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Eco-innovation, firms' 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 Structural Equations Models (SEM) and a two-step counterfactual analysis. Results show that export activities, spurred by engagement in innovation efforts, represent a powerful transmission channel through which innovation displays its effect on firms' growth. Moreover, results highlight the existence of some heterogeneity in the capacity of different types of innovation activities, i.e., standard-innovation and eco-innovation to leverage the export channel to foster firms' growth. In particular, the empirical evidence has identified a stronger indirect export-mediated impact for Efficiency-improving (EFI) than for Pollution-reducing (PR) Eco-innovation.

JEL: Q520, Q550, L250

Keywords: Eco-innovation, Export-mediated effect; Innovation-growth nexus.

1. Introduction[1]

The relationships between innovation and firms' growth, on the one hand, and between innovation and export performances, on the other, have been extensively analysed by the literature. In particular, the literature on the role of innovation as a determinant of firms' growth mainly concludes for the existence of a positive link between innovative activities and job creation, though some distinctions exist between the effects of product or process innovation (Pianta and Vivarelli, 2003; Vivarelli, 2013; 2014; Calvino and Virgillito, 2018; Montobbio et al., 2023). 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 and Rao, 2008; Colombelli et al., 2013; Mazzucato and Parris, 2015; Bianchini et al., 2015; Coad, 2016; Siepel et al., 2019; Flachenecker et al., 2020).

In parallel, previous research has explored the relationship between export and innovation activities from various perspectives. The literature found large evidence that both innovative inputs and outputs positively affect firms' export performance (see, for instance, Wakelin, 1998; Dosi et al., 2015; Ganotakis and Love, 2011; Grazzi et al., 2021), since innovation plays a significant role in shaping firms' competitive advantages (Fassio, 2022; Brancati et al., 2022). Moreover, exporting experience has been found to be relevant to guaranteeing stability in innovation activities and, hence, fostering innovation persistence (Andersson and Lööf, 2009; Antonelli et al., 2012; Lööf et al., 2015; Tomàs-Porres et al., 2023).

More limited are the contributions that have jointly investigated the relationships between the three dimensions, i.e., innovation, export, and growth performances (Love and Roper, 2015; Bogliacino et al., 2017). Among these, the distinction between standard innovation and eco-innovation has not been properly addressed. However, such a distinction is relevant because eco-innovation has specific characteristics that make the investigation of the relationship between innovation and growth even less straightforward than in the case of standard innovation (Crespi et al., 2015; Cainelli et al., 2011; Caravella and Crespi, 2022).

With respect to other (standard) innovations, eco-innovations represent a major technological effort to be pursued by firms, for which firms' 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 obtained just by combining a variety of

[1]This paper has been developed under the research agreement between SI.CAMERA – SISTEMA CAMERALE SERVIZI SCRL and the Department of Economics of Roma Tre University. We thank Elena Paglialunga for useful comments. The usual disclaimers apply.

dedicated knowledge and competences (Ghisetti et al., 2015; Caravella and Crespi, 2019). This implies that in the absence of adequate cognitive, technological, and financial capabilities that allow firms to exploit the economic potential of environmental innovation, companies risk missing the goal of enlarging their business and, hence, their productive and employment base. On the contrary, when adequate resources and capabilities are available, firms are more likely to succeed in the extraction of value from eco-innovation-related competitive strategies and consequently boost their growth potential.

In particular, smaller and younger firms have been found to be less capable of leveraging eco-innovation to grow (Caravella and Crespi, 2022). One possible explanation is that the export channel through which innovative activities may exert a relevant part of their effects matters, and it is more difficult to activate for smaller firms with fewer resources and capabilities.

Building on these considerations, this paper aims at providing a contribution with respect to previous literature by disentangling the growth-enhancing effect of standard and eco-innovation and by focusing on the potential role of export in mediating the innovation-growth nexus. In particular, the mediating role played by exports in explaining the relationship between innovation and growth for different types of innovative activities is investigated through an empirical analysis based on a representative sample of Italian firms built by integrating the 7th wave of the Italian CIS - Community Innovation Survey with the ASIA-FRAME database of the Italian National Statistical Office (ISTAT), that reports information on export values and employment dynamics. The econometric analysis is conducted by applying 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. Furthermore, the robustness of the econometric results obtained with SEM has been tested through a two-step counterfactual analysis, estimating the impact of the idiosyncratic effect of innovation (as well as standard vs. eco-innovation) on export over firms' growth.

The remainder of the paper is structured as it follows. The next section reviews the reference literature and sets out the research hypotheses; Section 3 describes the data, and provides the empirical framework and methodology. Results are discussed in Section 4, while robustness analysis is carried out in Section 5. Finally, Section 6 provides the conclusions and policy implications of the analysis.

2. Background literature and research hypotheses

The empirical debate on the direct growth-enhancing effects of innovation at the firm level is long-standing. 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 (Vivarelli, 2014; Calvino and Virgillito, 2018; Montobbio et al., 2023). 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 and market positioning, production efficiency and cost savings, and adaptation capacities with respect to market dynamics.

Moreover, innovative activities can indirectly sustain firms' growth through the export channel due to the positive relationship between firms' innovative capacity and export performances (Guarascio and Pianta, 2017; Antonelli and Feder, 2021; Benfratello 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 et al., 2006). Furthermore, innovative firms are more likely to better afford the cost associated with exporting activities thanks to the 'extra-returns' from innovation outcomes (Pianta and Vivarelli, 2003; Vivarelli, 2013; 2014; Calvino and Virgillito, 2018). 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 growth-enhancing potential of innovation is positively mediated by export dynamics.

However, by recognising 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 *Standard* (SI) and *Eco-innovation* (EI), where the latter basically embraces inventions that primarily aim to reduce environmental pressure from economic activities (Marzucchi and Montresor, 2017; Caravella and Crespi, 2020). In particular, EIs are developed within a less mastered technological space characterised by a higher degree of complexity (Carrillo-

Hermosilla et al., 2010, Ghisetti et al., 2015, Barbieri et al., 2020). 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 and 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 the innovation trajectory and the stronger the link between innovation and international performance (Lieberman and Montgomery, 1988; Tellis and Golder, 1996). Such an argument 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 and 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 and 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 growth-enhancing potential of innovation is influenced by the type of innovation (*Standard* or *Eco-innovation*).

Focusing on EI, 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 (García-Quevedo et al., 2020; Lewandowska, 2020; Meneto and Siedschlag, 2020; Chai, 2023; Martínez-Ros and Merino, 2023). Yet, we may also expect substantial heterogeneity in the strength of the export mediating role on growth channelled by different types of EIs, i.e., efficiency-improving innovations

(EFIs) or novelties merely aimed at pollution-reducing objectives (PR). 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; Veugelers, 2012; Horbach et al., 2012; Horbach, 2016). In a nutshell, PR refers to innovations 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 EFIs is pursued through a decrease in materials and/or energy input per unit of output, leading to efficiency gains (Caravella and Crespi, 2020). This implies that, compared to the former (PR), the realisation of the latter (EFIs) takes place through more radical and complex innovative processes that imply a higher degree of risk but also, potentially, higher economic returns. In this context, one may expect the potential positive relationship that links EI to export and growth, as well as the mediating role of export, to vary according to the specific class of environmental innovation carried out by companies. In particular, we expect that EFIs, since they are aimed at achieving a generalised cost reduction that allows firms to apply more competitive prices and be more competitive both on domestic and foreign markets, have a greater potential to spur growth performances with respect to SIs and PR *Eco-innovations*.

Against this background, we refine the previous hypothesis by introducing a third research question:

Hp3. The strength of the mediating role of exports on the growth-enhancing potential of *Eco-innovation* is influenced by the type of innovation (Efficiency-improving **or Pollution-reducing).**

3. Data, empirical framework and methodology

To investigate our research hypotheses, we employ 5,283 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 the innovation processes carried out during the three-year period 2012–2014 (types and objectives of innovation, existence of public or private cooperation, source of funding for innovation, etc.) while also distinguishing between standard and specific classes of *Eco-innovations* (Table 1). The second dataset 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.

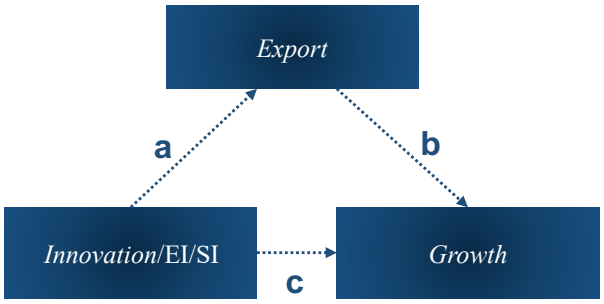
Table 1. Innovating firms* (2012-2014).

			Freq.	Perc.
No			2,517	47.64
Yes	*Standard-innovation*		994	18.61
	Eco-innovation		1,772	32.60
		Efficiency-improving	*701*	
		Pollution-reducing	*1,071*	
Total			5,283	100

*Manufacturing firms with a minimum of 10 employees

The conceptual framework used for the empirical analysis is sketched in Figure 1. Precisely, we focus on the link between innovation and a firm's 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.

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



We develop our empirical analysis within the framework of Structural Equations Models (SEM). In so doing, we conduct a path analysis to estimate the direct and indirect effects of innovation on firms' growth (in terms of employment growth as measured by variation in the total number of employees). Then, we distinguish between *Standard* and *Eco-innovation* (SI/EI). Finally, we dig further into the EI domain by looking at the distinction between Efficiency Improving (EFI) and Pollution Reducing (PR) EIs.

As represented in Figure 1, innovative activities can have a direct effect on a firm's growth given by *c* and an indirect effect through the *Export* channel, which is the mediator. This indirect effect is measured by the product between *a* and *b*, while the total effect is provided by the sum of the two effects (direct and indirect). Standard regression models can consistently investigate

only the direct effect, while the indirect ones remain unveiled. The advantage of SEM is thus represented by the possibility of assessing the role of mediating variables and identifying the magnitude of indirect effects.

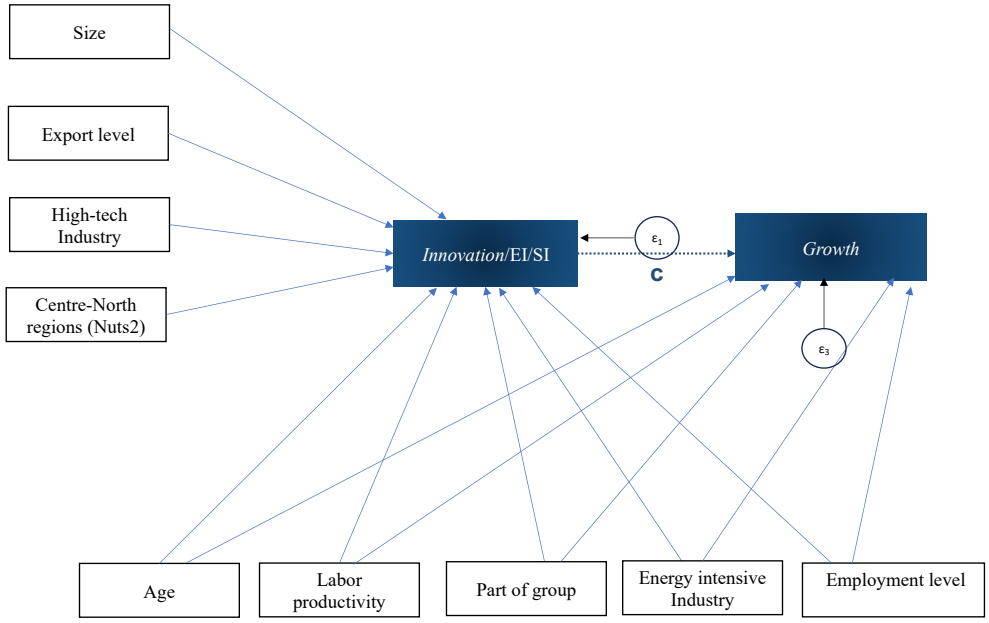
We therefore estimate a system of three simultaneous equations where we include a number of covariates that are usually considered the most relevant predictors of our endogenous variables. Table 2 describes the model variables.

Table 2. Variables' description

Variables	Description	Source
Endogenous		
Growth	The rate of growth of the number of employees between **2014-2016** for the short run and between **2016-2018** for the long run.	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
Covariates		
Employment level	The number of employees at time 2014.	ASIA-FRAME
Export level	The exported turnover at time 2014.	ASIA-FRAME
Size	Number of employees	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 between value added and employees at time 2014.	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

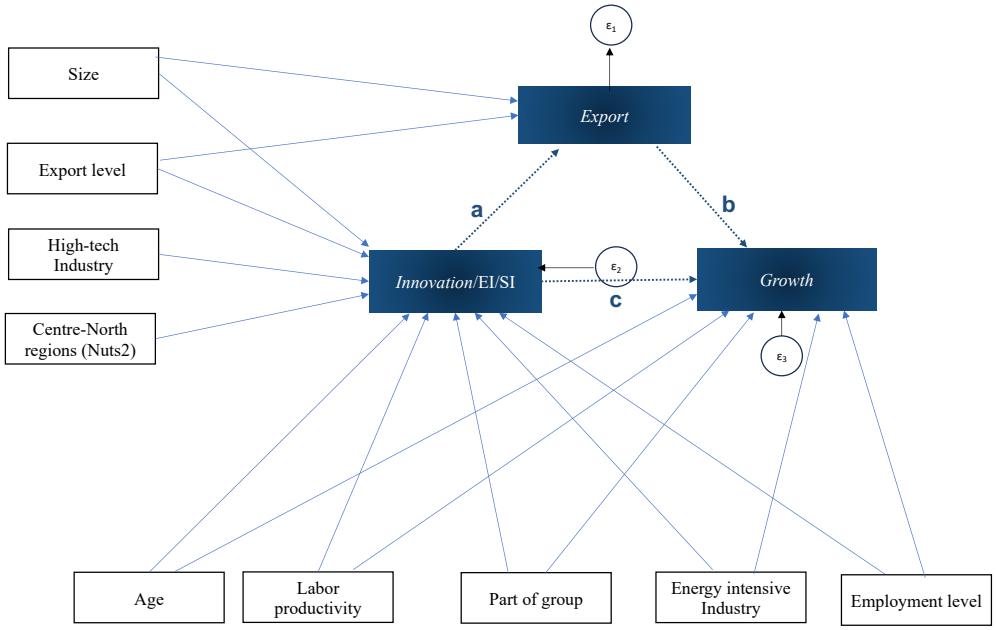
We start from a basic short run model investigating only the direct effect of *Innovation* on employment *Growth*, we then include *Export* as mediator into the analysis. The specification of the basic model is presented in Figure 2.

Figure 2. SEM specification: link between *Innovation* and *Growth* without *Export* mediation



As a second step, we test our hypotheses by including *Export* in the model as a mediating factor, as depicted in Figure 3. In so doing, we distinguish between a short-run effect considering employment *Growth* between the years 2014–2016 and a long-run effect taking the same variable for the time interval 2016–2018. In this way, we are able to assess not only the differentiated mediating effect of exports on firms' growth for different types of innovation but also the potential differences in terms of long-lasting effects. Moreover, the long-run model allows for the avoidance of contemporaneity between *Export* and *Growth* and thus offsets potential endogeneity problems due to reverse causality. As the relationship between *Innovation* and *Growth* (direct and indirect) might be attenuated in the long run, this approach will allow us to assess whether different types of innovation activities display different long-lasting (direct or indirect) effects in terms of *Growth*.

Figure 3. SEM specification: link between *Innovation* and *Growth* with *Export* mediation



4. Empirical results

Table 3 reports results on the short-run model that explores the direct effect of *Innovation* on *Growth*. Table 4 describes the short-run direct and *Export*-mediated effects of *Innovation* on employment *Growth*, while results in the long run are reported in Table 5. 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 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 and Jakobsen, 2016). Thus, a general recommendation is to jointly examine more robust model fit indices. As 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 and Bentler, 1999).[2] In general, all our estimated models show a good model fit with a very low error of approximation (RMSEA).

The short-run baseline model (Table 3) confirms results from previous literature on a general significant and positive relationship between *Innovation* and *Growth*. The coefficients of all considered variables associated with the different types of innovation activities are found to be

[2] 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.

highly statistically significant, with the largest effect detected for the EFI class (Column 4). Such a result confirms that firms that actively engage in innovative activities are able to enhance their competitiveness and enjoy superior growth performances with respect to non-innovators.

Moreover, overall results for the covariates included in the baseline model are consistent with expectations, thus confirming the reliability of the empirical setting built to test our research hypotheses[3].

Table 3. Short Run – No Mediation Effect

	(1)	(2)	(3)	(4)	(5)
Effect	***Innovation***	***Standard-innovation* (SI)**	***Eco-innovation* (EI)**	***Eco-innovation* Efficiency-improving (EFI)**	***Eco-innovation* Pollution-reducing (PR)**
Direct/Total	**0.0508***** (0.011)	**0.0418***** (0.015)	**0.0548***** (0.012)	**0.1022***** (0.000)	**0.0519***** (0.012)
N. Obs.	3,358	1,913	2,702	1,828	2,129
Chi-squared (p-val)	[0.5210]	[0.1737]	[0.3283]	[0.1270]	[0.122]
RMSEA	0.000	0.019	0.007	0.022	0.021
CFI	1.000	0.988	0.999	0.994	0.995
TLI	1.008	0.925	0.996	0.959	0.969
SMRS	0.003	0.006	0.004	0.006	0.006

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

The second step of our analysis is conducted by including *Export* growth as a mediating factor (Table 4), for which we observe a highly significant indirect effect in the short run. This result represents an initial validation of our first research hypothesis on the relevance of the mediating role of *Export* in the relationship between innovation and firms' *Growth.* The positive dynamics of export activities, spurred by engagement in innovation efforts, show up to be a powerful transmission channel through which innovation displays its effect on firms' growth. Introducing new processes and products turns out to be a way for firms to improve their international positioning. In doing so, innovation activities open up new opportunities for firms that become more attractive to foreign customers and, more generally, better able to enter or target new markets. Thus, the parallel enlargement of both domestic and foreign market possibilities induced by innovation activities significantly increases firms' potential to fuel their size growth. Interestingly, this result is confirmed for both *Standard* and *Eco-innovation*, irrespective of the type of green achievements enabled by the latter. This preliminary evidence appears to be in contrast with respect to our research hypotheses (Hp2 and Hp3), which state that the strength

[3] Due to space limitation we did not include in the text the tables reporting all results obtained with SEM which are particularly large. The full set of results is available upon requests from the authors.

of the mediating role of exports on the growth-enhancing potential of innovation is influenced by the type of innovation considered.

At least in the short run, we observe that the innovation premium on firms' growth is always amplified by the interference of export dynamics, suggesting that, independently of the types of innovation, internationalisation is a channel through which innovation efforts strengthen firms' chances to grow.

Table 4. Short Run – With Mediation Effect

	(1)	(2)	(3)	(4)	(5)
Effect	***Innovation***	***Standard-innovation* (SI)**	***Eco-innovation* (EI)**	***Eco-innovation* Efficiency-improving (EFI)**	***Eco-innovation* Pollution-reducing (PR)**
Total	**0.0579***** (0.0111)	**0.0472***** (0.0150)	**0.0618***** (0.0119)	**0.0635***** (0.0140)	**0.0596***** (0.0148)
Direct	**0.0408***** (0.0105)	**0.0342***** (0.0144)	**0.0448***** (0.0113)	**0.0486***** (0.0135)	**0.0435**** (0.0141)
Indirect	**0.0171***** (0.0036)	**0.0130***** (0.0044)	**0.0169***** (0.0037)	**0.0149***** (0.0038)	**0.0161***** (0.0045)
N. Obs.	3,358	1,913	2,702	1,828	2,129
Chi-squared (p-val)	[0.0000]	[0.0000]	[0.000]	[0.000]	[0.000]
RMSEA	0.048	0.049	0.050	0.052	0.051
CFI	0.944	0.920	0.950	0.942	0.947
TLI	0.814	0.733	0.833	0.807	0.825
SMRS	0.014	0.015	0.014	0.015	0.015

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

However, a different picture emerges when estimating the same model for the long run. Results reported in Table 5 suggest that the long-lasting effects, either direct or indirect, of innovation on firms' growth opportunities are lower for SI than for EI. In more detail, in the long-run analysis, the coefficient associated with the direct effect of the SI variable loses its statistical significance. On the other hand, the relevance of the direct effect is confirmed for the EI domain, with the strongest impact found for the PR Eco-innovations (Column 5).

Moreover, when the indirect effect of innovative activities mediated by *Export* is considered, we again find that such an effect is statistically more significant for EI than SI. In this case, a stronger indirect export-mediated impact is found for the EFI Eco-innovations (Column 4).

In conclusion, the long-run econometric analysis provided results that are in line with our research hypotheses (Hp2 and Hp3) on the existence of some heterogeneity in the capacity of different types of innovation activities in leveraging the *Export* channel to foster firms' *Growth*. In this regard, the empirical evidence suggests that firms that are able to undertake more complex and knowledge-intensive innovation processes, such as those associated with

Efficiency-enhancing Eco-innovations (EFI), have greater advantages in improving their growth performance. 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 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 enable superior growth opportunities.

Table 5. Long Run

	(1)	(2)	(3)	(4)	(5)
Effect	***Innovation***	***Standard-innovation* (SI)**	***Eco-innovation* (EI)**	***Eco-innovation* Efficiency-improving (EFI)**	***Eco-innovation* Pollution-reducing (PR)**
Total	**0.0182***	0.0185	**0.0207***	0.1971	**0.0288****
	(0.0097)	(0.0116)	(0.0115)	(0.0148)	(0.0128)
Direct	**0.0166***	0.0167	**0.0191***	0.0169	**0.0275****
	(0.0097)	(0.0116)	(0.0115)	(0.0148)	(0.0127)
Indirect	**0.0016****	**0.0018***	**0.0016****	**0.0027*****	**0.0012***
	(0.0007)	(0.0010)	(0.0007)	(0.0012)	(0.0007)
N. Obs.	5,283	3,511	4,289	3,218	3,586
Chi-squared (p-val)	[0.074]	[0.2008]	[0.0414]	[0.1251]	[0.0140]
RMSEA	0.012	0.010	0.015	0.013	0.019
CFI	0.995	0.991	0.994	0.994	0.990
TLI	0.982	0.969	0.982	0.981	0.967
SMRS	0.006	0.006	0.006	0.006	0.007

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

5. Robustness analyses

As a preliminary robustness exercise, our long-run model was estimated by modifying the baseline category against which hypotheses were tested. Specifically, when evaluating Hp2, instead of using the common baseline group of non-innovators, we used a group that included non-innovators and all other types of innovators, excluding the specific category we were testing. For example, in the case of eco-innovators (Column 3, Table 6), our comparison involved assessing them against a baseline group consisting of either non-innovators or standard innovators.[4] This approach enables a more nuanced understanding of the added benefits, or "premium," associated with EI in terms of its impact on growth when compared to

[4] Similarly, in Column 2 standard innovators are tested against the baseline group that comprises non-innovators and eco-innovators.

SI. Table 6 shows how for SI, direct, indirect, and total effects lose any statistical significance, while the indirect effect via EI still remains statistically significant (Column 3), thus driving the statistically significant indirect effect detected for *Innovation* in Column (1). This evidence corroborates our main results showing as EI, and in particular EFI (Columns 3 and 4), has a significantly positive export-mediated effect on firms' growth.

Table 6. Long run - Robustness

	(1)	(2)	(3)	(4)	(5)
Effect	***Innovation***	***Standard-innovation* (SI)**	***Eco-innovation* (EI)**	***Eco-innovation* Efficiency-improving (EFI)**	***Eco-innovation* Pollution-reducing (PR)**
Total	**0.0182***	0.0067	0.0153	0.0040	0.0160
	(0.0097)	(0.011)	(0.0104)	(0.0133)	(0.0116)
Direct	**0.0166***	0.0059	0.0141	0.002	0.0157
	(0.0097)	(0.011)	(0.0104)	(0.0133)	(0.0116)
Indirect	**0.0016****	0.0008	**0.0012***	**0.0765****	0.0003
	(0.0007)	(0.000)	(0.0006)	(0.018)	(0.0006)
N. Obs.	5,283	5,283	5,283	5,283	5,283
Chi-squared (p-val)	[0.074]	[0.046]	[0.067]	[0.060]	[0.049]
RMSEA	0.012	0.013	0.012	0.012	0.013
CFI	0.995	0.968	0.995	0.098	0.990
TLI	0.982	0.894	0.984	0.984	0.968
SMRS	0.006	0.006	0.006	0.006	0.06

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

As a further robustness exercise, we apply a two-step counterfactual analysis. The idea is to estimate the impact of the idiosyncratic effect of *Innovation* on *Export* over firms' *Growth*. Initially, we investigate how *Innovation* influences *Export* causally. Upon confirming this effect, we utilise it as a firm's *Growth* predictor. If a significant and positive coefficient is detected, it would indicate the presence of an innovation-mediated effect on growth through *Export*.

Thus, following Cerulli et al. (2016) and Cerulli and Potì (2012), as a first step, we estimate a conditional Average Treatment Effect (ATE(**x**)), representing the causal counterfactual effect of *Innovation* on *Export*; while 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 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 selection of a firm's observable characteristics $\mathbf{x}_i$, company i's idiosyncratic average treatment effect for the outcome Y, i.e., *Export*, is:

$$\text{ATE}(\mathbf{x}_i) = m_1(\mathbf{x}_i) - m_0(\mathbf{x}_i) \tag{1}$$

where $m_1(\mathbf{x}_i)=\text{E}(Y_i \mid \mathbf{x}_i, D_i=1)$ and $m_0(\mathbf{x}_i)=\text{E}(Y_i \mid \mathbf{x}_i, D_i=0)$, 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:

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

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

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

where the "hat" refers to a consistent estimator of $m_1(\mathbf{x})$ and $m_0(\mathbf{x})$.

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(**x**). In particular, the analysis of the ATET(**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(**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:

$$Growth_i = \beta_{ATE}\widehat{\mathrm{ATE}}(\mathbf{x_i}) + \beta_W \mathbf{x}_i + \varepsilon_{\mathrm{I}} \qquad (5)$$

where the firm's *Growth* is a function of the $\widehat{\mathbf{ATE}}(\mathbf{x})$ 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 and then separating *Standard-innovation* from *Eco-innovation*.
Furthermore, we conduct a heterogeneity analysis on the first step by exploring the conditional Average Treatment Effect on the Treated units and reporting an estimate of the ATET(**x**) distribution (see Figure 4). Defined as the average effect on treated firms conditional on the pre-specified covariates **x**, ATET(**x**) measures the firm-specific (average) effect of *Innovation* on *Export*. Thus, plotting its (estimated) distribution is meaningful. Based on the law of iterated expectations, ATET(**x**) distributions are centred 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 illustrates 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 realm of *Eco-innovation*. Following this, we delve into 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 of it positively impacting *Export*. However, with *Standard-innovation*, the probability drops to 74.95%, whereas *Eco-innovation* raises 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, which corresponds to 31.62% higher probability of increasing *Exports* for eco-innovators.[5]

Figure 4. Kernel density conditional Average Treatment Effects (ATET(x)) on the treated by innovation type.

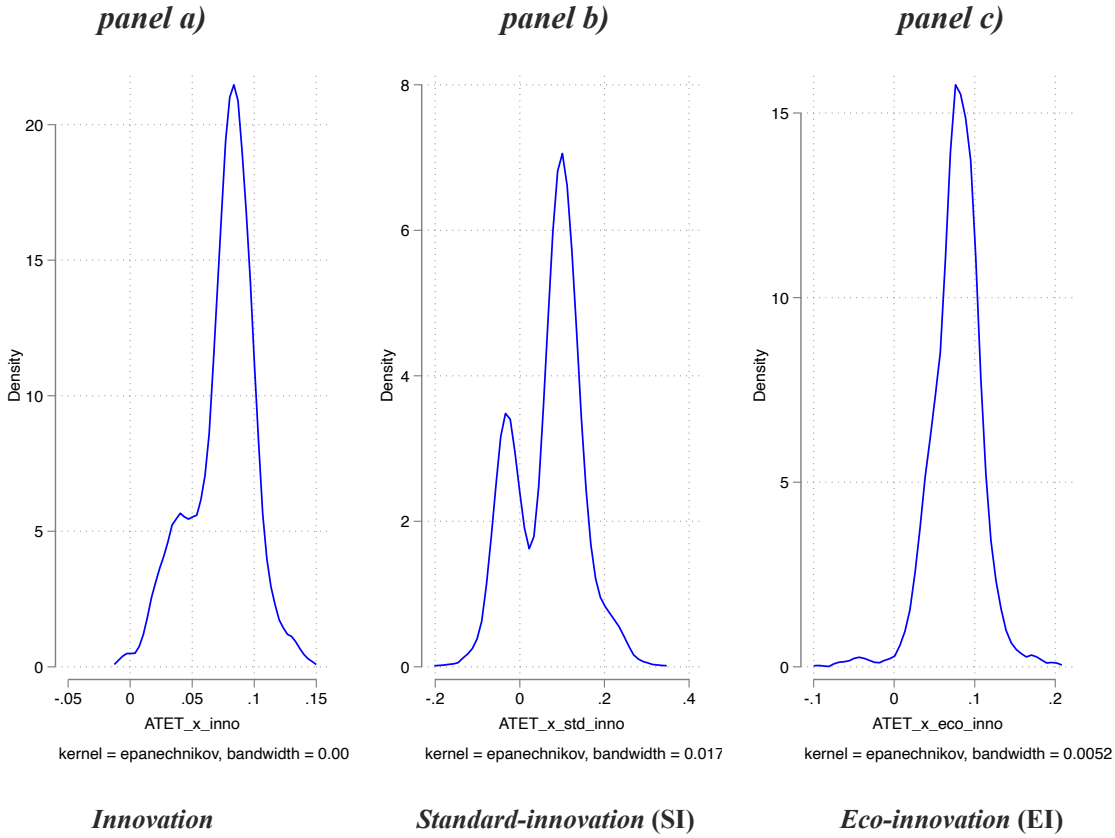


Table 7 finally reports the results of the two-step counterfactual analysis in three distinct columns, distinguishing by type of innovation. In each of these three scenarios—*Innovation*, *Standard-innovation*, and *Eco-innovation*—we observe a consistent pattern. In the first step, there's a clear and meaningful positive impact of the treatment 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* (from 1.472 for *Standard-innovation* to 19.79 in the case of *Eco-innovation*). This suggests not

[5] In the realm of *Eco-innovation* (panel c), out of a total of 1,772 treated firms, approximately 1,748 (98.64%) exhibit a positive treatment effect. In the scenario of *Standard-innovation* (panel b), among 994 treated firms, 745 demonstrate a positive treatment effect (74.95%). In the broader context of *Innovation* (panel a), among 2,766 treated firms, 2,754 showcase a positive treatment effect (99.57%).

just a greater influence of *Eco-innovation* on *Export* compared to *Standard-innovation* but also a significantly more substantial effect of this influence on firms' *Growth*.

Overall, our comprehensive robustness analyses, employing counterfactual methods, substantially validate the main conclusions drawn from our Structural Equation Models (SEMs). These findings consistently highlight the pivotal role played by *Eco-innovation* in enhancing a firm's *Growth* through its impact on *Export*. In essence, the corroborating results emphasise the significant contribution of *Eco-innovation* as a driving force behind fostering growth within firms via the facilitation of *Export* activities.

Table 7. Robustness: two-step counterfactual analysis

	(1)		(2)		(3)	
	Innovation		***Standard-innovation* (SI)**		***Eco-innovation* (EI)**	
	First step	**Second step**	**First step**	**Second step**	**First step**	**Second step**
VARIABLES	*Export*	*Growth*	*Export*	*Growth*	*Export*	*Growth*
Innovation*/*Standard*/*Eco	**0.0699****		**0.0568***		**0.0871*****	
	(0.0278)		(0.0295)		(0.0319)	
$\widehat{\text{ATE}}$(x)		**3.505*****		**1.472*****		**19.79*****
		(1.035)		(0.482)		(6.946)
Export level	-0.0378***	-0.0130***	-0.0379***	-0.0233***	-0.0377***	0.120***
	(0.00614)	(0.00326)	(0.00615)	(0.00666)	(0.00614)	(0.0433)
Size	-0.155***	0.0190	-0.157***	-0.0482***	-0.154***	0.539***
	(0.0394)	(0.0162)	(0.0393)	(0.0103)	(0.0393)	(0.198)
Age	0.00575	-0.0657***	0.00623	-0.00273	0.00562	-0.714***
	(0.0352)	(0.0185)	(0.0353)	(0.0120)	(0.0353)	(0.248)
Employment level	0.128***	-0.00258	0.128***	0.0315***	0.128***	-0.380***
	(0.0228)	(0.00479)	(0.0229)	(0.0106)	(0.0229)	(0.135)
Centre-North regions (NUTS2)	-0.0347	0.00928	-0.0118	0.00752	-0.0410	0.0133
	(0.0329)	(0.0118)	(0.0406)	(0.0135)	(0.0391)	(0.0131)
NC_reg	0.00838	0.156***	0.00762	0.203***	0.00859	-0.449***
	(0.0390)	(0.0393)	(0.0389)	(0.0569)	(0.0390)	(0.171)
Labour productivity	0.0306	-0.00244	0.0319	-0.0160	0.0303	0.142***
	(0.0268)	(0.0113)	(0.0268)	(0.0164)	(0.0268)	(0.0391)
Part of a group	0.0190	0.0352**	0.0183	0.0629***	0.0192	0.119***
	(0.0448)	(0.0141)	(0.0449)	(0.0185)	(0.0448)	(0.0445)
Energy intensive industry	0.00645	.	0.0113	.	0.00513	.
	(0.0345)	.	(0.0343)	.	(0.0345)	.
Constant	-0.150	-0.0548	-0.169	0.0945	-0.145	-1.725***
	(0.301)	(0.104)	(0.302)	(0.139)	(0.302)	(0.489)
Observations	5,283	5,283	3,511	3,511	4,289	4,289
R-squared	0.034	0.010	0.031	0.018	0.036	0.011

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.

6. 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 *Exports* in explaining the relationship between *Innovation* and *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 applies path analysis in Structural Equations Models (SEM), enabling a thorough investigation of the relationships between the considered variables and highlighting the statistical relevance of mediating effects among them. In the second part, the robustness of results obtained with the SEM methodology has been tested with a two-step counterfactual analysis by estimating the impact of the idiosyncratic effect of *Innovation* (*Standard* vs. *Eco-innovation*) on *Export* over firms' *Growth*. The obtained econometric results indicate that export activities, driven by engagement in innovation efforts, serve as a powerful transmission channel through which innovation manifests its impact on firms' growth. Moreover, the long-term econometric analysis provided results that confirm the existence of some heterogeneity in the capacity of different types of innovation activities to leverage the *Export* channel to foster firms' growth. In this respect, the empirical evidence suggests that firms that are able to undertake more complex and knowledge-intensive innovation processes, such as those associated with Efficiency-improving *Eco-innovations* (EFI), have greater advantages in enhancing their growth performance.

These results, drawn from Structural Equation Models, have been found to be substantially robust to additional tests, including the use of counterfactual methods. However, it should be recognised that the provided analysis represents only a first attempt to dig into the complex mechanisms explaining the growth-enhancing effects of innovation activities on firms' growth. Future research is certainly needed to further validate our results, in particular with respect to the possibility of testing the proposed econometric models on data samples from different countries, possibly including longer time spans, in order to properly account for the lag structure of identified relationships.

Nevertheless, the evidence contained in this paper has relevant policy implications, as it reveals the potential of leveraging through appropriate policies the growth effects of innovation activities by exploiting the export channel. In particular, the empirical analysis of the different types of innovation activities (standard and environmentally friendly) shows that, in order to maximise the impact of *Eco-innovation* on firms' growth, innovation policies should be complemented by policies aiming to promote firms' export capabilities. This implies that specific attention should be devoted to the construction of an appropriate policy mix in order to foster complementarities between different policy instruments and thus maximise 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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