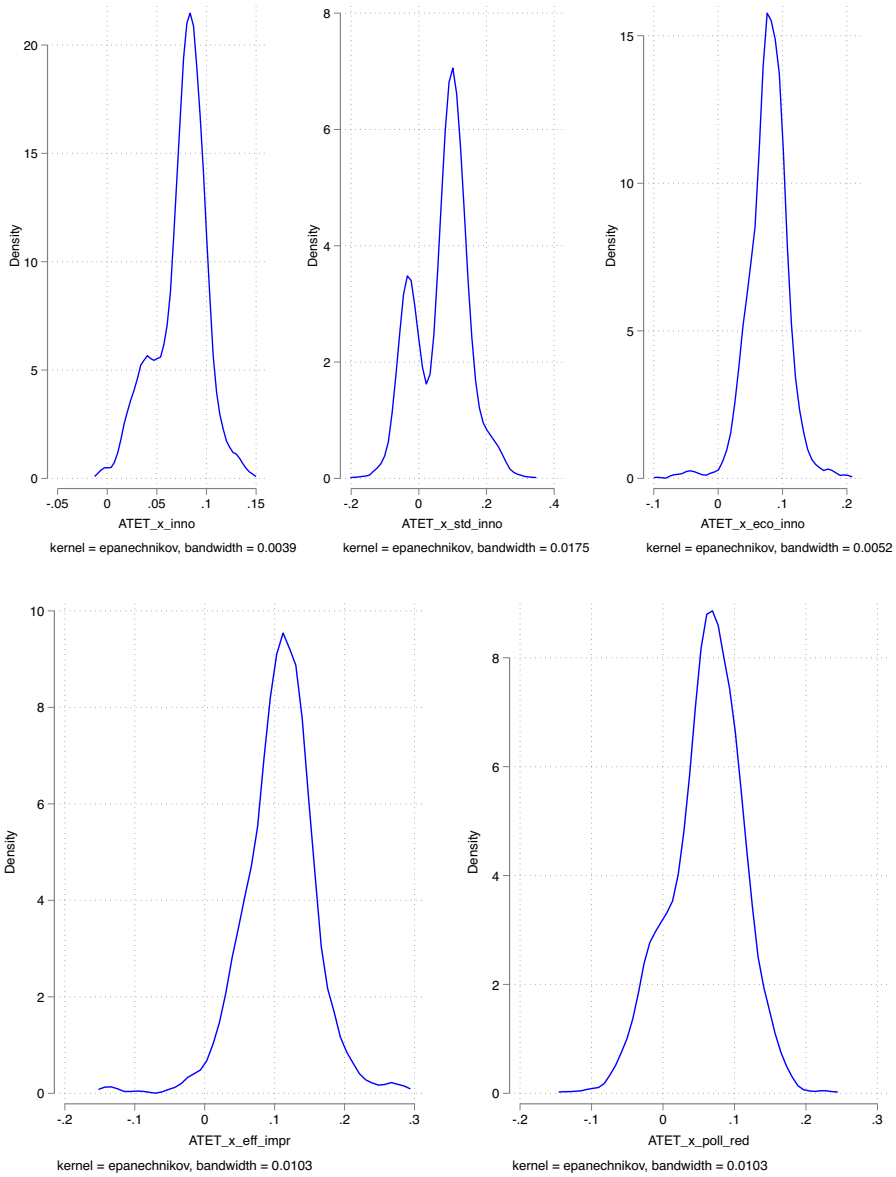

Fig. 2 Kernel density conditional Average Treatment Effects on the Treated (ATET(x)) by innovation type

A possible interpretation of this result can be twofold.[5] Firstly, as it will be further discussed in the next section, the relationship between PR EIs and employment

[5] We would like to thank one anonymous referee to helping us to clarify this point.

Table 3 Two-step counterfactual analysis

	(1)		(2)		(3)		(4)		(5)	
	Innovation		Standard-innovation (SI)		Eco-innovation (EI)		Eco-innovation Efficiency-improving (EFI)		Eco-innovation Pollution-reducing (PR)	
	First step	Second step	First step	Second step	First step	Second step	First step	Second step	First step	Second step
VARIABLES	Export	Growth	Export	Growth	Export	Growth	Export	Growth	Export	Growth
Innovation/Standard/Eco/EFI/PR	0.0699**		0.0568*		0.0871***		0.124**		0.0664**	
	(0.0278)		(0.0295)		(0.0319)		(0.0490)		(0.0335)	
$\widehat{\text{ATE}}(x)$		3.505***		1.472***		19.79***		1.326***		−1.175**
		(1.035)		(0.482)		(6.946)		(0.425)		(0.538)
Export level (initial)	−0.0378***	−0.0130***	−0.0379***	−0.0233***	−0.0377***	0.120***	−0.0378***	0.00617*	−0.0378***	−0.0103***
	(0.00614)	(0.00326)	(0.00615)	(0.00666)	(0.00614)	(0.0433)	(0.00615)	(0.00374)	(0.00614)	(0.00321)
Size class	−0.155***	0.0190	−0.157***	−0.0482***	−0.154***	0.539***	−0.156***	−0.0188	−0.155***	−0.0738***
	(0.0394)	(0.0162)	(0.0393)	(0.0103)	(0.0393)	(0.198)	(0.0393)	(0.0114)	(0.0393)	(0.0217)
Age	0.00575	−0.0657***	0.00623	−0.00273	0.00562	−0.714***	0.00591	0.0168	0.00571	0.0653*
	(0.0352)	(0.0185)	(0.0353)	(0.0120)	(0.0353)	(0.248)	(0.0353)	(0.0128)	(0.0353)	(0.0394)
Employment level (initial)	0.128***	−0.00258	0.128***	0.0315***	0.128***	−0.380***	0.128***	−0.0261**	0.128***	0.0246**
	(0.0228)	(0.00479)	(0.0229)	(0.0106)	(0.0229)	(0.135)	(0.0229)	(0.0119)	(0.0229)	(0.00955)
High-tech industry	−0.0347	0.00928	−0.0118	0.00752	−0.0410	0.0133	−0.0269	0.0238	−0.0368	0.00374
	(0.0329)	(0.0118)	(0.0406)	(0.0135)	(0.0391)	(0.0131)	(0.0469)	(0.0148)	(0.0425)	(0.0136)
Centre-North regions (NUTS2)	0.00838	0.156***	0.00762	0.203***	0.00859	−0.449***	0.00812	0.0309**	0.00845	0.0923***
	(0.0390)	(0.0393)	(0.0389)	(0.0569)	(0.0390)	(0.171)	(0.0389)	(0.0152)	(0.0390)	(0.0265)
Labour productivity	0.0306	−0.00244	0.0319	−0.0160	0.0303	0.142***	0.0311	0.109***	0.0305	0.0577***
	(0.0268)	(0.0113)	(0.0268)	(0.0164)	(0.0268)	(0.0391)	(0.0269)	(0.0244)	(0.0268)	(0.0147)
Part of a group	0.0190	0.0352**	0.0183	0.0629***	0.0192	0.119***	0.0187	−0.0256*	0.0190	−0.0119
	(0.0448)	(0.0141)	(0.0449)	(0.0185)	(0.0448)	(0.0445)	(0.0449)	(0.0152)	(0.0449)	(0.0164)

Table 3 (continued)

	(1)		(2)		(3)		(4)		(5)	
	Innovation		Standard-innovation (SI)		Eco-innovation (EI)		Eco-innovation Efficiency-improving (EFI)		Eco-innovation Pollution-reducing (PR)	
	First step	Second step	First step	Second step	First step	Second step	First step	Second step	First step	Second step
VARIABLES	Export	Growth	Export	Growth	Export	Growth	Export	Growth	Export	Growth
Energy intensive industry	0.00645		0.0113		0.00513		0.00811		0.00601	
	(0.0345)		(0.0343)		(0.0345)		(0.0344)		(0.0344)	
Constant	−0.150	−0.0548	−0.169	0.0945	−0.145	−1.725***	-0.157	−1.530***	−0.149	−0.776***
	(0.301)	(0.104)	(0.302)	(0.139)	(0.302)	(0.489)	(0.302)	(0.372)	(0.302)	(0.242)
Observations	5283	5283	3511	3511	4289	4289	3218	3218	3588	3588
R-squared	0.034	0.010	0.031	0.018	0.036	0.011	0.033	0.016	0.035	0.014

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. The coefficients interactions between the controls and the treatments are not reported for brevity, but available upon request. Note that each category (i.e., Innovation, Standard innovation, Eco-innovation, Efficiency-improving, and Pollution-reducing) are evaluated against the baseline on non-innovators

growth can be mainly explained by the direct effect of innovation on employment rather than by the indirect effect exerted through export. Secondly, as discussed in paragraph 2, the additional foreign demand induced by PR EIs might not fully compensate for the negative impact on employment growth exerted by the substitution effects associated with eco-process innovations and with compliancy costs.

Consistently with Hp3, the empirical evidence also suggests that firms that are able to undertake more complex and knowledge-intensive innovation processes, such as those associated with EFI EIs, have greater advantages in improving their growth performance via the export channel. On the one hand, achieving efficiency gains through more efficient use of inputs can lead to lower market prices and greater competitiveness. On the other hand, engagement in more complex innovation activities, when successful, can also lead to greater changes in business activities and more radical or highly valued innovation outputs, capable of providing firms with significant comparative advantages in foreign markets. These effects jointly contribute to the enlargement of market dimensions, which in turn further enhance their growth potential via the export channel.

4.1 Structural equation models and path analysis

Once the causal export-mediated effect of Innovation on firms' employment growth and the relative importance of EI and SI were identified and measured, we test whether the assumed causal links described in Fig. 1 are confirmed when developing a full-fledged Structural Equation Models (SEM). We therefore conduct a path analysis to estimate the direct and indirect effects of innovation on firms' employment growth.

As represented in Fig. 3, innovative activities can have a direct effect on a firm's *Growth* given by $\boldsymbol{c}$ and an indirect effect through the *Export* channel, which is the mediator. This indirect effect is measured by the product between $\boldsymbol{a}$ and $\boldsymbol{b}$, while the total effect is provided by the sum of the two effects (direct and indirect). As mentioned above, our model allows for the avoidance of contemporaneity between *Export* and employment *Growth* and thus offsets potential endogeneity problems due to reverse causality. The advantage of SEM is represented by the possibility of assessing the role of mediating variables and identifying the magnitude of indirect effects.

We include a set of control variables, usually considered the most relevant predictors of our endogenous variables, capturing firm-specific and structural characteristics. These include size, age, labor productivity, and group affiliation, which account for heterogeneity in resources, capabilities, and organizational structure. Sectoral and locational factors – such as belonging to a high-tech or energy-intensive industry and being located in the Centre-North regions – control for differences in innovation intensity, cost structures, and access to markets. Initial export level and employment size help account for firms' pre-existing international exposure and scale.

We therefore estimate the following system of three simultaneous equations (The entire system of equations is estimated using the entire sample of innovators, then looking at standard vs. eco-innovators as well disentangling between efficiency improving and pollution reducing eco-innovators.):

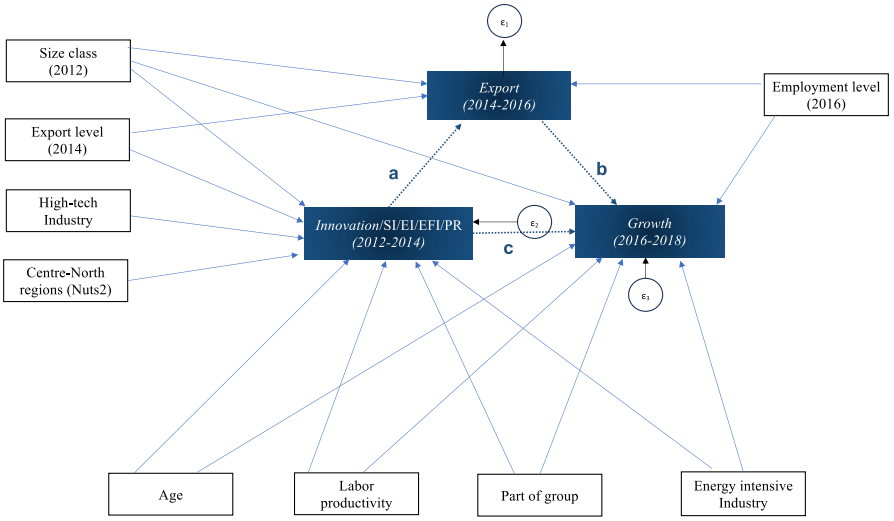

Fig. 3 SEM specification: link between *Innovation* and employment *Growth* with *Export* dynamics mediation

$$\begin{aligned} Innovation = {} & \alpha_0 + \alpha_1 Size\ Class + \alpha_2 Export\ level(initial) \\ & + \alpha_3 Hightech\ Industry + \alpha_4 Centre - North\ regions \\ & + \alpha_5 Age + \alpha_6 Labor\ productivity + \alpha_7 Part\ of\ a\ group + \varepsilon_I \end{aligned} \tag{6}$$

$$\begin{aligned} Export = {} & \beta_0 + \text{a } Innovation + \beta_2 \text{Size Class} + \beta_3 \text{Export level (initial)} \\ & + \beta_4 \text{Hightech Industry} + \beta_5 \text{Centre} - \text{North regions} + \varepsilon_X \end{aligned} \tag{7}$$

$$\begin{aligned} Growth = {} & \gamma_0 + b\ Export + c\ Innovation + \gamma_3 labor\ productivity \\ & + \gamma_5 Part\ of\ a\ group + \gamma_6 Employment\ level\ (initial) \\ & + \gamma_7 Energy - \text{int}ensive\ Industry + \varepsilon_G \end{aligned} \tag{8}$$

Results are reported in Table 4. For each model, we report a full set of diagnostics. A first test of goodness-of-fit is the Chi-squared test. However, there is a general consensus in the SEM literature that the Chi-squared test is highly sensitive (more statistically significant) to large sample sizes and model degrees of freedom (overfitting) (Acock, 2013; Mehmetoglu & Jakobsen, 2016). Thus, a general recommendation is to jointly examine more robust model fit indices. As it is common in the literature, we consider the following goodness-of-fit indices, whose rule-of-thumb reference threshold for indicating a good fit of the model is set out in the brackets: RMSEA (<0.10), CFI (>0.95), TLI (>0.95), and SRMS

(< 0.05) (Hu & Bentler, 1999).[6] In general, all our estimated models show a good model fit with a very low error of approximation (RMSEA).

The results presented in Table 4 indicate that the direct, indirect, and total effects of innovation on firms' growth opportunities are positive and statistically significant. Consistently with the results obtained through the RA methodology, this outcome is primarily driven by EI, as the effects for SI are not statistically significant. Moreover, when focusing on the distinction between different types of EIs, we find that in the case of PR EIs the prevailing mechanism behind the relationship between innovative activities and employment growth is the direct one. On the contrary, indirect effects of innovation efforts mediated by exports, are found to be statistically significant for EFI EIs (Column 4). This confirms that EFI EIs have a positive export-mediated impact on firm employment growth, while this is not true in the case of PR EIs.

In conclusion, the path analysis provides results that corroborate our main findings and research hypotheses (Hp2 and Hp3) regarding the existence of some heterogeneity in the capacity of different types of innovation activities to leverage the export channel in fostering firms' employment growth.

5 Conclusions and policy implications

This paper analysed the growth-enhancing effect of *Standard* and *Eco-innovation* by focusing on the potential role of export in mediating the innovation-growth nexus. In particular, the paper's main contribution focuses on the analysis of the mediating role played by *Export* in explaining the relationship between *Innovation* and employment *Growth* for different types of innovative activities, i.e., *Standard Innovation* and *Eco-innovation*. The empirical study has been carried out on a representative sample of Italian firms built by integrating two waves of the Italian CIS—Community Innovation Survey with the ASIA-FRAME database of the Italian National Statistical Office (ISTAT), which reports information on export values and employment dynamics. The econometric analysis can be divided into two parts.

The first part of the empirical analysis applies a two-step counterfactual procedure by estimating the impact of the idiosyncratic effect of *Innovation* (*Standard* vs. *Eco-innovation*) on *Export* over firms' employment *Growth*. The second part builds a path analysis based on a full-fledge structural equations model (SEM).

The results indicate that export activities, driven by engagement in innovation efforts, serve as a powerful transmission channel through which innovation exerts its impact on firms' employment growth. All in all, the econometric analysis provided results that confirm the existence of significant heterogeneity in the capacity of different types of innovation activities to leverage the *Export* channel fostering firms' employment *Growth*. In this respect, the empirical evidence suggests that firms that undertake more complex and knowledge-intensive innovation

[6] Through a simulation study, Hu and Bentler (1999) investigated the rejection rates under correct and misspecified models by applying various cut-off values for many fit indices.

Table 4 SEM Path Analysis

Effect	(1) Innovation	(2) Standard-innovation (SI)	(3) Eco-innovation (EI)	(4) Eco-innovation Efficiency-improving (EFI)	(5) Eco-innovation Pollution-reducing (PR)
Indirect	0.0016***	0.0014	0.0016**	0.0028**	0.0012
	(0.0006)	(0.0009)	(0.0007)	(0.0012)	(0.0007)
Direct	0.0166*	0.0138	0.0191*	0.0169	0.0274**
	(0.0097)	(0.0116)	(0.0115)	(0.0148)	(0.0128)
Total	0.0182**	0.0152	0.0207*	0.0197	0.0286**
	(0.0097)	(0.1161)	(0.0115)	(0.0148)	(0.0128)
N. Obs	5283	3511	4289	3218	3588
Chi-squared (p-val)	0.0060	0.000	0.000	0.0012	0.000
RMSEA	0.017	0.035	0.023	0.024	0.027
CFI	0.988	0.852	0.985	0.978	0.979
TLI	0.965	0.629	0.956	0.934	0.936
SMRS	0.006	0.013	0.007	0.007	0.008

Standard errors in parentheses

Note that each category (i.e., Innovation, Standard innovation, Eco-innovation, Efficiency-improving, and Pollution-reducing) are evaluated against the baseline on non-innovators

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

processes, such as those associated with EFI EIs, have greater advantages in enhancing their growth performance through export activities. In the case of PR EIs results showed a positive direct relationship between innovative activities and employment growth. However, even though PR EIs are able to stimulate export activities, this type of EIs do not show a positive mediated effect on employment via export.

We recognize that the analysis has several limitations related to sample country specificity and its dimension that does not allow us to enquire the distinction between product and process innovation. Other relevant limits regard the information availability, and the short time span considered in the analysis. Consequently the results provided in this paper should be intended as an attempt to explore the complex mechanisms underlying the employment growth-enhancing effects of different innovation activities, particularly eco-innovation ones. Future research is certainly needed to further validate our results, with respect to the possibility of testing the proposed econometric models on independent data samples from different countries, possibly including longer time spans, in order to properly account for the lag structure of the identified relationships.

The evidence provided in this paper has also relevant policy implications, as it reveals the potential of leveraging the employment growth effects of innovation activities by exploiting the export channel through appropriate policies. In particular, the empirical analysis of the different types of innovation activities (standard and environmentally friendly) shows that, to maximize the impact of

Eco-innovation on firms' growth, innovation policies should be complemented by policies aiming at promoting firms' export capabilities. This implies that specific attention should be devoted to the construction of an appropriate *policy mix* able to foster complementarities between different policy instruments, thus maximising their growth-enhancing effects on the overall economic system. Such considerations appear to be particularly relevant in the current European context, in which the Green Deal Industrial Plan of the European Commission is expected to substantially contribute to the transition to climate neutrality by enhancing the competitiveness of Europe's net-zero industry.

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