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Modelling Of Eco-innovation Diffusion: The EU Eco-label

Abstract

The aim of this article is to carry out a theoretical and empirical analysis of the process of eco-label diffusion. Eco-labels allow consumers to identify products and services that have a reduced environmental impact during their life cycle. Thus, they are aimed at diminishing the information gap between sellers and buyers. The results of the estimation using the Bass model indicate that the diffusion of the EU eco-label has been most dynamic in countries such as Hungary, Poland, Denmark, Germany and France. In turn, the scope of diffusion (absolute saturation level) reached the highest value for companies in France and Italy. In addition, the results of the study confirm the stimulating impact of the scope of eco-label diffusion on consumer awareness of environmental issues. This finding points to the need for environmental education among consumers, which could in turn encourage firms to undertake pro-environmental actions.

Keywords: *eco-label, eco-innovation, innovation diffusion, Bass model*

1. Introduction

The OECD (1991, p. 12) defined 'environmental labelling as "the voluntary granting of labels by a private or public body in order to inform consumers and thereby promote consumer products which are determined to be environmentally more friendly than other functionally and competitively similar products." Thus,

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eco-labelling, either as an information instrument or an environmental instrument, is aimed at increasing demand for environmentally preferable goods, which leads to a reduction of the environmental impacts of local economies. Eco-labels, regarded as a type of eco-innovation marketing, are complementary to eco-innovative products, since they offer information on products' quality and performance with respect to their environmental impacts during their life-cycles. The main objective of eco-labelling is to reduce information asymmetry, i.e. the inability of customers to judge the environmental impacts of the products before purchase, and hence encourage them to substitute "conventional" products with eco-labelled ones, which are more resource- and energy-efficient (Kenzo et al. 2002, pp. 227-248). Taking into account that most of a product's environmental characteristics are credence attributes, no signal/information is credible without third-party intervention. If consumers cannot be certain of the claim, the labelled products are to be crowded out by unlabelled ones.

According to the International Organisation of Standardisation (ISO), three voluntary eco-labels can be distinguished, namely ISO Types I-III (ISO 1999, ISO 2000, ISO 2007). Type I, considered in this study, refers to a criteria-based certification program that awards a license authorizing the use of environmental labels on products. These labels provide qualitative environmental information. Type II describes environmental claims made by manufacturers, importers and distributors without independent third-party certification. Type III provides quantified environmental data using predetermined parameters. Another classification of environmental labelling programs into five different categories on the basis of three distinctions is provided by the USEPA (1993, p. 11). This classification distinguishes between programs which promote positive attributes of products or the disclosure of neutral or negative information. Moreover, it differentiates between programs on the basis of whether they are mandatory or voluntary, or considers a single attribute or a range of environmental attributes.

Despite the direct and indirect environmental benefits of eco-labelling, research on the adoption process of eco-labels remains anecdotal. Within the field of environmental economics, the diffusion of eco-labelling programs has received much less attention compared to the diffusion of environmental technologies (Popp et al. 2010, pp. 899-910). There are a few papers that deal with the adoption of eco-labelling schemes by countries (Horne 2009, pp. 175–182), but firm level analyses are limited. This paper attempts to address this gap in the literature by providing an empirical analysis of the process of eco-labels' diffusion in EU firms. Moreover, the variations in the scope of diffusion in particular countries is explained.

The remainder of this paper is organized as follows: Section 2 provides a concise review of the nature of innovation diffusion and its drivers. Sections 3 and 4 present and discuss the methodology and the results of research. Section 5 presents conclusions.

2. Theoretical aspects of eco-innovation diffusion

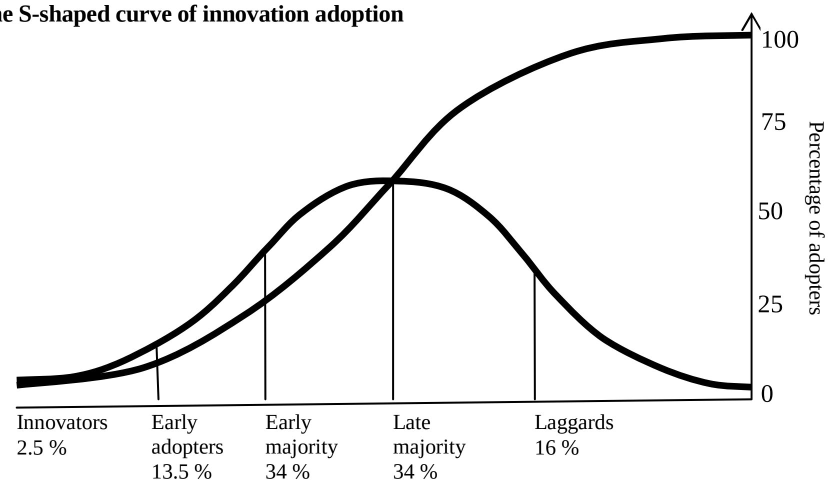
Within the field of economics of innovation, technological change is comprised of three stages, which are called a Schumpeterian trilogy, i.e: a) invention - the generation of new ideas), b) innovation - the development of those ideas through to the market, and c) diffusion - the spread of innovation across its potential users (Stoneman, Diederen 1994, p. 918). The concept of innovation diffusion is described and defined in various ways in the literature. Rogers (2003, p. 5) defines diffusion as the process by which an innovation is communicated through certain channels over time among the members of a social system. Consequently, he distinguishes between innovation diffusion and innovation adoption; in that the former occurs within a society, whereas the latter pertains to an individual (i.e. a firm or a person). Another frequently cited definition is that of Katz et al. (1963, p. 240), who defines diffusion as the acceptance over time of some specific item - an idea or practice by individuals, groups or other adopting units. The process of spreading innovation may be vertical or horizontal. The former pertains to the flow of information in the research and implementation processes, and the latter means that the transfer of innovation may be spatial or situational (Kijek, Kijek 2010, p. 55).

The diffusion of innovation is a gradual and dynamic process. This process generates the well-known S-shaped diffusion curve: innovations spread slowly in the initial period, next there is a recovery phase and then comes the phase of saturations. In one of the early diffusion studies (Ryan and Gross 1943, p.) the rate of adoption of hybrid seed by Iowa farmers followed the S-shaped normal curve when plotted on a cumulative basis. Ryan and Gross's study was expanded upon by Griliches (1957, pp. 501-522), who investigated the diffusion of hybrid seed in other agricultural regions of the United States. His research and other empirical works (Stoneman, Battisti 2010, pp.740-741) show some regularities in diffusion process:

- diffusion often follows the S-shaped path when plotted against time;
- diffusion paths differ across innovations and markets;
- adopters have different characteristics.

According to Figure 1, the adopters of innovation can be divided into five categories, namely: innovators (the area lying to the left of the mean time of adoption minus two standard deviations); early adopters (the area between the mean minus one standard deviation and the mean minus two standard deviations); the early majority (the area between the mean date of adoption and the mean minus one standard deviation); the late majority (the area between the mean and one standard deviation to the right of the mean); and laggards – the last 16 percent to adopt (Rogers 2003, pp. 280-281). Such a division is the result of the interaction of two factors. The first concerns the heterogeneity of social agents in relation to the tendency to risk and social/economic characteristics. The second results from the different rates of acquiring knowledge (learning) of individual units.

Figure 1. The S-shaped curve of innovation adoption



Source: Rogers (2003, p. 281).

Roger's diffusion theory can be applied to different types of innovations, including eco-innovations. The OECD (2009, p. 13) defines eco-innovation as a new or substantially improved product (manufacture or service), process, organization or marketing method, which reduces negative influences on the environment, i.e. environmental risk, pollution and harms, and/or optimizes the use of resources. It is quite obvious that the beneficial environmental impact of eco-innovations is socially desirable, but the double externality problem reduces the private incentives for firms to invest in environmental innovations. Apart from this characteristic of eco-innovation, Rennings (2000, pp. 319-332) identifies two more peculiarities, i.e.: the regulatory push/pull effect and the increasing importance of social and institutional factors for eco-innovations.

What is important is that the former makes eco-innovations more dependent on regulation compared to other innovations, while the latter stresses the role of networking with other firms and institutions for eco-innovation (Cainelli et al. 2011, p. 328-368).

Due to the above-mentioned peculiarities of eco-innovations they are assumed to have a slow rate of adoption, creating a more gradual slope of the S-curve, for example in 2006 solar power - commercially available for over 60 years - accounted for less than 0.1% of electricity generation in the US (Zhang et al. 2011, p. 152). According to Karakaya et al. (2014, p. 398) the importance of understanding diffusion of eco-innovations has been growing both in practice and theory. They give a concise review of recent studies on diffusion of eco-innovations using bibliographical evidence, and conclude that only the study of Ottman et al. (2006, pp. 24-36) focuses on the credibility of product claims and its impact on diffusion process. As mentioned previously, contrary to eco-innovative products and processes, marketing eco-innovations such as eco-labeling relies on non-technological mechanisms and concerns the firm's orientation towards customers by leveraging environmental issues. Piotrowski and Kratz (1999, pp. 431-432) identify some problems with eco-labelling which affect its adoption. First of all, the life-cycle assessment process and the determination of criteria are especially controversial due to the lack of a commonly-accepted methodology for carrying them out. Moreover, the constant tightening of eco-labelling standards may have the unintentional effect of excluding the majority of producers. Last but not least, there is the problem with the life cycle analyses costs. In order to improve the usefulness of environmental claims, the OECD (2011, p. 98) suggests following actions:

- developing environmental claims standards and codes;
- specifying relevant information to be included or required on labels;
- taking enforcement actions to counter false environmental claims.

According to the Hall's concept, several factors affect the rate of innovation diffusion, i.e. the benefits and costs perceived by adopters, the market and social environment, as well as problems regarding uncertainty and information (Hall 2004, pp. 12-20). The last factor results in the occurrence of the 'prisoners' dilemma' faced by firms considering investing in eco-labels where consumer preferences are unknown, i.e. no one wants to be the first to engage in such an investment. On the other hand epidemic models assume that one adoption generates further adoptions and thus a reduction in uncertainty is self-perpetuating (Mansfield 1971, p. 88).

In the case of eco-labels, a firm's cost-benefit analysis is based on the evaluation of two dimensions. The first relates to the extent to which an eco-label would increase the production and administrative costs (e.g. application fee, audit inspection, product testing etc.). The second refers to the extent to which consumers are willing to use the environmental information in their purchase decision-making process and ultimately pay more for an eco-labelled product. For example, a review of studies on premium and market valuation of environmental attributes, including organic food labelling, provided by Krarup and Russel (2004, p. 98), reveals that very few consumers are ready to pay more than 5-10% above the price of a standard product. So, the eco-labelling incentive will be undertaken if the net private pay off from such investment is positive. When the net benefit of eco-labelling is difficult to estimate, the fact that a large number of a firm's competitors have introduced eco-labelling may prompt the firm to introduce it as well. It is important to note that the sensitivity of consumers to environmental issues and their propensity to pay more for eco-labelled products are the result of their environmental education. It becomes clear that a low level of the consumer sensitivity to the environment reduces the scale of eco-labels' diffusion.

Apart from these market-based factors, environmental policy may affect the propensity to eco-label in direct and indirect ways. Eco-labels' diffusion may be fostered by public support, i.e. grants, subsidies and loans. On the other hand, regulations in the form of minimum product standards or requirements may also stimulate firms to apply for eco-labels, but this impact is indirect. As suggested by empirical analyses, environmental regulations have a direct positive impact on environmentally-innovative products (Wysokińska 2013, p.207), which are regarded as being complementary to eco-label certification (Mehamli 2013, pp. 51-63).

3. Materials and methods

The data on eco-labelling in European countries was obtained from the Eurostat dataset. The data included the number of Eco-label/EU Flower licenses in 12 countries during the years of 2000-2009. The EU Eco-label is a voluntary scheme, which means that producers, importers and retailers can apply for the label for all their non-food and non-medical products and services. The Community Eco-label was awarded for the first time in 1996 to products and services with reduced environmental impacts. It is administered by the European Commission and receives the support of all EU Member States and the European Free Trade Association (EFTA).

In order to model the diffusion of eco-labels in the EU countries, we used the Bass model, which can be expressed by following equation (Bass 1969, pp. 215-227):

$$\frac{dN(t)}{dt} = \left[p + \frac{q}{m}N(t)\right]\left[m - N(t)\right] \quad (1)$$

where:

$N(t)$ – the cumulative number of adopters at time t,

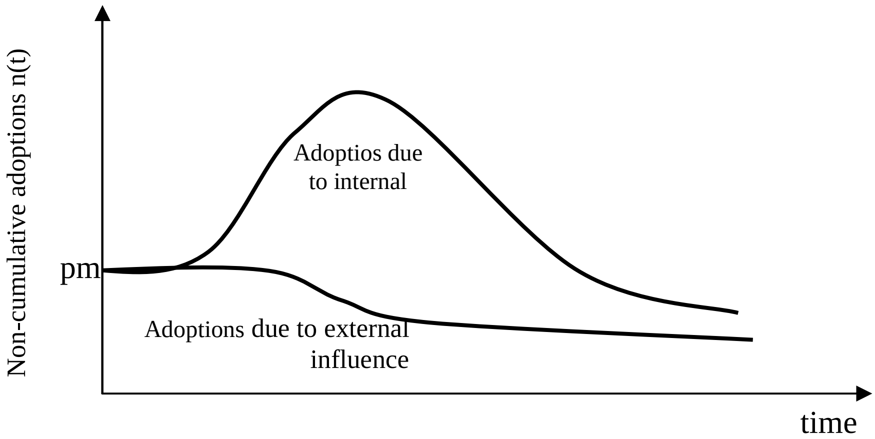
m – the ceiling,

p – the coefficient of innovation,

q – the coefficient of imitation.

The constant *p* in the equation is defined as a coefficient of innovation or external influence emanating from outside of a social system (Kijek and Kijek 2010, pp. 53-68). Under such a premise, it can be assumed that *p* depends directly on the information about innovation, formulated by market agents, government agencies etc., and aimed at potential users of innovation. In turn, the constant *q*, defined as a coefficient of imitation, reflects the interactions of prior adopters with potential adopters. So the speed of diffusion is a function of the *p* coefficient and the *q* coefficient (Figure 2).

Figure 2. Adoptions due to internal and external influences in the Bass model



Source: Mahajan et. al. (1990, p. 4).

Assuming $F(t) = \frac{N(t)}{m}$, where $F(t)$ is the fraction of potential adopters who adopt the technology by time *t*, the Bass model can be restated as:

$$\frac{dF(t)}{dt} = [p + qF(t)][1 - F(t)] \tag{2}$$

With the assumption that the ceiling of potential adopters *m* is a constant, equation (1) is a first-order differential equation with three parameters *p*, *q*, *m*. Integrating the differential equation yields the curve of innovation diffusion, i.e. the cumulated adopters distribution $N(t)$:

$$N(t) = \frac{m - \frac{p(m-N_0)}{p+\frac{q}{m}N_0} e^{-(p+q)t}}{1 + \frac{\frac{q}{m}(m-N_0)}{p+\frac{q}{m}N_0} e^{-(p+q)t}} \tag{3}$$

where $N_0 = N(t=0)$.

For the diffusion of innovation curve (3), the point of inflection i.e. $[dN(t)/dt]_{max}$ occurs when:

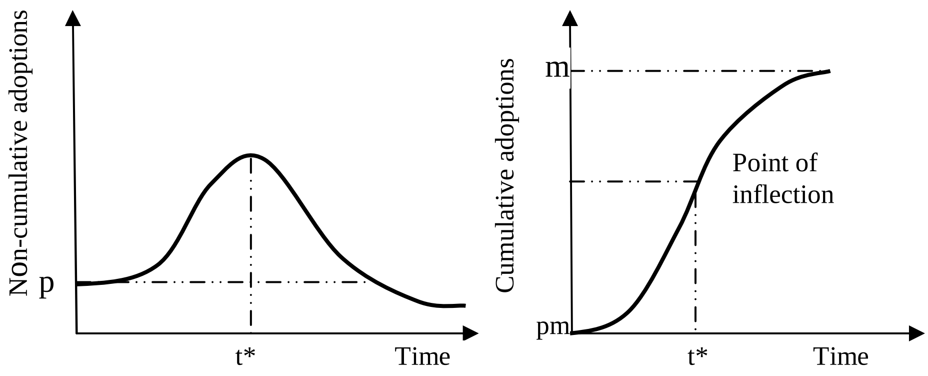
$$N(t^*) = m\left(\frac{1}{2} - \frac{p}{2q}\right) \tag{4}$$

$$t^* = -\frac{1}{p+q}\log\left(\frac{p}{q}\right) \tag{5}$$

$$n(t^*) = \frac{dN(t^*)}{dt} = m\left(\frac{q}{4} + \frac{p}{2} + \frac{p^2}{4q}\right) \tag{6}$$

The analytical structure of the Bass model is presented in Figure 3. As depicted, the adoption process is symmetric with respect to time around the peak time t*, which is the point of inflection of the S-shaped cumulative adoption curve, up to 2t*.

Figure 3. Analytical Structure of the Bass Model



Source: Mahajan et al. (1990, p. 4).

In a special case where the coefficient of innovation p is zero, the Bass model simplifies to the following equation:

$$\frac{dN(t)}{dt} = \frac{q}{m}N(t)[m - N(t)] \tag{8}$$

This model contains two parameters, *q* and *m*, and is referred to as the logistic model. Integrating the equation (8) yields the cumulated adopters distribution *N*(*t*):

$$N(t) = \frac{m}{1 + \frac{(m-N_0)}{N_0}e^{-qt}} \tag{9}$$

where $N_0 = N(t=0)$.

The nonlinear least squares (NLS) estimation procedure was used to estimate the parameters of the Bass model (Srinivasan, Mason 1986, pp. 169-178). Using equation (3), the model for the number of adopters X_i in the time interval (t_{i-1}, t_i) can be expressed as:

$$\mathbf{X_i = N(t_i) - N(t_{i-1}) + \varepsilon_i} \quad (10)$$

or

$$\mathbf{X_i} = \frac{m - \frac{p(m-N_0)}{p+\frac{q}{m}N_0} e^{-(p+q)t_i}}{1 + \frac{\frac{q}{m}(m-N_0)}{p+\frac{q}{m}N_0} e^{-(p+q)t_i}} - \frac{m - \frac{p(m-N_0)}{p+\frac{q}{m}N_0} e^{-(p+q)t_{i-1}}}{1 + \frac{\frac{q}{m}(m-N_0)}{p+\frac{q}{m}N_0} e^{-(p+q)t_{i-1}}} + \varepsilon_i \quad (11)$$

where ε_i is an additive error term. Based on equation (11), the parameters p, q and m and their asymptotic standard errors can be directly estimated.

Once the model parameters had been computed, the next step was to investigate the drivers of the diffusion process. Due to the lack of data on eco-label characteristics, i.e. the expected profitability of eco-labelling, the size of investment required to apply for it etc., we focused solely on the drivers of the *m* parameter such as: personal importance of environmental protection, financial subsidies on eco-innovations, and environmental regulations. The data was derived from Eurobarometer No. 295 “Attitudes of European citizens towards the environment”[1] and Eurobarometer No. 315 “Attitudes of European entrepreneurs towards eco-innovation. Analytical report”.[2] We used a multiple linear regression to find the determinants of the scope of the eco-label diffusion.

4. Results and discussion

After estimation of the parameters of the Bass model it turned out that the parameter *p* was either insignificant or took negative values in most cases. So we decided to apply the reduced form of the Bass model, which include only the parameters *q* and *m*. This approach seems to be appropriate, since the *q* coefficient plays a dominant role in the Bass model and, by its construction, it ought to be a subject to testing (Stoneman 2002, p. 149). Table 1 summarizes the results of parameter estimations of the reduced Bass model, their significance, and the adjusted coefficients of determination. The Table includes only statistically

[1] ec.europa.eu/public_opinion/archives/ebs/ebs_365_pres_en.pdf

[2] ec.europa.eu/public_opinion/flash/fl_315_en.pdf

significant parameters and hence omits countries for which the Bass model appeared not to be correct.

Table 1. Parameter estimations of the reduced Bass model

Parameters / Country	q	m	Adj. R^2
UE	0.373***	2306**	0.990
Austria	0.456**	81*	0.935
Denmark	0.737***	57***	0.903
Finland	0.316***	24*	0.957
France	0.690***	315***	0.948
Germany	0.717***	79***	0.992
Greece	0.145*	248*	0.959
Hungary	0.927***	8***	0.962
Italy	0.580***	451***	0.974
Poland	0.885***	14***	0.992
Sweden	0.184***	66*	0.977
United Kingdom	0.432***	109**	0.998

*Statistical significance at level 0.1, **Statistical significance at level 0.05, ***Statistical significance at level 0.01

Source: own compilation.

According to the results of the Bass model's parameter estimations, the diffusion process of eco-labels was the most dynamic either in scope, i.e. the *m* parameter, or in speed, i.e. the *q* parameter, in the firms from France and Italy. The high rate of eco-labels diffusion among French firms may be explained by the existence of large multi-national firms which drive the growth of eco-innovations. Moreover, France is one of the leading European countries in terms of total numbers of eco-patents.[3] It can be expected that patentability increases firms' capabilities of fulfilling the eco-label requirements. In turn, Italian firms face high internal demand for eco-innovative products and services, since there is an increasing interest on the part of Italian consumers for sustainability and ecological production.[4]

A high rate of diffusion was also observed in the firms from Denmark, Germany, Hungary and Poland. However, in the case of the firms from Hungary and Poland, the scope of diffusion had a limited extent. In general, development of eco-innovations in Poland and Hungary was significantly hindered by a number of barriers. The most important one concerned the lack of sufficient capital to invent

[3] www.eco-innovation.eu/France

[4] www.eco-innovation.eu/Italy

and implement eco-innovative solutions.[5] In interpreting the results of the research it should be noted that the study focuses on the "EU Flower" licenses, whereas there are many national environmental labelling schemes in the EU countries. For instance the first and oldest environment-related label – the Blue Angel – was initiated by the German government. The variety of eco-labelling schemes causes a proliferation of eco-innovation activities. In such circumstances, the analysis of the diffusion of a particular scheme does not give a full insight into the adoption of eco-labels at a country level.

Table 2. Determinants of the scope of eco-labels diffusion process

Variable	**Definition**
Customer attitudes - x_1	the percentage of people assessing environmental protection as very important
Financial subsidies- x_2	the share of firms indicating insufficient access to existing subsidies as a very serious barrier for eco-
Environmental regulations- x_3	the share of firms judging existing regulations and structures as main barriers for incentives to eco-

Source: own compilation.

To find the determinants of the scope of the eco-labels' diffusion, we regressed a vector of likely explanatory variables, i.e. exogenous factors, on the *m* parameter. Due to a formal rigour we made a strong assumption that these exogenous factors remain constant during the diffusion process. Table 2 gives a brief description of determinants of the scope of eco-labels' diffusion process.

Table 3 contains the results of the estimation of the multiple linear regression model and the results of its verification. In order to include only significant exogenous variables in the model, the backward stepwise regression method was used.

Table 3. Parameters' estimates and measures of model goodness-of-fit

Independent variables	Coefficient
Const.	x
X_1	2.008***
X_2	x
X_3	x
Adj. R^2	0.524
F (p value)	10.853 (0.008)

Note: x – eliminated variable, *Statistical significance at level 0.1, **Statistical significance at level 0.05, ***Statistical significance at level 0.01, F – test of model utility.

Source: own compilation.

[5] www.eco-innovation.eu/Poland; www.eco-innovation.eu/Hungary

The results of the research show that only the customers' attitudes towards environmental issues had a positive and significant impact on the scope of the eco-labels' diffusion process. This means that customer awareness is a prerequisite condition for the emergence and growth of eco-labelled products/services markets. As such, environmental education becomes of great importance, since it allows customers to consider eco-labels within their decision-making procedures and ultimately leads to a change in purchasing behaviour. This evidence that customers' environmental education can alter the diffusion process of eco-labels is likely to be welcomed by policymakers, because educational policy may be easier to implement than other forms of regulations. Contrary to the theory-based expectations, financial subsidies and environmental regulations turned out not to affect the scope of diffusion of eco-labelled products/services. This may be explained by the fact that these factors may directly affect eco-innovative products/processes, which in turn stimulate the firms to eco-labels.

5. Conclusions

Eco-labels can be regarded as a tool aimed at coping with the problem of asymmetric information. They allow customers to make a distinction between the environmentally 'good' products/services against 'bad' products/services. If consumer behaviour is at least to some extent influenced by environmental issues, then participation by firms in eco-labelling schemes may be seen as a rationale for providing for an increase in sales and market shares. At the same time, a number of problems arise from the adoptions of eco-labels, e.g. a possible lack of transparency in the life-cycle assessment process and high potential costs of complying with standards.

The diffusion of eco-labels is a dynamic process which can be described by the Bass model, grounded in the mathematical theory of the spread of infections during epidemics and the theory of information. The Bass model allows for the estimation of the rate of growth of eco-labels users and for forcasting their numbers in the future. The estimations of the reduced Bass model parameters show that the eco-labels' diffusion process was the most dynamic in countries such as Hungary, Poland, Denmark, Germany and France. However, in the case of the ultimate level of penetration (saturation) two countries, i.e. France and Italy, experienced the highest ceiling of potential adopters.

Moreover, the evidence suggests that the customers' attitudes towards environmental issues emerge as the main determinant of the scope of the eco-labels diffusion across the EU countries. This finding is consistent with the OECD's (2010, pp. 119-120) work, which found that there are benefits to promoting consumer education on the meaning and proper interpretation of claims and in heightening consumer awareness of the environmental consequences of their purchases.

This paper is not exempt from some limitations. The main drawback pertains to the fact that the Bass model assumes a constant ceiling of potential adopters. Another shortcoming of the study concerns the lack of analysis of potential drivers of the speed of the eco-labels' diffusion process. In order to overcome these limitations future research should incorporate the dynamic model with the exponential form for potential adopters and focus on a broader set of determinants of the eco-labels' adoption rate.

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Streszczenie

MODELOWANIE DYFUZJI EKO-INNOWACJI NA PRZYKŁADZIE WSPÓLNOTOWEGO OZNAKOWANIA EKOLOGICZNEGO

Celem artykułu jest teoretyczna i empiryczna analiza procesu dyfuzji oznakowań ekologicznych. Oznakowania ekologiczne umożliwiają konsumentom identyfikację produktów lub usług o niskiej uciążliwości dla środowiska w całym cyklu ich życia. Podstawowym celem stosowania oznakowań ekologicznych jest redukcja luki informacyjnej pomiędzy sprzedawcami a nabywcami. Wyniki estymacji parametrów modelu Bassa wskazują, że dyfuzja oznakowania ekologicznego „UE Eco-label" była najbardziej dynamiczna w takich krajach, jak: Węgry, Polska, Dania, Niemcy i Francja. Z kolei, zakres dyfuzji (absolutny poziom nasycenia) osiągnął najwyższą wartość dla przedsiębiorstw z Francji i Włoch. Ponadto, wyniki badania potwierdziły stymulujący wpływ znaczenia kwestii środowiskowych dla konsumentów na zakres dyfuzji oznakowań ekologicznych wśród przedsiębiorstw. Powyższa prawidłowość wskazuje na konieczność prowadzenia edukacji ekologicznej wśród konsumentów, co może przekładać się na skłonność producentów do podejmowania działań pro-środowiskowych.

Słowa kluczowe*: oznakowanie ekologiczne, eko-innowacja, dyfuzja innowacji, model Bassa*