



Modeling of the Socio-Economic Sustainability and Dynamics of European Regions on the Bases of Systems Complexity

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ABSTRACT

Globalization is one of the key challenges facing peripheral regions in Europe, bringing significant social, economic, cultural and political changes. Understanding the divergence between different regions of Europe, and between Europe and the rest of the world, implies considerable challenges, both in terms of quantification and analysis. The assessment of sustainability of economic system based on comparative analysis and growth of Gross Domestic Product (GDP) accepted by mainstream thinking of political system, does not reflect the objective reality. Comparative analyses of socio – economic structure have underlined the diversity in configurations and complexity level of knowledge and industrial production networks across the European Union (EU). The aim of this work is to analyze the sustainability and dynamics of economic development in North, South and East European countries, analyzing the selected countries production systems complexity trends during the last 10 years. The quantitative analysis of socio – economic systems complexity was carried out by modeling the landscape of countries production systems and calculating fractal dimension of the systems. As a result the fractal dimension of Sweden, Greece and Lithuania has been calculated, assessed and compared to productive part of total economy. The modeling results demonstrate the substantial differences in the assessment of countries sustainability trends, based on GDP from the one hand and production system complexity, based on fractal dimension on the other hand. The fractal dimension of socio – economic system produces a more realistic status and trends of the system sustainability and competitiveness.

Keywords: Socio-economic sustainability, complexity, fractal dimension, gross domestic product, GDP, general government gross debt, economic complexity

1. Introduction

Globalization has become a reality because of the networked global economy. Instead of a collection of closed economies, the world's economy has become transparently open, as the recent global financial crises attested. Newly developing technologies, such as nano- and biotechnology offer further dramatic new means to create value for customers. There are other profound social, economic and political undercurrents in play. For example, changing demographics now presents much more different world map with new opportunities and looming social / political problems. When the Cold War essentially ended with the collapse of the Berlin Wall in 1989, the EU was poised for greater regional cooperation, enabling the countries in Europe to participate more effectively in the world market. However, challenges are being faced because of the increasing organizational complexity as more nations join the EU. Anglo-Saxon, Continental, Mediterranean, and Nordic groups have different agendas (Sang and David, 2010). Complexity has always been a part of our environment, and therefore many scientific fields have dealt with complex systems and phenomena. Over the last twenty five years, a different approach to economics

has been slowly birthing and slowly growing complexity economics (Arthur, 2013). Over 6.4 billion people participate in a \$36.5 trillion global economy, designed and overseen by no one. How is wealth created within this global complex system? Some authors in contradiction to Neoclassical theory argue that the economy is a "complex adaptive system" in which physical technologies, social technologies and business designs continuously interact to create novel products, new ideas, and increasing wealth (Beinhocker, 2007). The complexity of the economy is related to the multiplicity of useful knowledge (Hausmann *et al.*, 2011) embedded in country or other socio – economic system. People in organizations have always sought, used, and valued knowledge (Snitka, 2002). Companies hire for experience more often than for intelligence or education because they understand the value of knowledge that has been developed and proven over time (Davenport and Prusak, 2000).

The Economist Newspaper Limited (2014) has carried out a research on economy growth of 10 countries which joined European Union on 2004. The results were stunning – 9 of 10 countries increased their economy from 6 to 54 percent, measured by Gross domestic product (GDP) growth. There are four clear winners in the prosperity league. Two Baltic countries, Lithuania and Latvia, together with Poland and Slovakia, have made gains of over 40% in GDP per capita. International Monetary Fund (2014) asserts the recovery of Europe and forecasts GDP growth almost in all Europe's regions. Thus, growing economy should add the amount of productivity and knowledge in the country and increase the complexity of all system. However, the opponents see the economic trends going to negative direction in the same countries.

There are several qualitative and quantitative methods to measure economic complexity of the system. One of them is the Economic Complexity Index (ECI) (Hausmann *et al.*, 2011). It is expressed in the composition of a country's productive output and reflects the structures that emerge to hold and combine knowledge. However, the ECI is highly related to GDP per capita growth, but not a growth of productive economy. Fractal dimension as a measure of complexity provides insights into the complexity of economy. By using fractal dimension of export networks landscape, the system complexity can be evaluated in terms of fractal dimension growth or decline (Abundo *et al.*, 2013).

The knowledge can only be accumulated, transferred and preserved if it is embedded in networks of individuals, organizations or countries that put this knowledge into productive use (Hausmann *et al.*, 2011). In other words, to become sustainable, countries have to strive to develop a complex trade networks with each other as a productive expression of the countries knowledge. Accordingly, the world economy is connected through network of international trade. In such World Trade Web, every country is a dynamical node, and the connections between any pair of countries are their imports and exports (Li *et al.*, 2003). It is assumed that the more connections in the trade networks the country has in World Trade web, the more complex socio-economic system is, more productive knowledge accumulates and more sophisticated high added value products can produce.

2. Research Question and Objective

The ability to measure the economic complexity, that reflects the amount of knowledge that is embedded in the productive structure of an economy (Hausmann *et al.*, 2011), is the key factor to the sustainability and productiveness of socio – economic system. Economic complexity index (ECI), introduced by Hildago A. and Hausmann R. in 2009, is proposed for assessment of economic complexity, and is related to GDP per capita growth. However, many authors' researches demonstrate that GDP does not reflect real economy value or sustainability, what was demonstrated during the financial crises. The aim of this work is to evaluate the productive part of economy through quantitative assessment. This leads to the following research question – *what is appropriate indicator for socio-economic sustainability and dynamics assessment?*

Thereafter, the study strives to understand the current socio – economic sustainability and dynamics of the European Union countries in different Europe's regions during past decade through quantitative mathematical model and estimate their complexity. In other words, the study investigates the complexity and sustainability trends of socio – economic systems (South, North and East Europe countries, that belongs to European Union) using fractal dimension.

3. Research Method

Fractal dimension allows us to measure the degree of complexity by evaluating how fast our measurements increase or decrease as our scale becomes larger or smaller (Paramanathan and Uthayakumar, 2008). A number of techniques that can be used for fractal dimension estimation were discussed by Mandelbrot (Foroutan-Pour *et al.*, 1999). The box - counting dimension is the most

frequently used fractal dimension counting method for measurements in various application fields. The reason for its dominance lies in its simplicity and automatic computability (Li *et al.*, 2009).

The study is accomplished by implementing research on three EU countries from various regions with different socio – economic agenda – Greece (South Europe), Sweden (North Europe), and Lithuania (East Europe). In this paper we investigate the combined analytic of fractal dimension (FD), GDP and country debt during the last decade to estimate the sustainability of the countries economical system.

Evaluation of complexity of the countries mentioned above was implemented by using export networks imaging (selected study period: 2001 – 2011 year) extracted from The Atlas of Economic Complexity Database (Simoes and Hidalgo, 2011) for each country separately. Each image was adapted for the software's requirements. *The Atlas of Economic Complexity* attempts to measure the amount of productive knowledge that each country holds. A central contribution of it - is the map creation of networks (or product space) that captures the similarity of products in terms of their knowledge requirements. This map provides paths through which productive knowledge is more easily accumulated.

Fractal dimension was calculated operating *ImageJ* (Image Processing and Analysis in Java) software, using box – counting method. In this method, each image is covered by a sequence of grids of descending sizes and for each of the grids, two values are recorded: the number of square boxes intersected by the image, $N(s)$, and the side length of the squares, s . The regression slope D of the straight line formed by plotting $\log(N(s))$ against $\log(1/s)$ indicates the degree of complexity, or fractal dimension (Foroutan-Pour *et al.*, 1999). Each image was scanned in 12 differential scan positions using Grayscale mode and block analysis.

All statistical data was collected from Eurostat Statistical Database (<http://epp.eurostat.ec.europa.eu/>). An assessment of the selected countries development potential was accomplished from the perspective of analyzing their current socio-economic and productivity network, economic complexity concept and data on productive knowledge accumulated in regional societies.

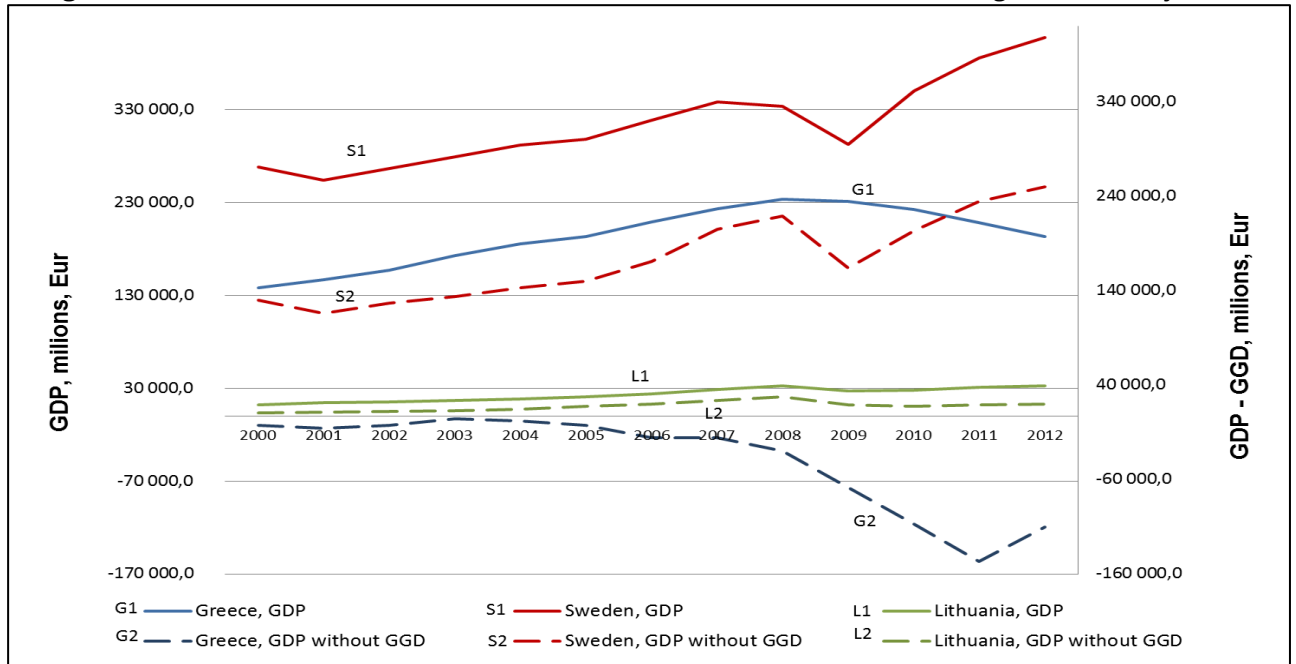
4. Results

The research results showed that GDP, normally treated as market value of all officially recognized goods and services, or GDP per capita as country's standard of living, does not always reflect objective economy value or sustainability. On the one hand, GDP is used for assessment of country economy growth. But on the other hand, when we talk about socio – economic sustainability or economic perspectives, GDP can be just one of the many indicators of the assessment. GDP is composed from elements that cannot be treated as economic growth and especially system sustainability or complexity index. Such as, government debt that rose considerably over the past decades in most advanced economies and this trend was accompanied by mixed GDP growth dynamics (Checherita-Westphal and Rother, 2012). It is important to understand that when the socio-economic sustainability and dynamics of the regions or countries are under investigation the advancement (not size) of economy is the most significant indicator. Depending on the composition and density of interconnections of economic system the fractal dimension indicates the economic complexity and development trends of the system. Therefore fractal dimension can be used as indicator for assessment of socio – economic sustainability and dynamics. Fractal dimension drawn together with GDP and General government gross debt (GGD) evolution produces a quite informative picture about the trends of socio – economic system during the time. Productive part of economic system was calculated subtracting GGD from total GDP, and represents the part of GDP directly related with system productivity and productive knowledge. Moreover, the curves of GDP and GDP minus GGD are extremely different (Figure 1) for different EU regional countries.

In the Nordic country, Sweden, the GDP and productive part of economy is in good correlation. However, productive part of economy is declining since 2005 in Greece case, at the same time the GDP is growing, because of growing part of GGD. In Baltic country, Lithuania situation is quite stable in global scale because of small scale of country economy. However, more detailed analysis demonstrated that the quite impressive growth of GDP during the last year (3%) is based on growing GGD with even declining productive economy part (GDP-GGD). What is in contradiction with optimism expressed in review (The Economist Newspaper Limited, 2014).

Looking at how the fractal dimension of the import – export networks coincided with productive part of economic system (GDP minus GGD) we can affirm that the proposed research method is suitable for evaluation of productive knowledge that country holds. Moreover, it reflects the information about system complexity level because complexity is expressed in the composition of a country's productive output (Hausmann *et al.*, 2011).

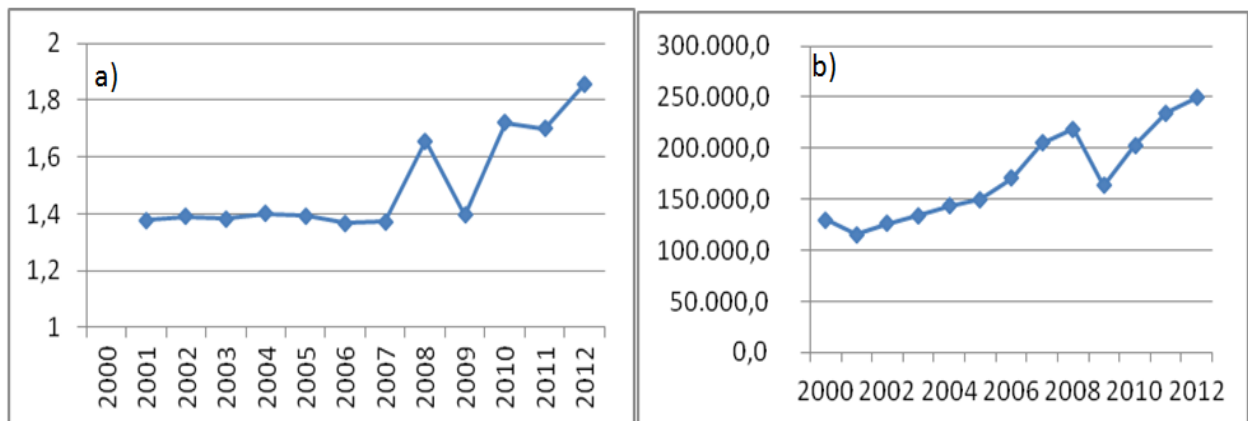
Figure-1. GDP and GDP-GGD of Greece, Sweden and Lithuania evolution during 2000 - 2012 year.



As shown in Figure 2, the fractal dimension of Sweden strongly corresponds to GDP without GGD curve. From 2001 till 2007 the stability of fractal dimension and slight growth of GDP without GGD debt is observed. Insignificant increase of GDP minus GGD appeared because since 2001 to 2007 year international investments has grown for 97 percent, GGD was stable – decreased for 3,7 percent and direct EU investment rose up for 59 percent. However, these investments did not increase economic complexity that is necessary for a socio – economic system (country) to be able to hold and use more productive knowledge.

Though from 2007 year notable changes and dynamics are visible in both curves. Fractal dimension expands for 20 percent till 2008 year and GDP without GGD reaches the highest point since 2001 year. The economy of Sweden was growing for 7 years in a row, but fractal dimension, that was stable for all research period, jumped to heights almost over the night. Moreover, Sweden government reduced GGD for 14 percent, while it had modest rise practically since 2001, even though the EU and international investments evolved marginally comparing to previous year (3 and 0,32 percent). What happened in Sweden in 2007? Since the end of 2006, major changes have occurred in Sweden. We can speculate that one of the primaries reasons of this variation – policy has changed radically: Social Democrats lost the election struggle after twelve years in a row and center - right coalition took over the governance of the country. These changes strongly influenced sustainability and economy of Sweden, as it reflected in Figure 2.

Figure-2. (a) fractal dimension of Sweden b) GDP without General government gross debt of Sweden, mln. Eur

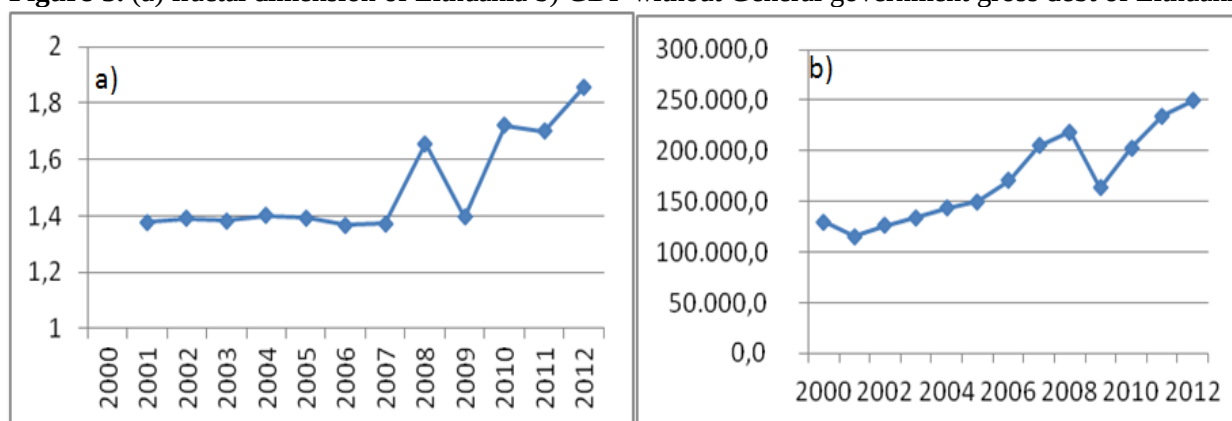


The global financial crisis at 2008, which originated in the advanced economies, has hit the world strongly, with some developing countries being particularly affected. However, the impact on economic activity has varied widely across countries (Berkmen *et al.*, 2009). Sweden was one of the countries that global financial crisis affected in short term period. Still, it made significant impact for Sweden exports – transportation export decreased for 49,8 percent, metals – 44,6 percent, machines – 28,4 percent, etc. Export did not grow in any of products group comparing 2007 and 2008 year. These results appear in fractal dimension too – after the rapid growth the fractal dimension has founded itself in the level of 2002 – 2005 year. Resembling results is observed in GDP without GGD curve – even though EU and international investments slightly increased during the global financial crisis.

After the crisis, in 2009, the economy of Sweden started to grow again. A big influence for local business made bold Sweden government decisions to (1) guarantee all bank deposits and creditors of the nation's 114 banks; (2) assume bad bank debts; (3) supervise institutions that needed recapitalization (Dougherty, 2008). As a result, economy recovered instantly, as it visible on fractal dimension (23,2 percent growth) and GDP without GGD (24,2 percent growth) curves in Figure 2. The export and export networks lost in 2008 was fully rebounded till 2010 year.

Assessing East Europe country Lithuania has given resembling results – fractal dimension strongly correlated with GDP without GGD dynamics (Figure 3). Since 2001 till 2004 economy of Lithuania grew stable without any precipitant. Since 2004, when Lithuania joined EU, GDP without GGD started to grow obviously faster till 2008 – in total for 85,9 percent. It was due to significant increase of direct EU and international investments (grow for 355 and 96 percent). Investments made a great influence on trade and exports – Lithuania started to export new products (plastic and rubbers, vegetable products), the amount of total export value increased for 144 percent, Lithuania created considerably more trade networks, especially in North America, started export to South America. European Union opened wide opportunities for Lithuania's economy complexity growth.

Figure-3. (a) fractal dimension of Lithuania b) GDP without General government gross debt of Lithuania



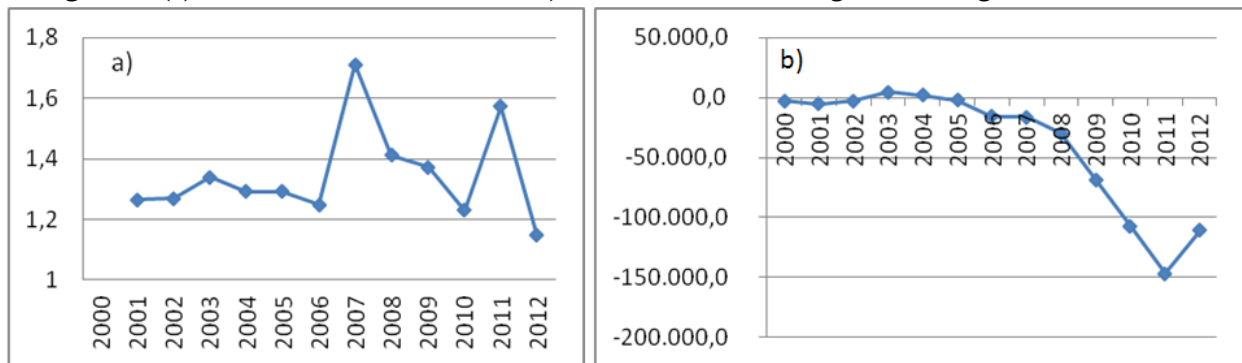
The Baltic countries – Lithuania, Latvia and Estonia - were more severely affected by the turmoil in global trade and financial markets than any other countries in the world (Purfield and Rosenberg, 2010). The condition of economy was abysmal – total export value declined for 46,6 percent, export networks with South America almost interrupted, emigration grew for 222,9 percent, general government gross debt increased for 55 percent and it made a great influence for sustainability of Lithuania.

The condition has slightly improved in 2011. Much greater increase is visible on GDP curve (Figure 1), but it does not reflect objective condition, because the general government gross debt grew for 135 percent comparing to 2008 year. Indeed Lithuania reverted to level of 2006 as obvious from fractal dimension and GDP without GGD curves in Figure 3. However, authors (Purfield and Rosenberg, 2010) who analyses GDP dynamics asserts that government took appropriate decisions and solve the crisis problem, but the results of GDP are not always objective as our research demonstrated. Complexity and sustainability is much more important than GDP growth or decline, because it does not reflect the productive knowledge the country holds and adapts in market.

The fractal dimension dynamics of Greece does not match with GDP without GGD curve (Figure 4). The basic reason of this expression is the permanent debt of economy. In other words, Greece have practically always lived in debt, spent more money than earned. A significant portion of the spending went not to stimulate the economy out of recession, but to pay for social welfare programs with

questionable return on economic growth and vitality (Abboushi, 2011). Therefore, the sustainability of Greece economy and complexity was incoherent and evolved by chance or self – assembling networks.

Figure-4. (a) fractal dimension of Greece b) GDP without General government gross debt of Greece



Despite of economic situation after 2005, when GDP has become absolutely reless, the economic complexity of Greece was stable and reflected objective economy (GDP without GGD) condition from 2001 to 2005. During this period the export increased in proportion, however Greece did not export new products and did not establish new export networks in this time. Inconsiderable decline is in sight on 2006 on both curves. But the most significant changes of economy complexity began in 2007. Fractal dimension jumped for 37 percent, because of the new trade networks in Europe and North America. Fractionally the export to Oceania increased too. These networks influenced sustainability and economic complexity as fractal dimension indicates.

The global financial crisis affected Greece distinctly. The weak economy of Greece began to collapse and launched long – term regression. It was the combination of the high debt to GDP, deficit to GDP, stagnant economy, shrinking tax base, and a dysfunctional tax collection system, that increased Greece vulnerability and exacerbated its shortage of liquidity (Abboushi, 2011). Export and fractal dimension declined for 17 percent, part of trade networks in Europe vanished, the rest trade partners imported less products. However, the International Monetary Fund (IMF) and EU approved €110 billion three-year loan for Greece on 2010 to help the country ride out its debt crisis, revive growth and modernize the economy (IMF Survey Magazine: In the News, 2010) and the complexity of economy started to grow again. The GDP without GGD declined longer for year, because of high financial liabilities and rising GGD till 2011 and increased on 2012 as a result of budget cuts and major austerity measures that included freeze on public sector wages, higher VAT taxes, cutting pension and social service payments, lifting retirement age, new business taxes, and many other austerity measures (Abboushi, 2011).

Despite of all contributions the economy of Greece was affected sorely – strained networks, artificially promoted manufacture did not last long in natural field of world economy. The financial support helped to reduce GGD, but not complexity of Greece as socio – economic system.

5. Conclusion and Future Research

Modeling of socio-economic system complexity was performed for North, South and East Europe countries – respectively Sweden, Greece and Lithuania. The fractal dimension was used to evaluate productive economy complexity in each country separately. Research results approved the suitability of fractal dimension for assessment of socio-economic sustainability and dynamics. It was demonstrated, that the fractal dimension calculated for the countries production landscape correlates with countries production value in majority of countries with quite different socio – economic structure. The comparative analysis of Scandinavian region with Greece and Baltic region shows a growing divergence between the complexity and sustainability trends of investigated socio – economic systems.

Future research will be positioned to develop fractal dimension as indicator for socio-economic sustainability and dynamics assessment and trends on the bases of systems complexity for several EU regional countries and developing countries of Asia. The next step to improve the method is the estimation of productive knowledge topography by 3D visualization.

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