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NEW MODELS IN SUPPORT OF THE ECO-INNOVATIVE CAPACITY OF COMPANIES – A THEORETICAL APPROACH

Abstract. *Recent years have seen the emergence of Eco-innovation as the way of the future, in which regards the valuation of the growth potential in a volatile environment. First regarded as a response to negative externalities, then as normal elements in the industrial dynamics, eco-innovations are acknowledged as extremely significant in the constantly changing competitive conditions. This paper presents the concept of eco-innovation and its taxonomy, in order to set the bases for further research within a project aimed at providing the Romanian SMEs with the necessary tools for improving their eco-innovative capacity and making use of their natural potential. In the first stages of the project, the research being reflected in this paper, a theoretical overview of the macroeconomic and microeconomic elements of eco-innovation, alongside a series of models (both based on indicators – The Shift Model, as well as mathematical modeling – The Percolation Diffusion Model) are presented. This work was supported by CNCSIS-UEFISCSU, project number PN II-RU TE_328/2010*

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JEL Classification: **O32, O33, Q01.**

1. Eco-Innovation – the Drive for the Future

In the context of a world dominated by climate change and diminishing resources, sustainability is both essential and urgent, and the magnitude of the problem must be met by the dimension, efficiency and quality of the solutions.

Mostly studied in the past three decades, sustainability, discussed by authors such as Brundtland (1987) in the famous 'Our Common Future' report or Newton and Freyfogle (2004) is new and current, and reunites three of the current themes for debate: economic growth, social development and environmental protection. The need for a global sustainable development is on the agenda of international bodies and organizations starting with the Conference on Human Environment in Stockholm, 1972, and yet, in comparison to the previous decades, nowadays new requirements are to be met. The high objectives set by the European Council regarding the reduction in Greenhouse Gas emissions, the energy from renewable sources or the increase in energy efficiency, according to the Kyoto Protocol – goals to be met by 2020, with the implementation of the Energy-Climate Package – cause the need for a new economic model that integrates the environmental concerns in production. Thus, the innovative processes that aim at sustainable development, also known as 'eco-innovation' (Rennings, (2000)) must be analyzed and modeled in order to be applied optimally, regardless of the size of the organization.

In the European Union, the concept of Eco-innovation (Fussler (1996)) has been taken into consideration as support for larger competitiveness and growth objectives, at first in the Lisbon Agenda and more recently, in the Europe 2020 Agenda. In 2004 the EU Environmental Technologies Action Plan (ETAP) has been established in order to promote and develop the eco-innovative capacity within the Union. This Action Plan defines eco-innovation as '*the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.*'. Moreover, eco-innovation is part of the Framework for Competitivity and Innovation 2007-2013 (CIP – Competitivity and Innovation Plan), focused on SMEs, mostly due to the share of this type of companies in the number of European companies, as well as their flexibility. CIP facilitates the access to financing, with a budget of 430 million Euro aimed solely at eco-innovation in SMEs, in order to reduce some of the major issues these companies face in their development, such as: lack of information on the environment and its risks; lack of knowledge (mostly from the management part) regarding the environment, eco-innovation, life-cycle approach, or any other method, model or measure that may reduce the impact of the company on the resources; lack of proper training in these issues.

A taxonomy of eco-innovation, both in its understanding as a response to a market failure deriving from the distribution of negative externalities, as well as in an evolutionary and industrial dynamics perspective (Andersen, (1999, 2002, 2008)), has been suggested in literature, in order to bring clarity to a concept considered thus far fuzzy. Andersen (2008) proposes five types of eco-innovations, presented in Figure 1, which may be used for analysis of the global techno-economic paradigm change encountered in the past decade (Kemp, (2004)).

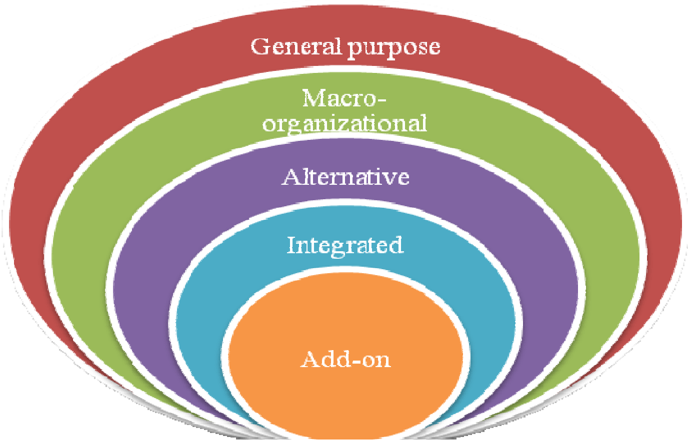

Figure 1 : A taxonomy of Eco-innovations, according to Andersen (2008)

In the view of Andersen (2008), add-on eco-innovations refer to pollution and resource handling technologies, integrated eco-innovations bring the next level of cleaner technological processes and products, alternative represent the new technological paths, macro-organizational eco-innovations bring a shift in the organizational structure and general purpose eco-innovations ‘affect the economy profoundly and the innovation process more specifically’ (Andersen, (2008) quoting Bresnahan and Trajtenberg (1995) and Helpman (1998)).

In order to gain long term competitive advantages, companies in general, and SMEs in particular, must take into consideration the new tendencies at world and European level regarding the improvement of the eco-innovative capacity on three major directions: the focal point of eco-innovation, the mechanism and the impact. The **target**, according to the Oslo Manual (OECD, 2005 and 2009) may be represented by the elements in Figure 2. The **mechanism** of eco-innovation is reflected in its nature, more specifically in the technological and non-technological aspects of it, the latter being the focus of the latest strategies and funding, after a long period in which all research aimed at developing new technologies in order to improve the impact on the environment. Four mechanisms may be identified in the process of defining eco-innovation:

- Alterations, modifications and minor adjustments to products and processes, usually implemented gradually
- The redesign of products, processes, organizational structures
- Implementation of alternatives, such as substitution goods, responding to the same need
- The creation and/or design of new products, processes, procedures, organization and institutional structures.

The **impact** of eco-innovation on the environment focuses on the technological performance in which regards the usage of energy and resources. The macro-economic analysis of eco-innovation is easier to achieve, as it covers a series of indicators slightly less complex than the indicators for a micro analysis. These macroeconomic indicators (OECD, 2009) usually refer to four topics: **input** (indicators regarding research and development, or other innovation expenditures), **intermediate output** (such as the number of patents), **direct output** (such as sales of products from innovations or the number of innovations), **indirect impact** (such as changes in productivity).

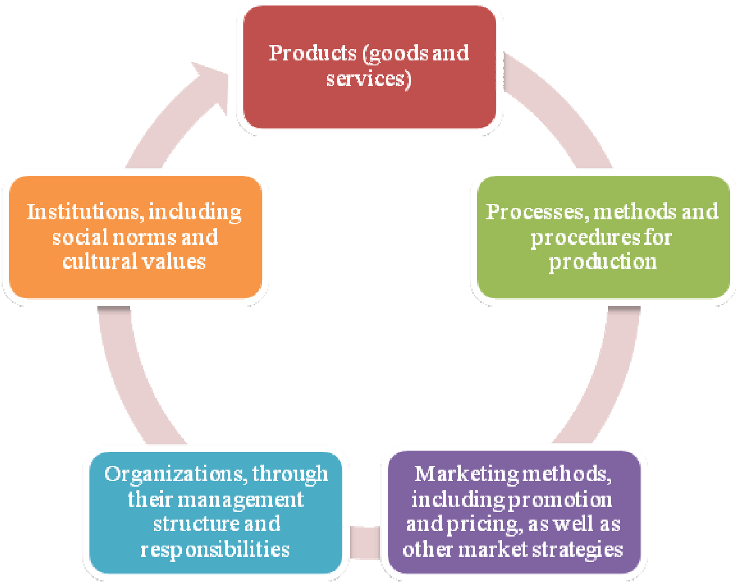

Figure 2 : The target of Eco-innovation, according to the Oslo Manual (2005)

In which concerns the eco-innovation – competitivity issues, a series of conclusions may be reached:

- a number of authors in literature (Kemp, M.M. (2004)) consider that eco-innovation may be a determinant of competitive advantage for European companies internationally, with a special focus on the importance of SMEs, due to their organizational flexibility;
- in Romania there is a increase in the number of books and articles on the issue of business strategy in the international competitive environment.
- Reports of the European Union on competitivity stress the fact that, usually, research on the topic are carried at a national level, with a focus on a national competitive advantage, and aim at comparing the economic performance with similar states and identifying through benchmarking the

sources of economic growth and competitivity. To this respect, both quantitative and qualitative research has been made, in general, by comparing Romania's competitive advantage in an European context (Cojanu (2007)).

Thus, eco-innovation is nowadays a matter of survival of the fittest in a world that is increasingly losing its resources, some of them at a higher rate, whilst battling a reduction in funding for non-core activities, especially in SMEs. Therefore, the need for models and methods supporting the eco-innovative capacity of companies is a self-evident.

2. New models in support of the eco-innovative capacity of companies

2.1. Indicators and Indices

The first step in creating a new model for assessment of eco-innovative capacity of companies is the establishment of a set of benchmark indicators, as well as the scope of the analysis. As proven in the previous section, a macro-economic view may prove to be biased as it presents a general image, which may be detailed on a regional or sectorial basis, and yet maintain the idea of 'average data'. Moreover, the lack of reliable data on indicators of direct output and indirect impact leads to a partial image, especially in countries with a lack of resources for a proper data collection system in this respect. Therefore, the modeling of eco-innovation at a country level may prove to be an exercise in futility as it leads to a skewed image. Moreover, the country level is useful in global comparisons, but also as a basis for policy making at a national, regional and international level, hence the need for an accurate image of the development of eco-innovative capacity in companies, both large and small.

At country level, indices such as the Technology Revealed Comparative Advantage (TRCA), as defined in Soete (1987), Archibugi and Pianta (1992) and Mahmood and Mitchell (2004), based on the widely-used reveal comparative advantage index (RCA) of Balassa (1965,1967,1977), may be adapted in order to reflect the impact of eco-innovation. Specifically, the TRCA index measures the relative distribution of a country's inventive activity in each field, compared to its own total patents, which allows the index to be neutral of the country size and specific fields. Defined as the ratio of country i's share of total world patents in sector j to country i's share of total world patents (Equation 1), TRCA is

$$TRCA_{ij} = \frac{(n_{ij}/\sum_i n_{ij})}{(\sum_j \frac{n_{ij}}{\sum_i \sum_j n_{ij}})}$$

where n_{ij} is the number of patents of country i in sector j. TRCA is above 1 when the country has a relative (not absolute) strength in patents as compared to the aggregate, is equal to 1 when the country has the same share of worldwide patents in a technology as in the aggregate, and is below 1 when a certain weakness is detected in this respect.

We propose an indicator similar to the TRCA, with an equation identical to Equation 1, named EIRCA (Eco-Innovation RCA), where n_{ij} shall represent the number of eco-innovative patents of country y in sector i, but applied to the eco-innovative patents, that takes into consideration the importance of patents in eco-innovation. Oltra, Kemp and de Vries (2009) claim that patent analysis may be used for measuring five attributes of eco-innovation:

(1) eco-inventive activities in specific technology fields,
(2) international technological diffusion,
(3) research and technical capabilities of companies,
(4) institutional knowledge sources of eco-innovation,
(5) technological spillovers and knowledge flows.

Considered to be an easy source of information, particularly suitable for academic research, as it allows statistical and econometric analyses, patents have their flaws: they refer mostly to inventions, not necessarily to all innovation; there are a certain number of innovations not patented; patent classification systems do not have a certain category for eco-patents, therefore a selection to be used in analysis may prove to be incomplete; the usage of patents in different sector may bias the analysis, as it becomes increasingly difficult to allocate patent data by company into a certain industry.

The econometric analysis of a like index shall include:

- descriptive statistics of the index
- comparisons at regional and world level
- impact analysis of various elements on the index such as: business groups (Mahmood, Mitchell (2004)), social networks (Abrahamson and Rosenkopf (1997), Spencer (2003) and Sheremata (2004)), etc. via
    - OLS Regression using Sector Dummies on Pooled Data
    - fixed-effects OLS (using the sector-specific components of the error terms as fixed effects in place of sector dummy variables)
    - between-sector OLS (regressing the sector means of TRCA on the sector means of the covariates)
    - Weighted Generalized Least-Square (WGLS) random effects
    - General Estimating Equation (GEE) random effects
    - Causality Tests Using Multiple Kernel Regressions

The works of Kesidou and Demirel (2010) studying the United Kingdom interest in eco-innovation have revealed the following elements to be considered while creating an eco-innovation indicator:

- There is the need in Romania of a general survey on environmental protection expenditure, as well as environmental R&D expenditure

(ECORD), such as the Government Survey of Environmental Protection Expenditure by Industry in the UK.
- Demand and organizational factors influence the decision of the firm to invest in eco-innovation and the level of investment in eco-innovation.
- The stringency of environmental regulations affects the level of investments in eco-innovation differently for less innovative firms and more innovative firms.
- The model used for modeling eco-innovation may be a Heckman model (1979), which defines ECORD for a company i as:

  $$ECORD_i^* = \alpha X_{0i} + \varepsilon_{0i}$$

  Where X_0 is a vector of determinants of eco-innovation, α is a vector of parameters of interest and ε is an error term.
- Considering that a lot of companies do not perform ECORD as such, the dependent variable is left censored, therefore an OLS regression cannot be applied.

- The results of the analysis prove that in the UK there is a high variance in such indicators such as ECORD, Environmental Operating Costs, and Environmental Capital Costs and companies do not define eco-innovation specifically in their R&D efforts. Furthermore, the study concludes that eco-innovation oriented policies, such as green public procurement, must be aligned with regulations on pollution abatement and with proper means for eco-innovative technologies diffusion.

Another important area in which a model for eco-innovation is necessary is the micro-economic level. A company must create its own framework, must choose from a wide range of indicators the ones that best apply to its activity, structure, industry and background and must implement a proper system of reporting and controlling in order to achieve the optimal position eco-innovation-wise. The impact of eco-innovation (according to the Oslo Manual) may be quantified at a micro-economic level via a series of indicators (OECD, 2009), among which:

- Key performance indices
- Material flow analysis
- Environmental accounting – calculating the costs of the environmental activities of the company
- Eco-efficiency indicators – based on the comparison between the environmental impact and the economic added value created by the activity causing the environmental impact – such as Factor X from Panasonic, defined as Eco-efficiency of the product to be assessed/Eco-efficiency of the benchmark
- Life-cycle assessment
- Sustainability indices

- Socially Responsible Investments indices, such as: Dow Jones Sustainability Indices or FTSE4Good.

Focused on the patterns underlying today's cyclical challenges, the Shift Index, created in 2009 in the Deloitte Center for the Edge by John Hagel III, John Seely Brown, and Lang Davison, is a measure of the change in the world economy, perceived as a complex adaptive system, where entities (organizations, companies, public and private institutions, individuals etc.) "interact adaptively to produce emergent patterns". The three indices forming the Shift Index: Foundation, Flow and Impact, merge into an analysis of eco-innovation by providing the framework in which a company adds value to this change. As seen from the list of indicators in Figure 3, a national economy with a Shift Index favoring change shall enable the introduction, creation and usage of innovation in general, and eco-innovation in particular. Apart from the overall effect on eco-innovation, these indicators may measure the potential for implementing new changes in the current status of the economy. Highlighted in Figure 3 are the indicators with a direct observable effect on eco-innovation (technology performance, having in view the fact that most of the eco-innovative actions are related to technological developments, public policy as a major driver for innovation – such as the implementation of Energy-Climate Change package, virtual flows as diffusion environments and physical flows as diffusion supports, all in the context of markets as both facilitators and amplifiers).

Figure 3 : Indicators in the Shift Index (Deloitte Center for the Edge, (2009))

The Shift Index comprises, therefore of 9 major components, that are aggregated in each of the three Indicators (Foundation, Flow and Impact) with a weigh of 1/3. These three indicators are then aggregated in the Shift index, yet again with a weigh of 1/3. An issue to be taken into consideration while calculating the Shift Index for a certain country (until present, calculations have been made solely for the US) is the fact that there might be correlations between the indicators.

2.2. Modeling the Diffusion of Eco-innovation

It is a characteristic of the current global market the fact that scientific knowledge diffuses from the innovator to the other global organizations "formal and informal knowledge-diffusion networks" (Cantono and Silverberg (2008)). Diffusion of a clearly beneficial innovation rests on potential adopters' access to knowledge. As any other innovation, eco-innovation has the same diffusion characteristics:

- If the eco-innovation is beneficial, its diffusion depends on the potential adopters' access to knowledge.
- Network effects and percolation models apply to diffusion
- Its diffusion falls under one of the four models: epidemic models, Probit models, legitimation and competition models, and information cascades models.
- Innovation (and therefore eco-innovation) diffusion follows and S-shaped path, due to the fact that the price of the innovation must fall below a certain threshold in order for the innovation to become mainstream.

Based on previous percolation models, Cantono and Silverberg (2008) develop a network model of new technology diffusion that combines contagion among consumers with heterogeneity of agent characteristics. The model is useful while evaluating the efficiency of public subsidies in the diffusion of eco-innovative measures, especially in view of the recent public developments at a European level.

In the Cantono-Silverbeg model, the learning curve as a macro effect is considered, while mathematically defining the price of the innovation at time t as in Equation 2:

$$p_t = p_0 \left(\frac{N_0}{N_{t-1}}\right)^{\alpha} (1 - s)$$

where N_0 is the initial number of adopters and N_{t-1} (defined as sum from i=0 to i=t-1of $_{ni}$) is the cumulative number of adopters, with n_i the number of adopters in period I; P_0 is the initial price and s is the percentage of the price that is subsidized; and α is a parameter of the model.

Percolation must be considered in this case. As modeled by Duffie and Manso (2007), percolation is defined mathematically as follows. Given a probability space and a 'continuum', they set a non atomic finite measure space of agents, which are initially endowed with a series of signals that may be informative of X, X being a random variable of concern for all agents involved in this space, with two possible outcomes and their corresponding probabilities (that is: H – high with probability v and L – low with probability 1-v). The signals emitted by the agents $\{s_1,\ldots,s_n\}$ are considered to be Bernoulli trials, therefore independent and identically distributed. Duffie and Manso (2007) suppose in their research of percolation in large markets that

$$P(s_i = 1|H) \geq P(s_i = 1|L)$$

In these conditions, the probability that X has a high outcome is

$$P(X = H|S) = \left[1 + \frac{1-v}{v}\left(\frac{1}{2}\right)^{\theta}\right]^{-1}$$

while the type θ of the signals is (considering that the higher the type θ, the greater the probability of a high outcome).

$$\theta = \sum_{i=1}^{n} s_i \log_{1/2} \frac{P(s_i = 1|L)}{P(s_i = 1|H)} + (1 - s_i) \log_{1/2} \frac{1 - P(s_i = 1|L)}{1 - P(s_i = 1|H)}$$

The theory of percolation states that it occurs when the probability that θ_i is larger than the market price p_i is less than the critical value of P_c. Therefore, considering a lognormal distribution of the integral of the density function at p_t that must be less than $1\text{-}P_c$, leads to the start of diffusion.

These types of diffusion models, particularly the ones considering percolation in larger markets (due to the fact that eco-innovation is aimed at being as widespread as possible), are relevant to the proper mathematical modeling of eco-innovation.

3. Conclusions and Directions for further research

Recent years have seen the emergence of a new direction to discuss while addressing competitiveness issues for companies, in their quest for diminishing the impact on scarce resources. Eco-innovation has established itself as the way of the future, in which regards the valuation of the growth potential in a volatile environment. First regarded as the response to negative externalities, then as normal elements in the industrial dynamics, eco-innovations are acknowledged as extremely significant in the constantly changing competitive conditions, and a clarification of the concept was necessary and has been made in several documents, ranging from academic research literature to policy documents at a European and international level.

This paper presents the concept of eco-innovation and its taxonomy in all its understandings, in order to set the bases for further research within a project aimed at providing the Romanian SMEs with the necessary tools for improving their eco-innovative capacity and making use of their natural potential. In the first stages of the project, a research that is reflected in this paper, a theoretical overview of the macroeconomic and microeconomic elements of eco-innovation, alongside a series of models (both based on indicators, as well as mathematical modeling) are suggested in this respect.

Further research on this subject, (part of which is to be conducted in the TE 328/2010 project), should be aimed at:

- Testing the relevance of the suggested models in general, on a theoretical level.
- Testing the relevance of the models in the Romanian market, in particular of the model focused on econometric modeling of indicators. Availability of data may prove to be an issue in this case.
- Stress testing the relevance of the models for SMEs in developed markets and in Romania
- Following the stress-testing of the models, adjustments shall be made, in order to provide a singular model for Romanian companies at a macroeconomic level. This model may represent the basis for a suitable policy for Romania in its quest for achieving the Europe 2020 objectives.
- The creation of a micro-economic model to be used as a tool for Romanian SMEs in order to support their implementation of eco-innovations.

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