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Original Research

Interorganizational Cooperation, Knowledge Sharing, and Technological Eco-Innovation: the Role of Proactive Environmental Strategy – Empirical Evidence from Poland

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Abstract

Although previous research has suggested that interorganizational cooperation and knowledge sharing may affect technological eco-innovation or proactive environmental strategy, there is little understanding of the interconnectedness of these variables. This paper investigates the links between interorganizational cooperation, knowledge sharing, proactive environmental strategy, and technological eco-innovation. In particular, it examines the influence of interorganizational cooperation and knowledge sharing on technological eco-innovation and explores these relationships through proactive environmental strategy. A research model has been developed and tested on a sample of 292 firms operating in Poland. In order to test the proposed research model and hypotheses, structural equation modeling using partial least squares has been applied. The findings indicate direct effects of interorganizational cooperation and knowledge sharing on proactive environmental strategy. However, the obtained results do not prove that interorganizational cooperation directly affects technological eco-innovation. Nevertheless, the study has shown the significant mediating role of proactive environmental strategy in relationships between interorganizational cooperation, knowledge sharing, and technological eco-innovation. Since proactive environmental strategy powerfully fuels technological eco-innovation and significantly mediates links between interorganizational cooperation, knowledge sharing, and technological eco-innovation, this research proves that it constitutes a unique organizational capability that may improve transformation of knowledge into better environmental and economic performance.

Keywords: interorganizational cooperation, knowledge sharing, technological eco-innovation, proactive environmental strategy

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Introduction

The efficient mitigation of the environmental burden caused by business activity requires firms to adopt proactive environmental strategies (PES) [1, 2] and to implement eco-innovation (EI) [3], in particular technological eco-innovation (TEI) [4]. Despite the increasing interest on EI and TEI, research in this field is still scarce [5]. Although an impressive amount of studies have been done on environmental strategies, additional studies are needed to understand the essential foundations of their success [6]. Therefore, research needs to pay more attention to the organizational capabilities that allow firms to implement PES and EI, which in turn may provide a competitive advantage [7].

According to a resource-based view of a firm, valuable, rare, imperfectly imitable, non-substitutable resources provide key sources of sustained competitive advantage [8]. The concept of the knowledge-based view [9] focuses in this area on the role of invisible assets such as organizational knowledge that provides, if sufficiently managed, a source of unsurpassed competitive advantage. This also concerns the environmental strategy, in general, on the basis of the natural-resource-based view of the firm [10], and in particular unique organizational knowledge assets related to improving environmental activity [11]. The issue of knowledge assets used in both the development of PES and eco-innovative activities is still rarely treated in the literature. For this reason, attention has recently turned, among other things, to external knowledge sources [12, 13], innovative interorganizational cooperation [5, 12, 14], absorptive capacity [6, 15], and knowledge sharing [16, 17] with regard to the implementation of PES and TEI. However, antecedents of PES and TEI have been analyzed separately so far.

The interorganizational cooperation (IC) constitutes a fundamental source of an external firm's knowledge acquisition, whereas knowledge sharing (KS) mostly contributes to a firm's internal knowledge transformation. These processes fuel a firm's absorptive capacity (AC) [18]. No empirical evidence has yet been obtained on how firms manage innovative IC and KS practices in order to implement PES and TEI together. To fill the identified gap, this study contributes to the literature dispute on knowledge-related antecedents of PES and TEI. It develops the research framework that links IC, KS, PES, and TEI. In particular, it examines the direct effects of IC and KS on TEI and explores this relationship through PES.

Theoretical Framework and Hypotheses Development

In general, researchers distinguish between two extreme approaches to environmental management: environmental reactivity, typical for firms that only implement the minimal compulsory changes to meet regulations, and the environmental proactivity, typical for firms that voluntarily take measures to reduce their impact on the natural environment [2]. Corporate environmental strategy is proactive if it exhibits a consistent pattern of environmental practices, across all dimensions relevant to their range of activities, not required to be undertaken in fulfillment of environmental regulations or in response to isomorphic pressures within the industry as standard business practices [19]. There are no commonly agreed constructs, dimensions, and variables involved in measuring PES. Some scholars have empirically studied the one-dimensional approach [19-21] by reducing different sets of PES practices to a single factor. On the contrary, other papers [2, 22, 23] suggested a multidimensional and contingent view of PES.

According to the recent definition, eco-innovation is the production, assimilation, or exploitation of a product, production process, service, management, or business method that is novel to the organization and which results, throughout its life cycle, in a reduction of environmental risk, pollution, and other negative impacts of resource use (including energy use) compared to relevant alternatives [3]. The definition of TEI is based on the general understanding of technological innovation as defined in the Oslo Manual [24], which distinguishes between product and process innovations. Therefore, TEI (i.e., product and process eco-innovations) is a specific type of technological innovation consisting of new or significantly improved products and processes to avoid or reduce environmental burden [4].

The complex nature of TEI requires firms developing or adopting it to employ specific resources and green capabilities. According to the natural-resource-based view of the firm [10], PES provides the accumulation of such resources and capabilities to prevent environmental degradation by innovative, environmentally friendly products, processes, and technologies [25]. PES also supports the experimentation and development of new opportunities, at the business-natural environment interface, in an efficient and effective manner [19]. Given the above, it is hypothesized that:

H1. Proactive environmental strategy has a direct positive effect on technological eco-innovation.

Interorganizational cooperation has been recognized as important for developing the innovative capabilities of organizations [26]. It comprises a variety of partners, including suppliers, customers, universities and research institutes, and even potential or existing industry competitors. The influence of IC on development of EI has been suggested by empirical research. With regard to technological environmental-related innovation, the usual structural characteristics of the firm may appear less important than R&D cooperation and innovative oriented industrial relations [27]. Improvement of technological capabilities by R&D cooperation triggers TEI [14]. The R&D cooperation increases the probability of becoming an eco-innovator because it makes more efficient use of the wide external knowledge sources that EI requires [13]. Technological eco-innovative firms cooperate on innovation with external partners (i.e., suppliers and research institutes and universities) to a higher extent than other innovative firms [5, 12]. On the contrary, other

research has found that cooperative R&D is insignificant for the development of environmentally friendly products and there is significant negative correlation between both R&D intensity and R&D cooperation, and EI goals [28]. The low R&D intensity and R&D cooperation are likely to be compensated for by the use of external sources of information. Thus, the following hypothesis is proposed:
H2. Interorganizational cooperation has a direct positive effect on technological eco-innovation.

The empirical research on the nature of the relationship between IC and PES is rather scarce. The structural configurations of strategic alliances for environmental improvements and competency-oriented alliances, characterized by exploration learning and diverse partners, may facilitate firms in their pursuit of PES [29]. The dynamic capabilities perspective to PES entail integration of divergent stakeholder perspectives [1, 19], and competitively valuable organizational capabilities such as stakeholder integration may emerge from the adoption of a PES. This may indirectly influence establishing partnerships with stakeholders for product and technology development, integrating environmental issues within the strategic planning process, using new environmentally friendly materials in operations and technological processes, and modifying logistical processes, etc. [30], resulting in upgrading the PES. The cooperation with external entities can serve as a crucial source of knowledge for adopting environmental best practices [31]. Therefore, it is hypothesized that:
H3. Interorganizational cooperation has a direct positive effect on proactive environmental strategy.

Knowledge sharing in an organization involves the transfer or dissemination of knowledge from one person or group to another [32] and refers to collective beliefs or behavioral routines related to the spread of learning among different people and units within an organization [33]. This process includes knowledge donating and knowledge collecting and affects the supply and the demand for new knowledge [34]. KS is a key component of learning orientation that strongly influences firm innovativeness [33]. Proficiency in KS improves the product and process innovation performance of a firm [35] and facilitates innovation speed and quality [36]. KS within the EI process differs from conventional innovation because firms are required to meet not only market demand but also the environmental regulations and customers' green preferences. The inter-functional collaboration and innovation-oriented learning might be critical success factors for EI.

Research in the electronics industry showed that KS positively influences TEI and new green product success [16]. In addition, firm-specific KS may support the generation of unique, environmentally sustainable, and innovative solutions [37]. Thus the following is hypothesized:
H4. Knowledge sharing has a direct positive effect on technological eco-innovation

KS is a pillar of organizational learning, which is one of the key internal firm capabilities that has been suggested as a prerequisite for implementing PES [10, 17]. Although few researchers have emphasized the importance of KS in the implementation of PES, very limited empirical evidence supporting this view is available. Previous research has found that achievements in environmental sustainability are better if appropriate organizational structures have been designed that facilitate knowledge sharing within an organization [21, 37, 38]. Studies on involving employees in the implementation of PES [39, 40] indirectly confirm the importance of KS in this process. Recent research indicates that learning-oriented hotels are more likely to deploy a PES and intra-organizational KS [30], and there are positive relationships between the practices of information sharing with employees and PES in the pharmaceutical industry [17]. This study also expects that:
H5. Knowledge sharing has a direct positive effect on proactive environmental strategy.

A firm's capability to search for new knowledge and to harmonize what it learns internally can contribute in a significant way to the creation and acquisition of new competencies needed for development of environmental practices and technologies [41]. IC constitutes a fundamental source of a firm's knowledge acquisition, whereas KS mostly contributes to a firm's knowledge transformation. These processes lead to the development of a firm's AC [18], which may influence innovative activities (e.g., the adoption and diffusion of innovations, participation in R&D interorganizational cooperation, etc.).

Managers can develop a firm's AC by effective KS related to the adoption of environmental management practices, and this process may provide a sustained competitive advantage [15]. Recent research has found the mediation effect of PES in the relationship between AC and firm performance, which means that competitive advantage from such a proactive approach seems largely fueled by a firm's AC [6]. In addition, EI can be seen as a distinctive and unique green capability developed with various resources, which should in turn contribute to competitive advantage and better business performance [42]. Since TEI leads to a reduction in the use of physical resources, it can consequently be a source of competitive advantage and thus it is expected to exert a positive effect on a firms' competiveness. Thus, cost savings and/or efficiency improving innovations positively may affect a firms' competitiveness [4]. Based on the mediating role of PES between AC and firm performance revealed by [6], and taking into account that, on the one hand, IC and KS fuel a firm's AC and, on the other hand, TEI seems to influence a firm's competitiveness, the following hypotheses is proposed:
H6. Proactive environmental strategy mediates the relationship between interorganizational cooperation and technological eco-innovation, and *H7. Proactive environmental strategy mediates the relationship between knowledge sharing and technological eco-innovation.*

The research model proposed in this study is shown in Fig. 1.

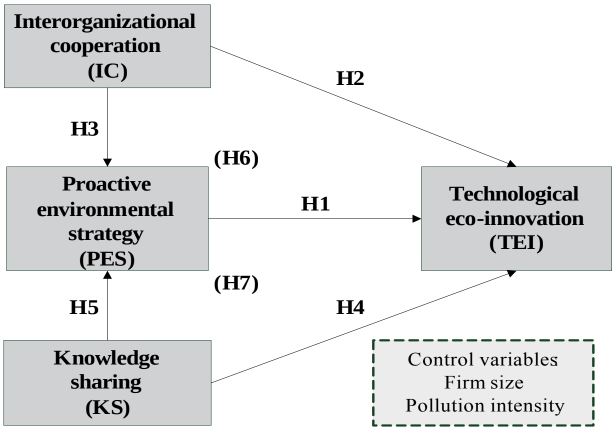


Fig. 1. The research model.

Research Methodology

Sample and Data Collection

The empirical study presented in this article is a part of research conducted in November and December 2013 on a sample of firms representing selected industries operating in Poland. It should be emphasized that, according to the Eco-Innovation Scoreboard, Poland is characterized by one of the worst overall eco-innovation performances in the European Union [43]. Therefore, this makes it particularly important to understand the antecedents of successful TEI implementation.

The research method applied was the computer-assisted telephone interview (CATI), conducted by the largest Polish research agency (PBS Ltd.), which meets the highest research standards. The interviews were conducted among representatives of firms: owners, management board members, or other decision-makers in a given organisation. In order to enable analysis in the established groups of firms in each of the determined categories, ratios by industry and employment size were used. After defining the categories and the size required to carry out the research, firms were randomly drawn from the nationwide business database with a stratification procedure along the dimensions of firm size (three categories: 10-49 employees, 50-249 employees, 250 employees or more) and selected industrial and service sectors. As a result of conducted interviews, representatives of 292 firms fully completed the survey questionnaire. The obtained response rate was 5.2%, which is consistent with the previous studies of PES [44-46]. In order to assess potential non-response bias, the early and late respondents were compared as suggested by [47]. The results of independent *t*-tests showed no statistical differences across key firm characteristics, and each analyzed measure at a significance level of 0.05. This suggests that non-response bias was not a concern.

Measures

All measures included in the questionnaire were based on a prior literature review. In addition, all questions were consulted with a panel of scholars and industrial experts in order to evaluate the validity of the items in the questionnaire. The seven-point Likert-type scales (1: strongly disagree/much worse/not at all, to 7: strongly agree/ much better/very high) were used throughout the questionnaire. The question items for the analyzed constructs are listed in the appendix.

IC was measured by five items used in the Community Innovation Survey [24]. Representatives of the surveyed firms specified whether they participated in R&D or other innovation-related projects with suppliers, clients or customers, competitors, and other firms from the same industry, universities and research institutes, and consultants and experts. These groups of cooperation partners have been used in previous studies [5, 26].

KS practices were measured by eight items adapted from previous studies [32, 33, 48]. These practices pertained to, among other things, mentoring programs, work teams, disseminating lessons learned from past failure, use of IT systems to facilitate knowledge sharing, incentives to encourage knowledge sharing, and training and development programs.

In order to measure PES, respondents were asked to score the degree of implementation of 16 environmental practices adapted from previous studies [2, 22]. These practices encompassed a wide range of environmental activities in different areas, such as strategy and a firm's objectives, organizational structure, environmental policy and long-term plans, product and process operational practices, marketing activities, purchasing policy, etc.

TEI was measured by six items. The scale was developed by referring to the previous studies on innovation and eco-innovation [4, 36]. Respondents were asked to assess statements that reflected on product and process eco-innovation number, TEI speed (i.e., a firm's agility at eco-innovative product launching and developing new environmentally friendly processes) and TEI quality (i.e., novelty and eco-efficiency of eco-innovative products and processes) as compared to the key competitors.

Since firm size is regularly incorporated as a control variable to explain the adoption of PES [2, 22] and TEI [4, 5], during the research an analysis was conducted taking into account the affiliation of the studied firms in groups of entities by their employment size. In addition, in the analysis firms pollution intensity was considered depending on their sector affiliation [44, 49]. The surveyed firms were divided into highly polluting sectors (e.g., chemicals and chemical products, basic metals and metal products, electricity production) and moderately polluting sectors (e.g., machinery and equipment, electrical machinery and apparatus, textiles).

Results Analysis

In order to test the research model and hypotheses proposed, structural equation modeling (SEM) using partial least squares (PLS) has been employed. PLS avoids small sample size problems and it is suitable where theory

Table 1. Measurement model.

Construct	Item	Mean	SD	Standardized loading	C-a	CR	AVE
IC	IC-1	4.263	1.514	0.714	0.771	0.845	0.521
	IC-2	4.332	1.572	0.703			
	IC-3	3.147	1.625	0.727			
	IC-4	2.911	1.780	0.709			
	IC-5	2.986	1.620	0.758			
KS	KS-1	5.240	1.657	0.749	0.893	0.915	0.575
	KS-2	5.188	1.659	0.751			
	KS-3	5.017	1.836	0.702			
	KS-4	5.144	1.668	0.707			
	KS-5	4.579	2.110	0.742			
	KS-6	4.842	1.728	0.821			
	KS-7	4.527	1.849	0.807			
	KS-8	4.781	1.872	0.779			
P&O-PES	PES-1	4.860	1.740	0.777	0.923	0.937	0.651
	PES-2	4.750	2.038	0.850			
	PES-3	4.641	2.064	0.863			
	PES-4	4.596	1.981	0.815			
	PES-5	4.589	2.116	0.749			
	PES-6	3.997	2.382	0.757			
	PES-7	4.795	1.986	0.834			
	PES-8	4.195	2.131	0.800			
O-PES	PES-9	3.990	2.018	0.738	0.916	0.932	0.633
	PES-10	4.955	1.798	0.860			
	PES-11	5.127	1.591	0.732			
	PES-12	4.904	1.670	0.856			
	PES-13	4.774	1.821	0.854			
	PES-14	4.705	1.839	0.775			
	PES-15	4.339	1.892	0.740			
	PES-16	4.531	1.877	0.799			
TEI	TEI-1	3.247	1.727	0.762	0.903	0.926	0.674
	TEI-2	3.661	1.637	0.852			
	TEI-3	4.014	1.727	0.841			
	TEI-4	3.264	1.702	0.780			
	TEI-5	4.106	1.699	0.840			
	TEI-6	4.209	1.652	0.847			

is still insufficiently grounded and the research focuses on predicting dependent variables [50, 51]. The two-step approach to data analysis has been adopted. In the first step, the measurement (outer) model was assessed to ensure reliability and validity of the constructs. In the second step, the causal paths between the constructs that composed the theoretical model were tested and the structural (inner) model was evaluated.

Table 2. Discriminant validity.

Construct	IC	KS	P&O-PES	O-PES	TEI
IC	0.521				
KS	0.321	0.575			
P&O-PES	0.207	0.339	0.651		
O-PES	0.210	0.398	0.526	0.633	
TEI	0.197	0.290	0.356	0.450	0.674

Diagonal figures present the AVE values. Off-diagonal figures represent the constructs' squared correlations.

Measurement Model Assessment

As an initial step, an analysis of the data's factor structure has been performed through principal component analysis. The exploratory factor analysis (EFA) revealed the two-factor construct for PES and one-dimensional constructs for the IC, KS, and TEI. The obtained two-factor construct of PES is similar to that discovered in [23]. The revealed factors were labeled as planning and organizational practices (P&O-PES) and operational practices (O-PES). The hierarchical model in PLS path modeling was constructed after exploring the scales structure. The P&O-PES and O-PES have been included in the model as first-order dimensions forming the second-order construct of PES.

Item reliability, internal consistency, and discriminant validity were used to test the reliability and validity of the model [50]. As shown in Table 1, all factor loadings are greater than the minimum threshold of 0.7 recommended in the literature [50], which indicates that the survey instrument was reliable for measuring each construct. Cronbach's α and composite reliability (CR) values also exceed the critical threshold of 0.7 for all constructs. This confirms the internal consistency for each construct [52]. The average variance extracted (AVE) values were above 0.5 for all of the scales, which demonstrates the convergent validity and justifies the use of all constructs [50].

Discriminant validity indicates the extent to which relevant construct differ from other constructs within the proposed model. Table 2 shows that the existence of discriminant validity has been confirmed since the AVE values are higher than the squared inter-correlations among the latent variables [53].

Structural Model Assessment

The proposed structural model has been examined through the significance of the path coefficients (standardized β) that denote the strength of causal relationships between constructs and by observing the R^2 values of the dependent variables. The bootstrap estimation with 5,000 subsamples was performed to assess the statistical significance of each path coefficient.

The model explains the 48.9% variance for TEI and the 45.0% variance for PES. In addition, the Stone-Geisser test utilizing the cross-validated redundancy approach was used to evaluate the predictive relevance of the model (which has predictive relevance when Q^2 is greater than zero) [51, 52]. The Q^2 values for both dependent variables were positive. In addition, by following Cohen's procedure the f^2 effect size was calculated to evaluate the substantive impact of each predictor (exogenous) construct on dependent (endogenous) constructs [54]. The obtained results indicate that IC and KS have a small effect on TEI, whereas PES has a large effect on TEI, and KS on PES as well. Finally, the goodness of fit index as suggested by [55] has been calculated. The obtained value of 0.531 should be considered high [56]. The aforementioned results of the structural model are shown in Table 3 and Fig. 1.

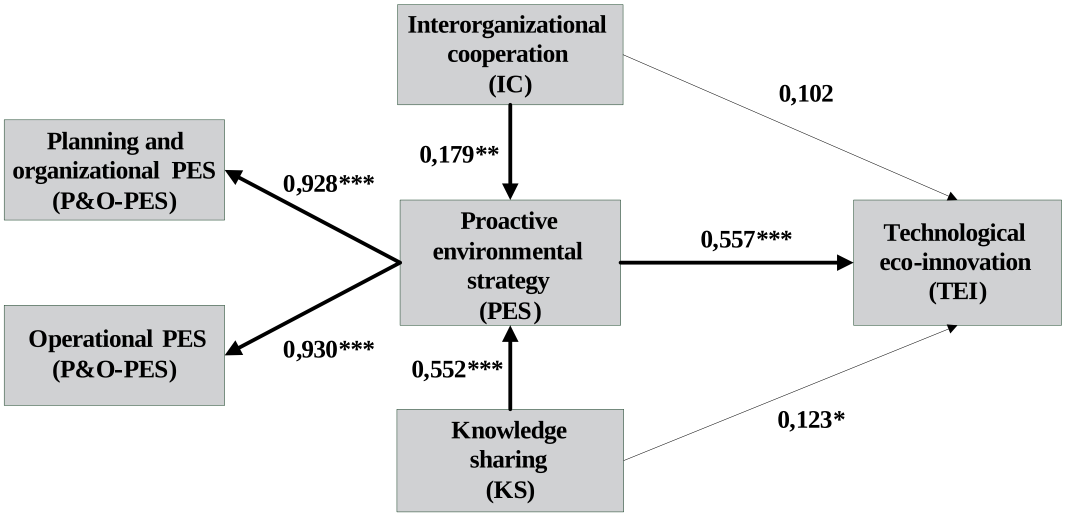
Analysis of Direct Effects

The research hypotheses have been tested through the interpretation of the structural path coefficients (Table 3). The results have shown that PES has a strong significant positive effect on TEI ($\beta = 0.557$; $p<0.001$), thus hypothesis H1 was supported. With regard to hypothesis H2, IC is not significantly related to TEI ($\beta = 0.102$, $p>0.05$), therefore hypothesis H2 was rejected. The obtained results suggest that IC does not directly affect TEI. However, the results have indicated that IC is significantly related to PES ($\beta = 0.179$; $p<0.01$), therefore hypothesis H3 was confirmed. For hypotheses H4 and H5, the effects of KS on TEI and PES have been examined, respectively. The direct effect of KS on TEI has a value of $\beta = 0.123$ and is statistically significant ($p<0.05$), therefore it provides support for H4. KS significantly and directly influences

Table 3. Results of the structural model.

Hypothesis	Estimate	t-value	f^2	R^2	Q^2
H1. PES → TEI	0.557	9.814***	0.334	R^2 (TEI) = 0.489	0.319
H2. IC → TEI	0.102	1.902	0.012		
H4. KS → TEI	0.123	2.066*	0.016		
H3. IC → PES	0.179	3.380**	0.040	R^2(PES) = 0.450	0.240
H5. KS → PES	0.552	10.433***	0.377		

Note: *p<0.05, **p<0.01, ***p<0.001.



Note: *p<0.05, **p<0.01, ***p<0.001.
Figure 2. Results of direct-effects testing.

PES (β = 0.552, p<0.001), hence hypothesis H5 was confirmed. The results of direct effects testing are shown in Fig. 2.

Analysis of Indirect Effects

The results of the structural model suggest the possible existence of mediating relationships between analyzed constructs. Thus, this study also explores these mediating effects. For this purpose the method of confidence intervals (CI) suggested by [57] with bootstrap estimation (number of subsamples equals 5,000) have been employed. According to this method, the indirect effect is significant if the confidence interval for a mediating variable does not include the value zero. The calculated indirect effects and total effects and relevant confidence intervals are shown in Table 4.

With regard to the results of estimation presented in Table 4, the indirect effect of IC on TEI has a value β=0.104 and is statistically significant (p<0.01). This means that IC does not influence TEI directly, but does so indirectly through PES. Moreover, PES significantly (p<0.001) mediates the relationship between KS and TEI. Since the direct effect of IC on TEI was not statistically significant, and the direct effect of KS on TEI was significant only at p<0.05, these findings reveal that PES mediates analyzed relationships respectively. Therefore, hypotheses H6 and H7 were fully supported.

Control Variables

The *t*-test has been used to determine if the mean values of analyzed constructs are significantly different in the established groups of surveyed firms on the basis of control variables. With regard to firm size, the first group consisted of small- and medium-sized firms and the second group comprised large firms. The next two groups, based on pollution intensity criterion, included firms from moderately polluting sectors and firms from highly polluting sectors. Taking into account firm size, the mean values of all analyzed constructs were significantly higher in large firms. This concerns TEI (p<0.001), PES (p<0.001), KS (p<0.01), and IC (p<0.001). As far as pollution intensity is concerned, only the mean values of PES were significantly different (p<0.05) and were higher in firms from highly polluting sectors.

In order to examine the effects of control variables, alternative models that consider these variables as moderators of the examined causal paths have been estimated. The two-stage approach has been employed for both control variables (i.e., firm size and pollution intensity) separately [55]. It involved the creation of new models with control variables adopting values of 0 or 1 (0 for small- and medium-sized firms/moderately polluting sectors or 1 for large-sized firms/highly polluting sectors) and in the second stage new interactions within models have been included, which had been derived by

Table 4. Results of the indirect effects estimation.

Relationship	Indirect effect path	Direct effect β	Indirect effect β	Total effect β	Indirect effect confidence interval	Total effect confidence interval
IC → TEI	IC → PES → TEI	0.102	0.104**	0.206**	(0.027; 0.180)	(0.029; 0.362)
KS → TEI	KS → PES → TEI	0.123*	0.302***	0.425***	(0.182; 0.437)	(0.216; 0.597)

Note: *p<0.05, **p<0.01, ***p<0.001.

multiplying the dependent and the moderator variables. This estimation in the research model indicates that for both firm size and pollution intensity all moderator paths were not significant.

Discussion and Conclusions

The increasing interest on TEI makes it extremely important to understand the idiosyncrasies of their successful implementation. This concerns, in particular, sufficient orientation of business activities and beyond-compliance behaviors, especially in adopting PES.

The aim of this study has been to explore the relationships between IC, KS, PES, and TEI. There is still scarce research done in this area and, in addition, up to now such a study has not been carried out in Poland. This paper contributes to the literature dispute on knowledge antecedents of TEI and PES.

On the basis of empirically tested models, the findings have shown that PES comprising both planning and organizational practices as well as operational practices strongly affect TEI. This is in line with assumptions from previous studies [19, 25] showing that PES seems to have a crucial capability to implement innovative and environmentally friendly products, processes, and technologies.

The performed analyses have indicated statistically significant direct effects of IC and KS on PES. This confirms that establishing partnerships with various stakeholders may result in upgrading PES [30] and can serve as an invaluable source of knowledge for adopting environmental best practices [31]. It must be emphasized that KS affects PES to a much larger extent than IC. Previous studies also have found that practices of information sharing with employees significantly influence PES [17].

The obtained results do not have a direct effect of IC on TEI. This is in contrast with most previous studies, but it has to be kept in mind that analysis in this research has considered as a dependent variable the construct that measures the level of TEI, whereas other researchers [5, 12, 14] have concentrated on the question of whether firms reported the introduction or adoption of any specific kind of TEI instead. This may also mean that IC is significant for the implementation of TEI regardless of its level. In addition, the above-mentioned studies [5, 12] have suggested that technological eco-innovative firms cooperate with suppliers and research institutes and universities, whereas their cooperation with clients or customers and competitors or other firms of the same industry does not seem to be significant. However, in this research IC has been measured as a one-dimensional construct that was composed of all partners.

The significant direct effect of KS on TEI have been indicated and that confirms findings of [16]. The identified influence is rather small but it is worth mentioning that analysis has comprised the general KS, not particularly regarding environmental issues.

Through analyses of direct and indirect effects this study clarifies a mechanism by which knowledge contributes to TEI. The results have revealed that PES significantly mediates the relationships between IC, KS, and TEI. Since PES largely fuels TEI and mediates the above-mentioned analyzed links, this means that it plays a vital role in the transformation of knowledge acquired from innovative cooperation and shared among employees on eco-innovative products and processes. However, in order to implement TEI successfully, firms should develop learning capabilities prior to the advancement of PES. Furthermore, because TEI can contribute to a competitive advantage and better business performance [42], PES constitutes an organizational capability that may improve conversion of knowledge into better corporate environmental and economic performance.

It should be emphasized that previous research showed that among different difficulties affecting PES, only endemic limitations prevent firms from advancing such a strategy [44]. This shows how important the attitudes and decisions of managers seem to be because they determine overcoming internal barriers in the development of organizational capabilities linking PES with TEI. Their efficiency may facilitate firms with more rapidly adapting to environmental changes and creating market value.

The findings of this study confirm the immense importance of KS for TEI and, in particular, for PES. KS is a fundamental process through which knowledge of individual employees can be transformed into capabilities allowing for effective knowledge application and implementation of innovation. The previous research indicated critical factors that influence successful KS. They especially include culture emphasizing trust and innovation, management and supervisor support, and employee self-efficacy and confidence in sharing useful knowledge with others [58]. Therefore, the focus on the improvement of these factors seems to be crucial for managers who intend to successfully advance PES and implement TEI.

This research has concerned IC and KS with regard to general knowledge assets. It must be emphasized that advancement of PES requires firms to continually improve the process of general and specific environmental knowledge management that comprises environmental knowledge creation, accumulation, sharing, utilization, and internalization [11]. Therefore, future study should focus on the analysis of complex interconnected influence of general and environmental knowledge management and, in particular, general and environmental AC on PES and TEI.

The study has revealed one-dimensional constructs for TEI and IC. Previous studies have suggested that diverse antecedents might vary with regard to TEI type [49]. In addition, prior research has indicated that the type of specific external partner might have a different influence on TEI [5]. Therefore, future research should consider an expanded number of variables that measure both constructs in order to achieve multi-factor constructs. This will allow for more detailed analysis on links between relevant types of TEI and its diverse determinants.

This research has some limitations that must be considered. First, it relies on self-reported data and the single informants as the source of information. In order to get around this limitation, the absence of common method variance has been tested. Harman's single-factor test has been applied [59]. The results confirmed the lack of a unique factor and that the one general factor has not accumulated the majority of the variance. Nevertheless, future study should attempt to obtain data from various informants within the same firms. Second, the study is based on cross-sectional data. A longitudinal sample collected over multiple points of time would help support the obtained results. Furthermore, scales employed in this study might be used as checklists for firms to evaluate themselves in analyzed areas. Third, links between a limited number of constructs and firm characteristics were examined. Therefore, future research should examine additional variables that are likely to influence the explored relationships. Such studies could also consider a firm's location in the value chain to investigate possible heterogeneity of relevant causal paths. In addition, it would be particularly interesting to complement a quantitative approach with qualitative research and case studies.

Finally, the findings do not entail a definitive conclusion about the analyzed relationships and might have limited generalizability due to the sectors and geographical specificity of the researched sample. Thus, further empirical research from different types of business activity and geographical context is needed.

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Appendix

Items for the analyzed constructs

Interorganizational cooperation

IC-1. Cooperation with suppliers.

IC-2. Cooperation with clients or customers.

IC-3. Cooperation with competitors and other firms from the same industry.

IC-4. Cooperation with universities and research institutes.

IC-5. Cooperation with consultants and experts.

Knowledge sharing

KS-1. Our top management repeatedly emphasizes the importance of knowledge sharing in our firm.

KS-2. Our firm uses senior personnel to mentor junior employees.

KS-3.Our firm groups employees in work teams.

KS-4. Our firm analyzes its past failures and disseminates the lessons learned among its employees.

KS-5. Our firm implements and invests in IT systems that facilitate knowledge sharing.

KS-6. Our firm develops mechanisms of sharing the experiences gained from completed projects.

KS-7. Our firm offers incentives to encourage knowledge sharing.

KS-8. Our firm provides a variety of training and development programs.

Proactive environmental strategy

PES-1. Environmental issues are high priorities in our organization's objectives and strategy.

PES-2. We have explicitly defined and documented environmental policy.

PES-3. We have clearly defined and documented environmental objectives and long-term environmental plans.

PES-4. Our top management regularly measures and assesses the environmental performance.

PES-5. We conduct periodic environmental reviews and internal audits.

PES-6. Our organizational structure includes management representative responsible entirely for environmental issues.

PES-7. We have management representative responsible for environmental issues actively participating in formulation of firm's objectives and strategy.

PES-8. Our employees participate in environmental trainings.

PES-9. We conduct periodical environmental impact assessments of products with regard to all stages of their life cycle.

PES-10. We take into account environmental criteria in design and development of products.

PES-11. We use cleaner technology and environmental friendly processes.

PES-12. We take into account environmental issues in design and development of production methods, maintenance and logistics.

PES-13. We take into account environmental criteria during suppliers selection.

PES-14. We require our suppliers and subcontractors to improve environmental activities and to keep relevant environmental standards.

PES-15. We consider environmental issues during selection of mode of transport and distribution channels.

PES-16. We emphasize commitment to environmental protection in marketing activities

Technological eco-innovation (during the last three years as compared to key competitors)

TEI-1. We usually were the first on the market to introduce new eco-innovative products.

TEI-2. We have introduced more products that are eco-innovative.

TEI-3. We have introduced products that are more eco-innovative.

TEI-4. We usually were the first to introduce new, environment friendly methods of manufacturing, maintenance and logistics.

TEI-5. We have introduced more new or significantly improved processes bringing environmental benefits.

TEI-6. We have been improving environmental parameters of our processes more effectively.

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