ULBS
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PhD THESIS

USING A FRACTALIZED MODELING TOOL TO ANALYZE CREATIVITY AS A PRODUCTION FACTOR

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1. CONTENTS OF THE PHD THESIS

KEYWORDS: Modeling tool, fractal, creativity, economic growth, creative destruction.

2. RESEARCH DIRECTIONS AND OBJECTIVES

In order to analyze the creative economy pillar, by debating the theories that make up the concepts underlying this pillar, as well as conducting studies to validate the hypotheses introduced in this research, I intend to analyze the following aspects, which are exactly the objectives of the research:

1. Studying creativity. Holistic approach of the concept. Studying the phases of creativity, the types of creativity, the methods of developing creativity, the tests that measure creativity and the impact of creativity in the process of economic growth.
2. Identifying the main theories and models of economic growth, related to creativity and innovation.
3. Research the production factors and neofactors of the production process, their evolution and the mathematical models that validate them.
4. Validation of creativity as a neofactor of production, by respecting the validation criteria
5. Validating creativity as a parameter of economic growth by extending a model of economic growth and observing its impact at the microeconomic and macroeconomic level.
6. Analysis of a new economic modeling tool, based on the theory of fractals and lattice automata. Achieving a growth model based on this instrument.

The thesis is contributing in many fields, such as ***Economic modeling,*** by introducing a vector modeling tool, which is based on a group of automorphisms and the trivalent logic of Ilie Prigogine, as a tool for economic growth. Also, ***The process of economic growth*** will have a new approach, in line with the new theories that have emerged in the economic growth literature. The process of economic growth will include, in addition to the classic factors of production, the level of expertise and creativity. If the classical process of economic growth involves classical and neoclassical factors of production, this approach will consider the importance of creativity on the dynamics of the results of production processes.

Creativity will be technically exposed, with a review of its development methods, creativity measurement tests and stages in the creative process. ***Innovation*** will be approached from a purely economic perspective, it will be assigned a function that will define it in a process of

endogenous economic growth. Existing theories of economic growth will be expanded in order to validate the integration of creativity among classical factors of production.

In the field of neofactors of production, the main neofactors validated in the existing theories will be identified and creativity will be validated as a neofactor of production.

3. THESIS STRUCTURE

In the introduction are presented the research directions, the objectives of the paper and the research methodology, as well as the research hypotheses.

The first chapter of the thesis describes the creative process together with the main delimitations of the theories that define it. This chapter refers to the conceptualization of the creative process, the presentation of the creative capital and the creative class, the identification of all the techniques for the development of creativity, as well as the introduction of a new technique for the development of creativity. The creative process is thus defined as the act of generating a new idea. Imagination is the main cognitive process used in the creative process. The creative process captures a fluency in its realization that also explains its definition. It begins with the stage of preparation, incubation, lighting and verification (Hammershøj, 2014). Innovation is the process by which an idea goes from creativity to the materialization phase through invention, and then to the implementation phase through innovation. The difference between creativity and innovation is a conceptual one determined by the time flow of the two processes. Creativity cannot exist without innovation, but it has no economic basis, while innovation cannot exist without creativity. The chapter classified 61 techniques for developing creativity into associative, challenging, intuitive, inventory and confrontational techniques (Tassoul, 2009a), to which are added the techniques for developing creativity by controlling the environment of the creative process. In addition to the 61 techniques for developing creativity, in chapter 1 has been shown that visual mnemonics can also be attributed to this category. A temporal analysis of the countries of the European Union, regarding their level of creativity is exposed at the end of the chapter.

Chapter 2 sets out the main classical, neoclassical and evolutionary theories and models of economic growth, along with the main theories that foster the importance of creativity in the growth process. The classical theories of economic growth introduce the three classical factors

of production: labor, land, and capital. Within exogenous neoclassical economic growth theories and models, economic growth is associated with technological progress that increases the parameter of technological productivity, i.e. the current state of technological knowledge held by workers. In exogenous models, technological progress has no other causality. There are several directions in endogenous growth theories and models. These neoclassical theories include Schumpeter's approach to economic growth through creative destruction, that is, the removal of previous innovations out of necessity. The chapter also includes a review of theories that support the importance of creativity in growth models. Creativity appears in many forms in the theories discussed in this chapter, such as entrepreneurial creativity, creativity as an investment, the general theory of entrepreneurial creativity, the theory of creativity proposed by Amabile, the theory of organizational support and inventive creativity as a precursor to the invention. These theories address economic growth at the organizational or macroeconomic level and relate creativity as an emerging factor. Theories have been detailed according to their importance and impact in the literature. Chapter 2 also addressed the differences between the factors of production and the parameters of economic growth. It also includes a review of the neofactors and presents the criteria for validating a parameter as a neofactor of production. The main parameters of economic growth identified in the specialized literature are: entrepreneurship, education, accumulated knowledge, technological level, knowledge transfer, managerial ability, personality and cooperation between entrepreneurs. The main production neofactors identified are: energy, information and technological level. In (Berczi, 1985) are exposed six factors for validating a concept as a neofactor of production. In order to validate creativity as a neofactor of production, the observance of these factors was analyzed and it was concluded that creativity is a factor of production associated with the theories of neofactors of production.

Chapter 3 covers an extension of the Aghion-Howitt endogenous growth model, based on creativity, expertise and managerial competence. In the model used, technological progress is endogenous, and innovation is measured by an occurrence rate and a size. In order to introduce creativity as a parameter of the economic growth, we have endogenized the size of innovation as a variable determined by creativity, expertise and managerial competence. γ is a factor in increasing the technological parameter (conventionally equivalent to increasing productivity). γ will be expressed in terms of managerial competence, creativity and expertise, so γ becomes:

- $\theta\ (c)$ is a function of creativity;
- M is the level of managerial competence, which is constant, identified by the historical course and the political and educational systems, as well as the customs and mentalities of the region;
- ε_t is the level of expertise (level of specialized knowledge);
- ή and ό are the elasticities of creativity and expertise.

$$\upsilon(\gamma) \rightarrow \upsilon(\gamma)_{M,\theta,\varepsilon}$$

The function of the innovation is as follows:

$$\text{(B)} \qquad \upsilon(\gamma)_{M,\theta,\varepsilon} = M \cdot \theta\ (c)^{\acute{\eta}} \cdot \varepsilon_t^{\acute{o}},$$

While the logarithmic variant allows estimation by multiple linear regression:

$$log\left(\upsilon(\gamma)_{M,\theta,\varepsilon}\right) = log\left(M \cdot \theta(c)^{\acute{\eta}} \cdot \varepsilon_t^{\acute{o}}\right)$$

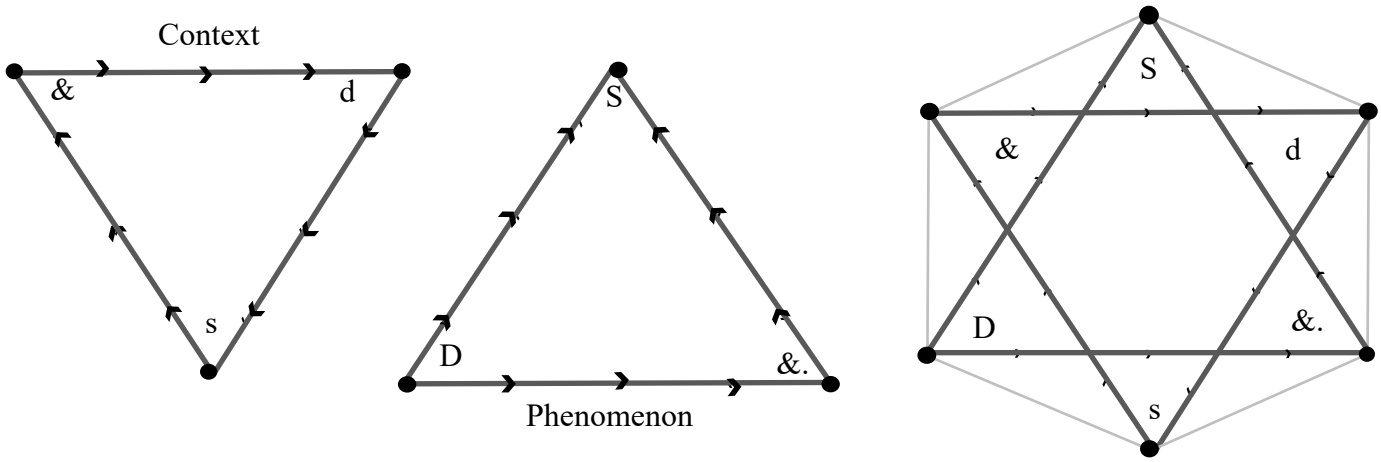
$$log\left(\upsilon(\gamma)_{M,\theta,\varepsilon}\right) = log\ (M) + \acute{\eta} \cdot log\ (\theta(c)) + \acute{o} \cdot log\ (\varepsilon_t)$$

- where: $\varepsilon_t \equiv \gamma_{t-1}$,

To validate this model, we conducted a study on the impact of creativity and expertise on innovation. The results show that the level of expertise is the most important in determining national innovation. The Student Test indicates that the variables creativity and expertise contribute significantly to explaining the variation of innovation. Also, the multiple linear regression shows that the increase in creativity by one unit increases the level of innovation by an average of 0.633 units, if all other explanatory variables remain unchanged. An increase in the level of expertise by one unit is associated with an increase in the level of innovation by 0.29 units. The study also included estimates with fixed and random effects, as well as multiple regression models, extended with control variables.

Chapter 4 contains a fractalized model of economic growth. This chapter presents the types of logic classified by truth values, automorphisms, feedback loops, fractals, and finite automata. As an early stage, the use of the model focuses on identifying feedback cycles and then commutative diagrams. Then the model is structured on successive levels of determination, which are built by repeating, in different sizes, its structure into new and stable structures that self-determines. The primary pattern of behavior is directed by arrows that clearly show the behaviors between the source, sensor, and decision maker and that they are determined by the

time factor, each having the ability to self-stimulate or self-inhibit (Prigogine, 1984). The **source** is the point of nutrition in the system, the **sensor** represents the implementation of a measurability system and the **decision maker** is the node that measures the level of fit between the source and the system. For the basic structure a feedback cycle and a commutative diagram are drawn up, which represents the context, respectively the phenomenon that is applied in the context, according to the following Figure:



Where:

S - phenomenon source,

& - phenomenon sensor,

D - phenomenon decision maker,

s - source of context,

&. - context sensor,

d - context decision maker.

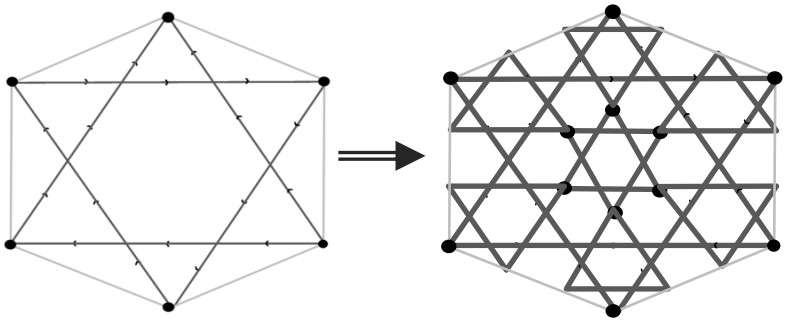
The semantic architecture of the nodes contained in the structure is based on the following methodology, taken from (Caraiani et al., 2015):

a. Any equivalent triangle in the figure must have self-generating content. Any two contents determine the third. By contents we mean the source points, sensor, decision maker.
b. The content of the obtuse point of any isosceles triangle is generated by the content of the points at the sharp angles of the same triangle.
c. The content of the points on the same line in the figure represent logical intermediate steps, necessary to start from one semantic point to another semantic point of the evolution vectors

of the system, together with the support lines that pass directly through the center of the hexagon.

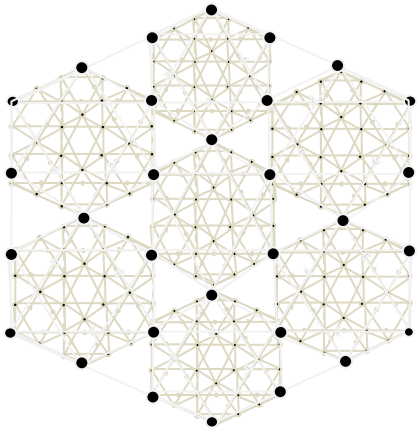
d. Thus it is shown that the method is evolutionary, the construction starting from the peaks located at the end to the nearest peaks of the center of the hexagon.

Next, the model can be fractalized to generate new systems that are related:



The level of granulation represents the number of changes in the size of the basic structure, to reach the fractalized structure. The level of fractalization refers to the sustainability and unsustainability levels of the components between a hexagonal structure. Thus, the hexagon that is positioned on the outside is always sustainable, having the same behavior over time, and the hexagon that is positioned in the center is unsustainable and has the ability to produce changes.

Next, the fractal reaches higher levels of granulation, by resuming the previous process, on a smaller scale, according to the following figure:



Due to the fractal character of the model, which respects the Hausdorff – Besicovitch size, the granulation levels have no formal limit.

Qualitative modeling of creativity as a parameter of economic growth is discussed in the thesis, using the model presented above, up to level II of granulation. Thus, the main differences between the econometric and the qualitative approach to economic growth can be formed. Within the endogenous model discussed in this thesis (Aghion & Howitt, 1992), a series of correlations are formed that allow bivalent relationships of the introduced parameters (Aghion & Howitt, 2014). In the fractalized model these correlations can be exposed using feedback cycles that form inside or between hexagons on different levels of fractalization (Colceag, nd, 2001). Aghion Howitt's endogenous model is based on bivalent logic, where variations in the output parameter can either increase or decrease. In the fractalized model, the logic used is trivalent, so that a parameter is identified by source, sensor and decision maker. Thus, the parameter expressed by the source, measured by the sensor and capitalized by the decision maker can have several valences depending on the size of the sensor.

The relationship within the hexagonal fractalization system is done through feedback loops and commutative diagrams, which allows self-stimulation and self-inhibition of the system as well as the formation of accumulation zones, while the endogenous growth model develops its relationship through determination functions. Both models allow the addition of parameters for continuous endogenization. Thus, in the fractalized model a new level of granulation can be added, and in the endogenous model new functions for defining the introduced parameters can be added. The fractalized model allows a more complex structuring through the network of feedback loops, as well as the fusion of several interrelated systems.

In the endogenous growth system, the modeling is quantitative, the units of measurement are quantitative, while the fractalized model involves a qualitative measurement, using syntactic operations. Within the fractalized system, complex relationships are formed, such as those of inter-relationship between different systems (initially formed in a hypercubic dimension). This allows you to observe the effects of changes in a parameter, even if the effects occur in another system.

Chapter 7 contains the conclusions and contributions of this paper, as well as the most important directions for future research.

4. PERSONAL CONTRIBUTIONS

a. Theoretical contributions

This thesis summarizes a series of theories and characteristics of creativity and innovation. The first part includes a review of creative development techniques classified into analytical, challenging, intuitive, inventory and confrontational techniques. This review includes the source and description of each technique in the annexes. In addition to these techniques, the first part of the paper also includes a review of existing and internationally validated creativity tests, also present in the tables attached to the paper.

Creativity is approached as a neofactor of production, systematizing the available scientific sources on this issue, while conducting a review of them.

A new theory of using creativity as a parameter of economic growth is introduced, through the causality that creativity has on innovation. The innovation is thus determined by the level of creativity of the employees active in research, being moderated by the expertise and the managerial capacity.

A sustainable vector tool for modeling a complex system is analyzed, then a comparison is made between the fractalized model of economic growth and the neoclassical, endogenous model of economic growth.

b. Practical contributions

The present research introduces a new method of developing creativity, namely visual mnemonics, a method that is currently used to improve the process of storing information. This method is used in the education system in order to improve the storage of information, but this research validates the use of the method to develop creativity.

The results of the study on secondary data analysis on creativity and innovation, as well as the study on the evolution of creativity in the European Union, validate the importance of creativity for innovation and growth, as well as the importance of education for innovation. The strongest correlations of dependence on creativity and innovation were the educational parameters. This research provides guidance on decisions aimed at economic growth.

The fractalized model, included in this paper, allows its use as a decision-making tool, through the complexity of the relationships that are formed between the values introduced. This fractalized model lays the groundwork for a qualitative approach to growth theories.

c. Scientific contributions

The present research includes an extension to the endogenous Aghion-Howitt growth model, by endogenizing innovation, using creativity, expertise and managerial competence as parameters. In the Aghion-Howitt model, the size of innovation is characterized by creativity, expertise and managerial competence.

In addition to extending the neoclassical model of economic growth, we also introduced a fractalized model of economic growth, based on a trivalent logic. This fractalized model of economic growth can be built up to any level considered relevant to the phenomenon studied. In the present paper, the model was developed up to level II of granulation. This introduces a new category of growth models, which allows for a more complex approach compared to the classical, neoclassical or evolutionary growth models.

d. Dissemination of results

During the doctoral studies and the previous documentations, I published as first author and co-author a number of 16 articles and scientific papers and a book chapter:

- 4 articles published in indexed journals Clarivate Analytics Web of Science - WoS (ISI), with impact factor;
- 4 scientific papers published in BDI indexed specialized journals;
- 8 Papers published in the volumes of international scientific events;
- 1 book chapter.

5. FUTURE RESEARCH DIRECTIONS

Future research directions include the use of creativity as a parameter in evolutionary growth models, by including it for a function of innovation or as an individual parameter of growth.

Future research may also focus on the development of models that include all the neofactors of production exposed in this paper: energy, entrepreneurship, education, knowledge, technological level, knowledge transfer, managerial capacity, personality and cooperation between entrepreneurs; together with classical factors of production: labor, land and capital. It is also possible to extend the multiple regression set out in the study on the influence of creativity and expertise on innovation, in order to include the other determinants of innovation, set out in chapter five. The development of the endogenizing function of innovation can also be pursued in the future, in order to use creativity as a factor of production.

The fractalized growth pattern can grow up to level three or four of granulation, only if the effects that level four of granulation has on level one of granulation are significant.

Transforming the fractalized growth model into a cellular automaton is one of the priority directions for future research.