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Conditions Driving Eco-Innovation in a Catching-Up Country—ICT vs. Industry in Poland

Arkadiusz Świadek *, Jadwiga Gorączkowska and Karolina Godzisz

Faculty of Economics and Management, University of Zielona Góra, Licealna 9, 65-417 Zielona Góra, Poland; j.goraczkowska@wez.uz.zgora.pl (J.G.); kargod29@gmail.com (K.G.)
* Correspondence: a.swiadek@wez.uz.zgora.pl

Abstract: There is a necessity to combine the development of the European Union with a model of a sustainable economy, which is important to stimulate eco-innovation. The government of each member state is obliged to create support mechanisms that will encourage entrepreneurs to implement pro-environmental solutions. This requires the identification of determinants for eco-innovation. This paper identifies and compares conditions of eco-innovation in two sectors in Poland: ICT (information and communication technologies) and industry. Putting together many different types of conditions into one model (including government, science, industry, and ICT) allows us to explain what is more important when making a decision about implementing new eco-solutions. The study covered over 3000 enterprises. Stepwise logit regression was used to examine all relationships of interest. We discovered two separate (independent) paths of approach to eco-innovation for ICT and industry. This means that another condition should be fulfilled to reach any eco-innovation in each of the sectors. There are just a few factors supporting new environmental solutions in ICT with strong impact—cooperation with suppliers, journals as a source of new knowledge, or financial support by credit institutions with high materials and energy efficiency at the end of the process. Industry could be described more like a horizontal approach—a wide number of conditions with low impact on eco-innovation. Therefore, innovation policies in the catching-up country should be more sophisticated and take care of more relevant tools for both sectors.

Keywords: eco-innovation; environmental innovation; ecological innovations; innovation policy; ICT; industry; developing economy; catching-up country; Central and Eastern Europe

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1. Introduction

Eco-innovation plays an important role in the modern economy. The current discussion is not whether it is reasonable to implement eco-innovation, but how to do it in order to achieve a reduction in greenhouse gas emissions to 55% of 1990's levels by 2030 and to achieve climate neutrality by 2050 [1]. Because of this, it is necessary not only to create new technologies with commercial potential but also to create economic conditions that will accelerate the transition processes towards a green economy. In the context of the European Union, this is a complex and complicated process. On the one hand, the member states are steadily improving their environmental performance regardless of the economic situation (stagnation or growth), while on the other hand, the countries that joined the EU after 2004 have a significantly worse environmental performance than the founding members [2]. There is a risk that the gap between these countries in terms of pro-environmental solutions will widen rather than narrow. This makes it necessary to create policy solutions that support catching up in the countries admitted to the EU after 2004 in relation to the founding members. It is important to emphasise that solutions cannot be unreflectively transferred between countries because the behaviour of European countries is not homogeneous in terms of environmental solutions. The European Commission creates environmental guidelines common to all member states, while individual EU countries are responding by creating their own regulations with varying degrees of success [3].

The disparities between the European Union countries highlight the problem of fruitful support for eco-innovation. Economic analyses indicate that when creating different support models, it is necessary to take into account the specific characteristics and level of technological advancement of the countries where the solutions are implemented [4,5]. It follows that transferring solutions from developed countries to catching-up countries without modifying and adapting them to the conditions in the catching-up countries significantly reduces their efficiency. Regulatory pressure plays an important role in creating pro-environmental solutions [6,7], but it requires different support tools in catching-up and developed countries.

Current research in the field of eco-innovation refers to the publication of the results of technologies that have commercialisation potential even before they are implemented, e.g., [8], and to economic studies that point to the determinants associated with eco-innovation. These include publications that show the performance of different pro-environmental solutions in different sectors or firms [9–12]. They are based on individual data and are not economy-wide. They are important because they show how environmental solutions are put in the economic life cycle. They provide a good practice base for actors who want to implement effective tools to reduce negative environmental impacts in the short term. In parallel, however, research is needed on the basis of which it will be possible to build tools to support pro-environmental solutions on a systemic (macro) level.

In this context, a research gap becomes apparent, which is the lack of studies covering the broad determinants of eco-innovation implementation. In particular, this concerns research relating to Central and Eastern Europe, which strongly deviates in terms of pro-environmental performance compared to Western Europe [2]. This problem is particularly pressing since, observing the results of the Eco-Innovation Index and the Eco-Innovation Scoreboard, one does not notice that the new EU members are mostly catching up compared to the founding countries.

The authors of this study decided to fill this gap by analysing the conditions that affect the implementation of eco-innovation in Poland, a country admitted to the European Union after 2004. The aim of the study is to identify the determinants that condition decisions to implement pro-environmental solutions (eco-innovation) in enterprises. For the analyses, microdata collected by the authors of the study were used. Thanks to such a selection of variables, not only the factors commonly analysed in studies on eco-innovation were taken into account, but also those characteristic of a catching-up country such as Poland. The use of these data allows for a broader and deeper insight into the relationships between the various actors in the system who influence the implementation of eco-innovation.

The subjects of analysis are two sectors of the economy distinguished on the basis of the Polish Classification of Activities 2007: industry (manufacturing) and modern services in the field of information and communications technology (ICT). These two groups were chosen for three reasons. Firstly, industry has the largest share of the GDP in Poland [13], so it plays an important role in the development of the economy. ICT, thanks to its services, has the potential to stimulate innovation processes among the enterprises that are their customers [14,15]. Second, industry and ICT are the key actors in technological development. Third, comparing these two groups will test whether there are significant divergences in the determinants of eco-innovation between ICT and industry within a single country. Given the previously mentioned literature, this may be the case. Thus, the research hypothesis is that the conditions driving eco-innovation in the ICT sector are significantly different from those in industry, so support for green solutions should follow two independent paths for both sectors.

2. Literature Review

Nowadays, sustainable development is one of the most important factors for economic growth. Eco-innovations are one way to find the right balance between economic, social and environmental priorities. On the one hand, they bring economic and environmental benefits to companies [16–18], while on the other, they involve new challenges for companies [19]. Therefore, it is important to choose the right instruments to support the implementation of pro-environmental solutions in companies. Indeed, the implementation of eco-innovation depends on many factors related to the economy, climate and energy policy, society, culture, and law [20–22]. This requires changes not only in technologies and business strategies themselves but also in institutions and consumption practices [23].

One of the determinants affecting the implementation of environmental innovations is the size of the firm [24]. Studies show that as firm size increases, the chances of implementing environmental innovations increase [25–29]. Large firms adopt environmental innovations faster than small ones [30–32], although the literature shows that, for example, performance in product innovation is not affected by firm size [33].

Nowadays, it is assumed that the business cycle in the market significantly determines the implementation of not only eco-innovation but also other innovative solutions. Companies during a recession are less likely to initiate innovation projects, more easily abandon projects already underway, and are reluctant to undertake new innovation projects [34]. Despite this, performance related to eco-innovation is improving in the European Union even in times of stagnation. Western European countries are more active in this area [2]. This may be related to a better technological background, as firms that conduct their own R&D are more resilient to business cycle fluctuations [35].

Corporate knowledge competence is considered an important factor in value creation. It opens new production possibilities and increases innovative labour productivity [36]. It is essential to a firm's competitive advantage [37]. The literature suggests that internal R&D efforts and having skilled employees play an important role in the implementation of environmental innovation [38,39]. Environmental innovators do not differ from other innovators in terms of resources devoted to R&D activities, but rather in terms of implementing these activities continuously. Moreover, the results confirm the existence of a substitution effect between internal R&D activities and R&D cooperation with external partners [25]. Wu et al. [40] complement this finding by showing that firms with higher technological capabilities prefer cooperative R&D, while those with lower technological capabilities choose internal R&D [41]. This means that R&D, in fact, not only generates new knowledge and ultimately innovation, but also increases a firm's 'absorptive capacity', i.e., the ability to identify, assimilate and exploit knowledge from external sources. In this view, firms' internal capabilities dynamically adapt and influence those of external partners, mainly customers and suppliers [42].

The constantly changing environment and new challenges require modifying existing knowledge or generating radically new knowledge [43,44]. Since innovation draws ideas from multiple sources, firms need to compensate for their own deficit with knowledge from the milieu to increase the chances of successful innovation [45,46]. The COVID-19 pandemic has further highlighted the need to use external knowledge in eco-innovative initiatives and projects [47].

External knowledge includes different types of knowledge sources, often classified as supply chain and network sources (i.e., suppliers, customers, and competitors), non-supply chain sources (e.g., research organisations and government organisations), and other/specialised sources (e.g., conferences, trade fairs, exhibitions, standards and regulations) [48,49]. Companies' participation in conferences, exhibitions, and trade [50–52] is an opportunity to identify the latest trends and experiences and develop their own innovation strategy [53]. Trade, scientific, and business journals are another mechanism for knowledge diffusion and have a significant impact on the introduction of both product and process eco-innovation [54]. There is also a technical and organisational interdependence between knowledge, skills, and resources [55–57]. In fact, innovation is rarely the result of a single firm's actions [58,59].

The ability of firms to implement eco-innovation depends on the active participation of different actors and the absorptive capacity of pro-environmental solutions [60,61].

Companies need to develop the capacity to build knowledge that is continuously expanded internally and externally [62]. Sharma and Bansal [63] suggested that sustainability-based cooperation should be based on mutual learning processes, which can be a consequence of developing long-term relationships based on trust [64]. A wider range of knowledge sources or partners used by entrepreneurs contributes to learning and innovation [65]. Success increases as the number of knowledge sources used by the firm grows [66]. It is important to stress that a network of actors is also needed to ensure knowledge transfer between firms and the external environment [25,67]. This indicates the importance of cooperation in the processes of eco-innovation creation.

Cooperation with suppliers is important to ensure the supply of raw materials or components with environmentally friendly characteristics [68]. In addition, creating an innovative product/process that reduces negative environmental impacts is a rather complex task and often requires information and skills that differ from the traditional knowledge base of a sector [69,70]. Consequently, entrepreneurs who recognise supplier knowledge as an important resource are likely to be better able to deal with complex problems, diversify R&D activities, and identify new technological opportunities [71,72]. The situation is different when it comes to sharing knowledge with competitors. Companies fear the risk of knowledge leakage, undesirable spillovers, and knowledge looting. This situation raises tensions about knowledge sharing and knowledge protection. Entrepreneurs may also try to cheat by manipulating and distorting information against their partners [73,74].

In the process of creating eco-innovation, collaboration with institutions from the scientific domain as intermediaries of innovation outside the supply chain is playing an increasingly important role. These institutions include universities at the national level [42,75–80] and abroad [26], as well as research centres and science and public and private technology associations [49,81]. However, they rarely act as a direct source of information or knowledge for firms' innovation activities. Interactions between universities and firms remain largely indirect, subtle, and complex [82,83].

Cooperation between firms plays a role in terms of the scale of the novelty of the innovations created. This level (novelty for the firm, market, country, and world) is closely related to the collaborative networks in which firms operate—the higher it is, the more extensive the collaborative networks are [84]. In this arrangement, suppliers, customers and research organisations play an important stimulating role, while competitors play a destimulating one [71,85].

Both developed and catching-up economies have institutional forms of support for technology transfer (Business Support Organisations—BSO). These include innovation centres, financing institutions, and entrepreneurship centres. Research shows that innovation centres have the greatest potential for stimulating innovative activity: technology parks and incubators, academic business incubators, and technology transfer centres.

In technology parks, innovation processes are strengthened by locating firms in one area and establishing cooperation between them [86–88]. Firms located in incubators, through service support in the first years of operation, manifest a greater propensity to create innovative solutions [89–92]. Moreover, this effect is amplified in university incubators, where there are effects related to the commercialisation of knowledge coming from universities [93]. Technology transfer centres play an important role in innovation generation processes, exploiting links with universities and commercialising technologies produced at universities [94–96]. The indicated studies refer to the support of innovation activities in general. It seems interesting to see whether these institutions will have an impact on the implementation of eco-innovation.

Financing institutions (business angel networks, local or regional loan funds, and credit guarantee funds) are complementary to each other. Angels finance innovative projects with high development potential [97]. Money from loan and guarantee funds, due to the lower amounts allocated for support, is for projects with lower innovation potential and entrepreneurial character. These two institutions are specific to Central and Eastern

Europe and can therefore better adapt to the needs of enterprises in Poland [98], especially during the economic crisis [99].

Training and consulting centres provide so-called innovation consulting. However, these services must be of adequate quality. Consultants should have the ability to respond quickly to tasks and build trust within the supported company [100]. This contributes to product quality, as best practices of technical consultants are usually more valuable than internally generated knowledge [101].

The effects of innovation activities play an important role in the implementation of pro-environmental solutions. Research shows that technological innovation and sustainability outcomes can be achieved simultaneously [7,102]. This relationship has been studied in detail by Cheng et al. [103], who showed that product eco-innovations mediate the performance of process eco-innovations. Both types of innovations act as a bridge that transfers the positive impact of eco-organisational innovations to firm performance. There is a path that enables the implementation of pro-environmental solutions while implementing new solutions related to core business activities [6]. This is a very important observation, as some organisational cultures are not conducive to the implementation of sustainability-related innovations [104].

In the literature, innovation barriers are seen as difficulties that prevent innovation activities in firms [105] or as obstacles that can be overcome by specific efforts [106]. It seems that barriers are largely relative and depend on the context of the firm and its characteristics. For example, obstacles reported by small firms may be irrelevant to larger ones [107].

Most researchers divide barriers to innovation into internal and external. Internal barriers are factors that influence the innovation process in the company (e.g., competences, processes, resources, organisational structure). External barriers are related to external actors and the market (education system, availability of specialised human resources, financial system) [108].

Financial barriers are commonly cited by researchers as innovation difficulties [109]. This type of barrier results from a market failure in the understanding of innovation, which removes the most useless innovation projects [110]. At the same time, this barrier is most often removed through innovation policy instruments around the world [111]. Financial barriers arise from the high risks associated with involvement in innovation, the lack of own financial resources, and the high costs associated with innovation [112], which affect the time of return on investment.

Financial barriers can be overcome by firms through cooperation or applying for public funds. Zahler et al. [111] write that policy instruments in a developing country such as Chile (with low levels of innovation) correspond to financial support through grants and tax breaks, as well as innovation insurance provided by development banks. De Fuentes et al. [113] analysed the sector of service and manufacturing firms in Mexico, showing that cost-related barriers (economic risk, lack of finance, cost of innovation) have a positive and significant impact on the decision to innovate. Mohnen et al. [114] and D'Este et al. [115] suggest that this may be due to the fact that only firms involved in innovation have the ability to identify and notice barriers to innovation.

The creation of effective instruments to support the implementation of eco-innovation in enterprises is a two-stage process. The first stage refers to the correct identification of the factors influencing the choice of pro-environmental solutions in a country [4,5] and the second to their correct utilisation. The number of studies on the determinants of eco-innovation is very large (Table 1). This means that the conclusions and recommendations that are presented in these studies should be approached with caution when designing supporting programmes. Therefore, the authors decided to collect in one analysis the factors that may affect the implementation of pro-environmental solutions and identify those that, from a systemic perspective, determine eco-innovations.

Table 1. Potential determinants of eco-innovation.

Groups of Determinants	Theoretical Support
Company size	[24–32]
Business cycle	[2,34,35]
Internal resources of the company (R&D activities, internal knowledge)	[25,36–38,41,42]
Level of novelty of the created innovations	[71,84,85]
Innovation cooperation	[25,26,42,49,58,59,64,67–83]
Institutional support for innovation	[86–101]
Sources of innovative activity	[36,37,42,45–52,65,66]
Effects of innovative activity	[6,7,102–104,110,113]
Barriers to innovative activity	[105–113]

Source: own study based on literature review.

3. Materials and Methods

The survey was conducted twice in Poland in two sectors of the economy. The first one was industry (data collection period was 2013–2018) and the second one was ICT (data collection period was 2016–2018). The database of enterprises for the industry sector came from the commercial database teleadreson.pl, while the database for ICT was purchased from Statistics Poland. The first database was commercial in nature and was continuously updated. As a result, all entities included in the database were in business and the survey return rate was 12.5%. The database from Statistics Poland was not updated—it contained all enterprises that had started a business in Poland. At the stage of contacting entrepreneurs, it turned out that some enterprises did not exist. The return rate of the questionnaires was at the level of 6%. The research material was collected by the researchers of the Department of Innovation and Entrepreneurship at the University of Zielona Góra with the participation of students who attended courses taught by the Department's employees during the period of their study. The involvement of students in the research process in catching-up countries with research funding difficulties is suggested by Lunvall [47]. To ensure that the survey forms were reliably collected, the authors of the study carried out post-verification. Students indicated which companies had completed the survey forms. The authors of the survey telephoned the enterprises that had been identified as respondents to the survey and confirmation of the fact that the questionnaire had been completed.

Product and process innovations that contributed to the reduction in harmful environmental impacts were used as dependent variables. The independent variables were developed based on the literature review and supplemented by the Oslo methodology guidelines [116,117]. They were divided into seven groups. The first group consisted of firm attributes, which included R&D expenditure and investment in new buildings related to the production of a new product or technology. The second group included the level of novelty of the innovations created (novelty for the company, the country, and the world). The third group referred to innovation cooperation between enterprises (with a supplier, customer, competitor, and within a capital group) and with science institutions (with universities, the Polish Academy of Science (PAN) departments, domestic and foreign R&D institutes). The fourth group analysed institutional support for eco-innovation, which consisted of business environment institutions (technology parks, technology incubators, academic business incubators, technology transfer centres, business angel networks, local or regional loan funds, loan guarantee funds, training and advisory centres). The fifth group of variables covered sources of innovation activity (internal sources, competitors, customers, suppliers, PAN departments, universities, domestic and foreign R&D institutes, professional conferences and meetings, branch literature and journals, professional associations, and trade unions), and the sixth group covered barriers (lack of funds within the enterprise, lack of finance from sources outside the enterprises, too-high cost of innovation, lack of qualified personnel, lack of information on technology and markets, difficulty in finding co-operation partners, market dominated by established companies, uncertain demand). The seventh group referred to the effects of innovative activity (increasing the range of goods and services, entering new markets, improving the quality of goods and services, improving the flexibility of production or service provision, increasing the capacity of production or service provision, reducing unit labour costs, reducing the consumption of materials and energy, meeting regulatory requirements). The control variables were firm size (small, medium, or large), ownership (domestic, foreign, or mixed), business climate (prosperity, recession, or stagnation), and a time variable. The inclusion of time was important because the study in industry covered a five-year period and in ICT a three-year period. This variable was rejected in the process of building the model using logistic forward stepwise regression because it was found to be statistically insignificant. This allowed the results of the analyses obtained to be interpreted, despite the research period of several years.

The research method used in the analyses is logit modelling. The choice of method was dictated by the nature of variables adopted for the study—these were dummy variables. Entrepreneurs were not asked how much money was spent. e.g., on R&D activity, but whether any money was spent there or not. An affirmative answer was assigned the value 1, and a negative answer was 0. A similar procedure was applied in the case of other variables. Such an approach to the variables made it easier for entrepreneurs to fill in the questionnaire form and allowed us to obtain a larger number of correctly filled-in questionnaires.

Logit modelling determines the probability of the dependent variable influencing the independent variable. The estimated model takes the form of a logistic function. Due to the fact that the slope of such a function may take negative values or values above one, they are not interpreted. If its value is less than 1, it means that the probability of the occurrence of the expected phenomenon in the group of enterprises that dealt with the independent variable (e.g., conducted R&D) is lower than in the group of entities that did not deal with the independent variable (e.g., did not conduct R&D). In the case of values above 1, the situation is reversed. Additional measures and auxiliary tests were used to assess the quality of the model. Wald's χ^2 test, the *p*-value, and the Hosmer–Lemeshow test were used to assess the validity of the model. The Wald test assesses constraints on statistical parameters based on the weighted distance between the unrestricted estimate and its hypothesised value under the null hypothesis, where the weight is the precision of the estimate [118,119]. The *p*-value is the level of marginal significance within a statistical hypothesis test, representing the probability of the occurrence of a given event [120]. Hosmer–Lemeshow goodness-of-fit statistics assesses whether or not the observed event rates match expected event rates in subgroups of the model population [121]. Cox and Snell R^2 and Nagelkerke R^2 are other measures known as pseudo-R-squared measures. Note that Cox and Snell's pseudo-R-squared has a maximum value that is not 1. Nagelkerke R^2 adjusts Cox and Snell's so that the range of possible values extends to 1 [122]. The ROC curve accurately depicts the relationship between sensitivity and specificity. The area under a (ROC) curve, abbreviated as AUC (area under curve), is a single scalar value that measures the overall performance of a binary classifier [123]. A case classification matrix (observed and predicted) was also included to assess the prediction ability.

Statistica 13 software (TIBCO Software Inc., Palo Alto, CA, USA, 2017) was used for the analyses. Not all independent variables included in the study met the conditions of statistical significance. The variables that were used in the estimation process in the model are presented in Table 2.

Table 2. Definition of the variables used in equations.

Variables	Description
Dependent Variable	
ECO_INN	Nominal variable; 0: lack of eco-innovation; 1: ecoinnovation
Independent Variables	
Enterprises Attributes	
BUIL_*inv*	Dummy variable; 1: new building investment; 0: otherwise
R&D_inv	Dummy variable; 1: R&D investment; 0: otherwise
Innovation Novelty	
*New*TECH_*ent*	Dummy variable; 1: new technology to the enterprise only; 0: otherwise
*New*TECH_*coun*	Dummy variable; 1: new technology to the country; 0: otherwise
*New*TECH_*glob*	Dummy variable; 1: global new technology; 0: otherwise
Sectoral and Science	
COOP_*sup*	Dummy variable; 1: inn. cooperation with supplier; 0: otherwise
COOP_*com*	Dummy variable; 1: inn. cooperation with competitor; 0: otherwise
COOP_*foreignS*	Dummy variable; 1: inn. cooperation with foreign science unit; 0: otherwise
COOP_*group*	Dummy variable; 1: inn. cooperation within capital group; 0: otherwise
Support System	
SUPP_*techinc*	Dummy variable; 1: cooperation with technology incubator; 0: otherwise
SUPP_*loanfund*	Dummy variable; 1: cooperation with local or regional loan fund; 0: otherwise
SUPP_*creditfund*	Dummy variable; 1: cooperation with credit guarantee fund; 0: otherwise
SUPP_*traincentr*	Dummy variable; 1: cooperation with training and consulting centre; 0: otherwise
Source of the New Knowledge	
SOUR_*insid*	Dummy variable; 1: Source: inside the firm; 0: otherwise
SOUR_*maga*	Dummy variable; 1: Source: magazine and publication; 0: otherwise
SOUR_*sup*	Dummy variable; 1: Source: supplier; 0: otherwise
SOUR_*com*	Dummy variable; 1: Source: competitor; 0: otherwise
SOUR_*cus*	Dummy variable; 1: Source: customer; 0: otherwise
SOUR_*confe*	Dummy variable; 1: Source: conference and trade fair; 0: otherwise
SOUR_*assoc*	Dummy variable; 1: Source: scientific and technology association; 0: otherwise
SOUR_*univ*	Dummy variable; 1: Source: university; 0: otherwise
SOUR_*foreignS*	Dummy variable; 1: Source: foreign scientific institutes; 0: otherwise
Barier for Innovation	
BARR_*cost*	Dummy variable; 1: Barrier: cost of new technology; 0: otherwise
BARR_*fin*	Dummy variable; 1: Barrier: lack of money; 0: otherwise
Effect of innovation	
EFF_*mat*	Dummy variable; 1: reduction in materials and energy consumption; 0: otherwise
EFF_*num*	Dummy variable; 1: increasing the number of different products; 0: otherwise
EFF_*capa*	Dummy variable; 1: increasing production capacity; 0: otherwise
EFF_*mark*	Dummy variable; 1: entering a new market; 0: otherwise
EFF_*law*	Dummy variable; 1: fulfilment of regulations and standards; 0: otherwise
EFF_*labo*	Dummy variable; 1: reducing unit labour costs; 0: otherwise
EFF_*qual*	Dummy variable; 1: improvement in the quality of products; 0: otherwise
Control Variables	
SmallF	Dummy variable; 1: small firm; 0: otherwise
MediumF	Dummy variable; 1: medium firm; 0: otherwise
LargeF	Dummy variable; 1: large firm; 0: otherwise
t	Time variable

Source: own study based on the collected research materials.

A formal expression of these equations for a firm *i* is as follows:

$$\begin{aligned} ECO\_INN_t\ (ICT\ or\ Industry) = {} & \alpha_0 + \alpha_1 BUIL\_inv_i + \alpha_2 R\&D\_inv_i + \alpha_3 NewTECH\_ent_i \\ & + \alpha_4 NewTECH\_coun_i + \alpha_5 NewTECH\_glob_i + \alpha_6 COOP\_sup_i + \alpha_7 COOP\_com_i \\ & + \alpha_8 COOP\_foreignS_i + \alpha_9 COOP\_group_i + \alpha_{10} SUPP\_techinc_i + \alpha_{11} SUPP\_loanfund_i \\ & + \alpha_{12} SUPP\_creditfund_i + \alpha_{13} SUPP\_traincentr_i + \alpha_{14} SOUR\_insid_i + \alpha_{15} SOUR\_maga_i \\ & + \alpha_{16} SOUR\_maga_i + \alpha_{17} SOUR\_sup_i + \alpha_{18} SOUR\_com_i + \alpha_{19} SOUR\_cus_i + \alpha_{20} SOUR\_confe_i \\ & + \alpha_{21} SOUR\_assoc_i + \alpha_{22} SOUR\_univ_i + \alpha_{23} SOUR\_foreignS_i + \alpha_{24}\ BARR\_cost_i \\ & + \alpha_{25}\ BARR\_fin_i + \alpha_{26}\ EFF\_mat_i + \alpha_{27}\ EFF\_num_i + \alpha_{28}\ EFF\_capa_i + \alpha_{29}\ EFF\_mark_i \\ & + \alpha_{30}\ EFF\_law_i + \alpha_{31}\ EFF\_labo_i + \alpha_{32}\ EFF\_qual_i + control\ variables + t_i + u_i. \end{aligned}$$

4. Results

Two logit models were built in this paper. The first one describes the determinants of eco-innovation in enterprises providing advanced ICT services. The second describes the determinants of eco-innovation in Polish industry. We begin our empirical study with a brief comparison of the two models. Tables 3 and 4 concern the ICT sector. As can be seen in Table 3, the number of variables influencing eco-innovation in ICT is lower than in industry (Table 5). This indicates that entrepreneurial decisions in ICT depend on a narrow set of determinants, but they are more pronounced (higher odds ratio values than in industry). In industry, they depend on many variables, but with a lower strength of influence. Both models, although based on data from different economic sectors, have similar model statistics (the coefficient of determination is high for the logit function and all independent dummy variables). The Wald statistics are high and the *p*-value is close to zero. Both models pass the Hosmer–Lemeshow test. We can therefore move on to discuss the details of the models.

Table 3. Determinants for eco-innovation in the Polish ICT sector in 2018–2020, logit function.

Independent Variables	Eco-Innovation (Odds Ratio)
BUIL_*inv*	5.26 ***
SOUR_*maga*	6.07 ***
SOUR_*com*	2.42 **
SOUR_*cus*	2.37 *
COOP_*sup*	7.35 ***
COOP_*com*	0.04 ***
COOP_*group*	0.04 **
SUPP_*creditfund*	6.79 ***
SUPP_*traincentr*	2.52 *
*New*TECH_*coun*	3.65 **
EFF_*mat*	9.04 ***
Sample	383
Wald χ^2	127.61
R^2 Cox–Snell	0.28
R^2 Nagelkerke	0.54
AUC	0.91
p-value	0.00
Hosmer–Lemeshow test	
chi-square	9.93
p-value	0.19

***—statistical significance at 1%; **—statistical significance at 5%; *—statistical significance at 10%. Source: own calculation based on questionnaire research.

Firm size (Table 3) was a control variable in the model but was rejected in the estimation process. This means that firm size is not relevant for eco-innovation in the ICT sector. Entrepreneurs mainly use external, open sources of information (branch journals) and from competitors and customers. In the first case, the chances for eco-innovation are six times higher than in those where no publications are followed. Accordingly, in the case of knowledge obtained from competitors, the chances increase by 2.42 times, and from customers, by 2.37 times. Companies investing in new buildings are more than five times more likely to introduce environmental innovations. Knowledge acquisition from competitors stimulates eco-innovation, while cooperation does not. The chances of eco-innovation in the case of collaborations decrease dramatically—by 96%. Group companies are also not interested in environmentally friendly solutions. The only ones who cooperate in the field of ICT and contribute to eco-innovation are suppliers (the chances increase more than sevenfold). It should be noted here that the sources of knowledge about eco-innovation and cooperation take place only in the business sector, without the participation of science. The process of creating eco-innovations is actively supported by local guarantee funds and training and consulting centres. However, there is a lack of other support organisations, especially those dealing with technology transfer. ICT companies, which introduce innovations on a national scale, more often (by 265%) decide on environmental innovations. Such an approach results not only in green solutions but above all in low-carbon solutions. ICT companies are more than nine times more likely to achieve savings in materials and energy. This is the strongest factor in the model for ICT.

The model estimated for ICT companies gives a chance of success of 90.1% (AUC value). The success rate for ones is 58.3% and for zeros 97.9% (Table 4, Figure 1). This means that a company that completes the conditions of the model has a 58.3% chance of introducing eco-innovation. At the same time, if it does not meet the conditions, the chances for such innovations drop to 2.1%. It is worth mentioning that the number of eco-innovations in ICT companies is not high—only 12.5% of entities have implemented them. Despite the lower odds ratio of ones (innovative activity), the whole model achieves a high AUC value, as this ratio is a weighted mean of the successes of zeros and ones (Figure 1).

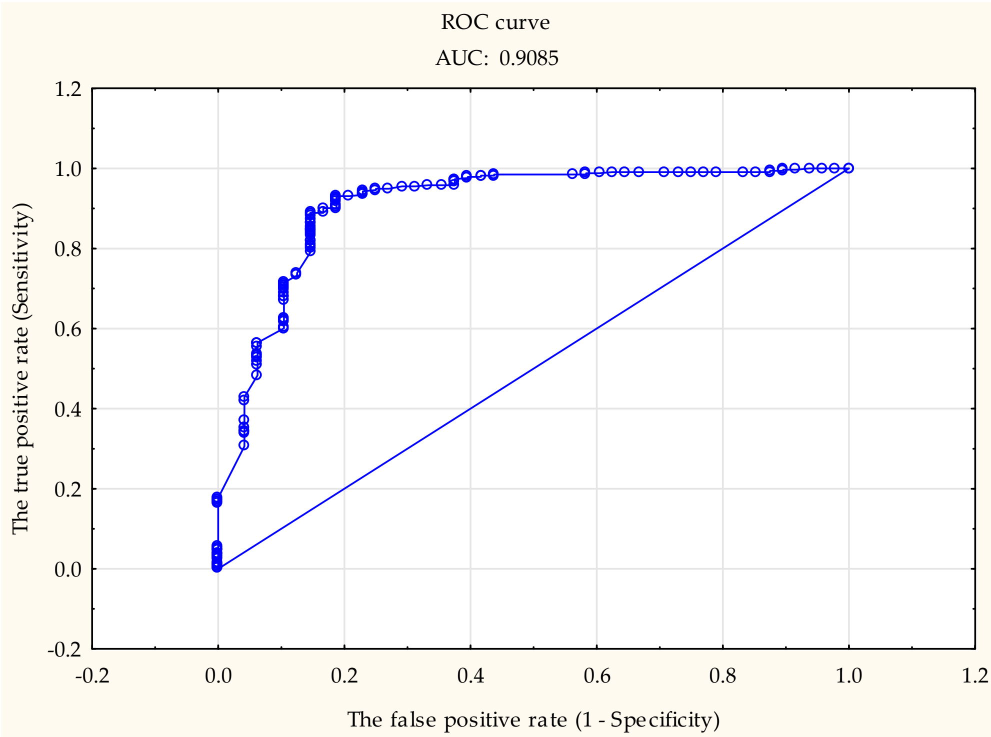

Figure 1. ROC curve for the Polish ICT sector—eco-innovation equation. Source: own calculation with Statistica software support based on questionnaire research.

Table 4. Matrix of case classification—Polish ICT sector.

Real Belonging of Objects	Classification of Objects Based on the Logit Model		
	Predicted: 0	**Predicted: 1**	**Correct (%)**
Observed: 0	326	7	97.90
Observed: 1	20	28	58.33

Source: own calculation based on questionnaire research.

The model estimated for industry is similar in terms of the quality of fit but clearly different in terms of the factors influencing eco-innovation in Poland. Here, the size of the company does matter. Small, medium, and large companies introduce such solutions more often—by 76%, 87%, and 156%, respectively (Table 5). Research and development activity is important for eco-innovation, although the odds ratio and the level of statistical significance compared with other stimulants are lower. Entrepreneurs deciding on new building investments are less interested in eco-innovation by 33%—quite different compared to ICT. Industry uses a wide range of sources of knowledge about new technologies, not only environmental sources. The strength of impact is similar to that in ICT, but one type of source is particularly important; namely, science and technology associations.

Next in terms of positive impacts are foreign scientific institutions (71% higher odds), branch journals (50%), suppliers and universities (both 47%), internal sources within the company (46%), and conferences or trade fairs (40%). When companies gain new technology knowledge from competitors, the chances of new eco-innovations decrease by 42%. Innovation cooperation is generally not important for the introduction of eco-innovative technologies in industry. Cooperation with foreign scientific institutions, while important as a source of knowledge, reduces eco-innovation odds by 92%. In other words, such relationships have quite different goals not related to ecological ones. Three support institutions play an important role in eco-innovation, namely technology incubators (102% chance), regional credit funds (86%), and guarantee funds (47%). Other institutions do not play a role. Barriers to new green technologies in Polish industry include the cost of purchasing new technologies and the lack of own resources. However, they have an unexpectedly positive impact. They are therefore not a constraint. At this point, hypotheses can be put forward, which should be verified in the future: (1) entrepreneurs in Poland perceive costly innovation as a Veblen snob effect and decide to purchase it despite high prices and financial constraints. (2) Despite high prices, competitive pressure on the market is so strong that enterprises are forced to purchase or create new technologies internally. The consequences of the technological activity of enterprises are new technologies but not new products. Interestingly, the increasing scale of their novelty increases the chances of eco-innovation. If such solutions are new only for the enterprise, the chances of eco-innovation increase by 93%, for the country it is 111%, and globally 162%. At the same time, we see that even technologies new to the enterprise can strongly stimulate the creation of eco-innovations. The industry in Poland uses many sources of new technologies and, at the same time, achieves many different benefits as a result of implementing green technologies. The most important of these is a reduction in unit labour costs—the odds are 189% higher, and this is also the strongest factor in the presented model. Another is the improvement the product quality—the odds are 128% higher than in companies that do not implement green solutions. This is followed by regulatory compliance (77% higher odds), low-carbon emissions (53%), increasing production capacity and entering into new markets (both 39% higher odds), and increasing the number of products (27%).

Table 5. Determinants for eco-innovation in the Polish Industry sector in 2013–2018, logit function.

Independent Variables	Eco-Innovation (Odds Ratio)
SmallF	1.76 ***
MediumF	1.87 ***
LargeF	2.56 ***
R&D_*inv*	1.32 *
BUIL_*inv*	0.67 ***
SOUR_*insid*	1.46 ***
SOUR_*maga*	1.50 ***
SOUR_*sup*	1.47 ***
SOUR_*confe*	1.40 **
SOUR_*assoc*	1.97 ***
SOUR_*com*	0.58 ***
SOUR_*univ*	1.47 *
SOUR_*foreignS*	1.71 **
COOP_*foreignS*	0.12 ***
SUPP_*techinc*	2.02 *
SUPP_*loanfund*	1.47 **
SUPP_*creditfund*	1.86 ***
BARR_*cost*	1.29 *
BARR_*fin*	1.40 **
*New*TECH_*ent*	1.93 ***
*New*TECH_*coun*	2.11 ***
*New*TECH_*glob*	2.62 ***
EFF_*num*	1.27 *

Table 5. *Cont.*

Independent Variables	Eco-Innovation (Odds Ratio)
EFF_*capa*	1.39 **
EFF_*mark*	1.39 **
EFF_*law*	1.77 ***
EFF_*labo*	2.89 ***
EFF_*mat*	1.53 **
EFF_*qual*	2.28 ***
Sample	2645
Wald χ^2	942.68
R^2 Cox–Snell	0.30
R^2 Nagelkerke	0.48
AUC	0.89
p-value	0.00
Hosmer–Lemeshow test	
chi-square	10.44
p-value	0.24

***—statistical significance at 1%; **—statistical significance at 5%; *—statistical significance at 10%. Source: own calculation based on questionnaire research.

The matrix of case classification shows a similar model performance for industry (Table 6) as for the ICT sector. When the conditions of the model are met, the chances for new green technologies are 56.4%, with 18.8% of enterprises declaring such innovations (50% higher than in services). If the conditions of the model are not met, the lack of eco-innovations is almost certain—the success rate is 95.25%. Here, it is similar to the model for the ICT sector—the weighted mean success rate is high at 88.7% and observations with a value of zero are much more numerous than ones.

Table 6. Matrix of case classification—Polish Industry.

Real Belonging of Objects	Classification of Objects Based on the Logit Model		
	Predicted: 0	Predicted: 1	Correct (%)
Observed: 0	2045	102	95.25
Observed: 1	217	281	56.43

Source: own calculation based on questionnaire research.

The estimated theoretical model illustrates well the behaviour of entrepreneurs in Polish industry. The coefficients of determination are high for logit modelling with dummy variables only. The model passes the Hosmer–Lemeshow test. It is rich in factors supporting entrepreneurs' decisions to introduce eco-innovations in Polish industry or not. At the same time, it is flat in terms of odds ratios. This means that eco-innovation policy in Poland has broad opportunities to influence (systemic tools) the level of green technologies, but with less power than in the ICT sector.

The ROC curve (Figure 2) accurately depicts the relationship between sensitivity and specificity. The high AUC value, as described earlier, indicates the high testability of the theoretical model. An eco-innovation policy built on the basis of such a model will reduce the chance of lack of interest in green technologies to 4.57% and increase the chance of success by 56.4%.

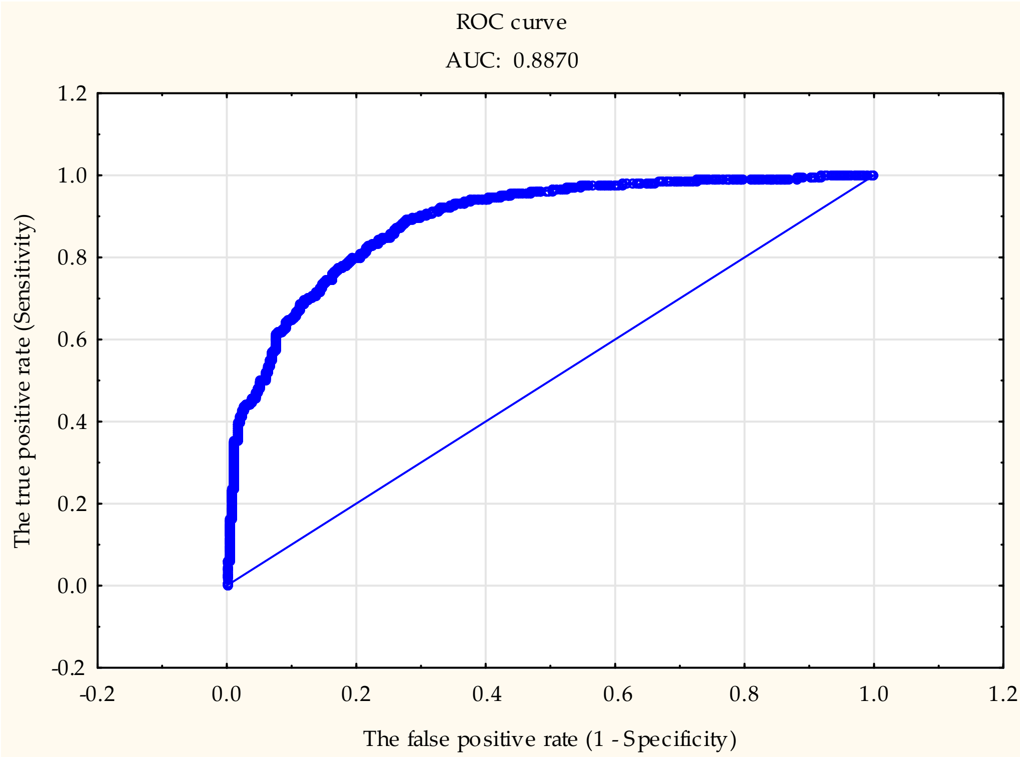

Figure 2. ROC curve for the Polish Industry—eco-innovation equation. Source: own calculation with Statistica software support based on questionnaire research.

5. Discussion

Implementing eco-innovation in Poland is a difficult process. As a country that is catching up on costly investments in new green technologies, they encounter obstacles not only from the entrepreneurs' side but also from political groups, including the government. Law changes concerning wind power plants or photovoltaics limiting the demand for such installations are just two of many examples of how the number of innovative green solutions in the Polish economy is decreasing.

Over three thousand companies in Poland from the manufacturing and ICT sectors, as the main channels of technological progress, were studied. Using raw data, two logit models were constructed to show the determinants of firms' decisions to invest in environmental innovations. Despite similar measures of the quality of fit of the two models, the causes, constraints and effects are different in the manufacturing and ICT sectors.

While firm size is not relevant for eco-innovation in ICT, it is relevant to industry. The industry-related thesis is confirmed in studies conducted in various countries by Chien et al. [24], Penasco, et al. [26], Kesidou and Demirel [31], and Scarpellini [124], among others. It is no different in a catching-up country such as Poland. However, the problem is that such a statement is only true for industry, and environmental policies that take into account company size will discriminate against ICT firms. This leads to the conclusion that the size effect thesis is only partly true.

In developed countries, among the sources of knowledge about eco-innovation, the main role is played by internal R&D, i.e., the company's own efforts to improve environmental solutions. This approach can be observed in publications by Hervas-Oliver et al., [36], Badir et al. [37], or Dost et al. [125]. At the same time, other researchers turn to external sources, seeing them as particularly beneficial for eco-innovation [44,70,71]. A study in Poland shows that the case is more heterogeneous. In the case of ICT, only external and branch sources (journals, competitors, and customers) play an important role, while in industry, the catalogue is much broader. Here, in addition to branch sources, the scientific domain and internal sources also play a role. In industry, internal and external sources should be equivalent. In ICT, external sources determine whether companies introduce environmental innovation. The formulation of tools to stimulate the development of eco-innovation directed at the internal work of companies will be beneficial for industry but not for ICT.

We have also shown the controversial role of investment in buildings that are intended to create innovative products or services. While in ICT they are complementary to eco-innovation, in industry they are substitutable. When manufacturers choose to make new building investments, they reduce expenses on green solutions. While this is an interesting finding, unfortunately, we did not find similar studies in the literature to compare these terms in other countries.

In the literature, authors often write positively about the role of innovation cooperation in eco-innovation [38,66,67]. In particular, they refer to scientific institutions [26,51,52,83], suppliers [73,74], and competitors [77,78]. They cite arguments in favour of collaboration, such as the high uncertainty of innovation and the need to go beyond the firm's core competencies. Thus, they put the issues of technological innovation in general and environmental innovation on an equal level. In studies conducted in Poland, cooperation in eco-innovation resembles the logic of a less-developed country. This is because, according to the thesis of Wu et al. [40], where technological capabilities are smaller, firms prioritise independent R&D over cooperation with other organisations. It is particularly interesting to note that companies in ICT regard competitors as an important source of knowledge about new technologies but are not interested in collaborating in this area. The situation is analogous in industry, where they treat cooperation with foreign research institutions only as a source of knowledge. The exception is suppliers in ICT. Here, companies often cooperate with them in order to jointly develop a new ecological solution. It should not be forgotten that the Polish ICT sector is highly competitive in relation to other countries, which cannot be said about industry. This is where the role of cooperation ends. Industrial companies prefer to work independently on new solutions. They show competence immaturity in accordance with the concept of Wu et al. [40] and the principle of the substitution of internal versus external R&D [25]. In a country at a lower level of development, innovation cooperation is not common at all. For this reason, we cannot on innovation cooperation of an ecological nature, either, which should be treated as a natural process of maturation and transition from less to more advanced countries.

Business support organisations in other countries help companies to create eco-innovations [126]. The study conducted here diagnosed eight types of support organisations, which can be divided into three groups: innovation centres, financial institutions, and entrepreneurship centres. Polish industry and ICT are interested in financial leverage and the training of employees rather than technological support. Perhaps the quality of support is not adequately matched to the needs of companies, but this is a hypothesis rather than a research conclusion. An exception to this rule is the young industrial companies using the services of technology incubators. This may mean that for young enterprises, pro-environmental solutions are important from the beginning of their activity on the market.

Every innovation process encounters various obstacles on its way, as it is often complex and staggered and requires large amounts of material and personnel resources. This is pointed out by many researchers in the world [105–107,111]. In the Polish economy, due to its level of development, they should be even more pronounced than in more developed countries. However, it turns out that in ICT, they were all rejected in the estimation process, while in industry, two types remained and in a positive relationship for eco-innovation. This is not an unexpected phenomenon since, for example, in the Netherlands, according to Mohnen et al. [114], for the innovation obstacle variable there was often no relationship or even a positive correlation. The interpretation of a positive relationship between innovation and its obstacles was already studied by Baldwin and Lin [127] in Canada. The positive relationship may mean that firms, despite the presence of the indicated restrictions, are able to introduce new solutions anyway. In other words, they do not limit innovative activity but only hinder it. This may induce the introduction of additional subcategories of obstacles, i.e., those preventing the introduction of innovations and those only hindering such undertakings. Another interpretation of the positive relationship between innovation and barriers is the thesis of Tourigny and Le [128]. They stated that the barriers to innovation revealed in CIS studies should not be interpreted as preventing innovation, but rather as indicating the path that firms had to take to achieve success on their way to innovation. The thesis of the Veblen snob effect and competitive pressure also remains unverified.

The consequences of the innovation activities carried out are solutions with a different scale of novelty. ICT in Poland creates eco-innovations that are new to the country, while industry interacts at every level, i.e., at the level of the enterprise, the country, and the global. This means that eco-innovations significantly support the competitiveness of enterprises, as they often create solutions that are unique to the market, which guarantees an advantage. As indicated by research conducted by Amara et al. [129], increasing the level of novelty of an innovation requires greater or higher learning capabilities than for innovations with a lower level of novelty. This means that ICT in Poland is characterised by higher learning capacity in the context of new technological solutions, while incremental eco-innovations also play an important role in industry. The level of novelty is not related to networks in this context, as it is in Spain [71]. In the case of ICT, the positive relationship between eco-innovation and cooperation appeared only for suppliers and was not reflected in industry. This confirms previous findings on collaboration in Poland.

It also seems interesting to analyse the effects of eco-innovation on the enterprises in question. It turns out that the effects of innovation activity have a much broader impact on eco-innovation in industry than in ICT. In both cases, material and energy intensity decreased, while other areas, such as cost reduction, quality improvement, and the expansion of markets, occurred for industry only. A similar structure of effects occurred in Czech companies [130]. This shows that it may not be appropriate to form general conclusions on the promotion of environmental innovation. The ICT sector, due to smaller benefits associated with implemented eco-innovations, may require larger support mechanisms. This is important because the outcomes of sustainability and technological innovation can be achieved simultaneously [7,102]. Industries may be more inclined to implement eco-innovation because they also reap the benefits of innovations in core activities or, conversely, eco-innovation arises when innovations in core activities are implemented [6].

6. Conclusions

Eco-innovation is an important element of the concept of sustainable development in the economy. Without the diffusion of new technologies that save energy and materials or do not harm the environment, it will not be possible to achieve the goals of a low-carbon or zero-carbon economy. Should support for such progress be the same for all businesses or differentiated depending on the economic sector? The authors sought to answer this question in this article. Two surveys were conducted in the two sectors where technological progress is greatest, namely: industry and modern ICT services. Logit modelling was carried out independently for each of them to assess what factors entrepreneurs take into account when deciding to introduce new environmental solutions. Over three thousand companies were surveyed.

The hypothesis that different conditions determine the implementation of eco-innovation in ICT and industry was confirmed. This means that support with innovation policy tools should be different in these sectors. Establishing a uniform programme for the whole economy will, in fact, favour some of them and the results obtained will not be optimal. For example, investment decisions to develop production in ICT go hand in hand with environmental innovations, while in industry, they crowd out ecology (complementarity vs. substitutability).

Policies to support green technologies in ICT should be narrow, i.e., they should cover only a few areas. The odds are high that the growth of eco-innovation will then be very dynamic. Areas of influence include innovation cooperation with suppliers, the development of loan funds and training and advisory centres, or conducting research on innovative technologies of competitors and consumer preferences. An important source of knowledge for entrepreneurs is journals and magazines. The consequences will be eco-innovation at the national level and a significant reduction in low-carbon emissions.

The situation in industry is different. On the one hand, the wide possibilities of influence contrast with a much lower impact. In other words, we can touch industry in many different places, but each time, the effect achieved will be much weaker than with ICT. As the size of the company increases, the opportunities for environmental innovation increase as well. Expanding a company (new buildings) limits such innovations, while doing R&D favours them. Entrepreneurs in industry use a broad base of sources of new knowledge, mainly external. An important and positive role is played by national and foreign scientific institutions and a close sectoral environment outside the competition. Companies in a country such as Poland are not interested in ecological innovation cooperation, but young entrepreneurs often use the help of technology incubators. Capital from regional loans and guarantee funds also plays an important role. The analyses note that the new production technology is implemented by entrepreneurs and greater odds for environmental innovation appear. This means that environmental and technological progress are complementary. Although there are obstacles to eco-innovation, this should rather be seen as an indication of the problems faced when implementing green projects. Industry also achieves a large pool of effects as a result of a new eco-innovation solution, which shows that it provides both economic benefits and environmental ones.

With this study, we provide a glimpse into what is important to entrepreneurs when they decide to implement eco-innovation. We do not give ready-made solutions for politicians, but we indicate directions that should be supported or changed. The next stage should be a discussion and research on what instruments should be used to accelerate ecological changes in the economy.

Although industry and ICT are very important for technological progress in general, they are not responsible for the whole economy. Research should therefore be carried out in other sectors to find out what determines eco-innovation there. The discussion here is based on a survey fully representative of ICTs and a large but unrepresentative population in industry. Depending on the possibilities, a fully representative survey would be preferable. It might also be interesting to compare the results of this survey with other countries at higher and similar levels of development for a broad systemic framework of circumstances limiting and fostering eco-innovation.

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