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XV. NEMZETKÖZI TUDOMÁNYOS NAPOK

15TH INTERNATIONAL SCIENTIFIC DAYS

XV. INTERNATIONALE WISSENSCHAFTLICHE TAGUNG

„Innovációs kihívások és lehetőségek 2014-2020 között”
„Challenges and Prospects for Innovation between 2014-2020”
„Herausforderungen und Möglichkeiten von Innovationen zwischen 2014-2020”

A TUDOMÁNYOS NAPOK PUBLIKÁCIÓI
PAPERS OF SCIENTIFIC DAYS
PUBLIKATIONEN DER WISSENSCHAFTLICHEN TAGUNG

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KÁROLY RÓBERT FŐISKOLA
TUDÁSSAL A JÖVŐÉRT

Gyöngyös
2016. március 30-31.
March 30-31, 2016
30-31. März 2016

OPEN INNOVATIONS AS A KEY DRIVER OF BIOECONOMY DEVELOPMENT IN EUROPE

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Abstract
The concept of bioeconomy is developing nowadays, mostly through linking companies into innovative value chains, as well as clustering different socio-economic processes of several sectors of economy. The paper aimed to present how the open innovations drive the development of bioeconomy. It shows that such industrial organization, alternative to classical market structure, by applying knowledge and innovative technologies, is able to deliver competitive products and services, through achieving objectives important from private and public point of view. It is argued that the transition from the classical linear model of innovation's development towards the application of non-linear models is a turning point in the diffusion of bioeconomy concept. A part from theoretical analysis, there were used empirical evidences from the biofuel difussion in Europe. It was shown that the turn from close to open innovation difussion speeded up the growth of this market.

Keywords: bioeconomy, open innovations, biofuels, European Union
JEL codes: L11, L50, Q01

Introduction

The relativist approach to economic thought imposts the perspectives of time and place to all sets of inter-related production and consumption activities, which are results of decisions taken under varying constrains. Those constrains are also important while, using constructivist paradigm, determining and analyzing how scarce resources are allocated in order to fulfil unlimited and changing needs. Taking this line of reasoning one could say that at the beginning of XXI century the idea of the knowledge based bioeconomy (later called bioeconomy) is gaining significant and growing importance, not only from the theoretical point of view, but perhaps above all, from policy choices and practical reasons.
The bioeconomy is recognized as a concept, which core function is the use of natural and renewable resources, by applying the cross sectoral cooperation and innovative technologies. It encompasses more than the production and consumption of goods and services, including a shift from non-renewably resources to renewably and from fossil fuels to the use of renewable energy. Maciejczak [2015a] points out that use of renewable resources and application of circularity are the basic contributions of bioeconomy to the development based on sustainable principles, through ensuring a positive environmental and social impact associated with the economic growth.

However, the up to date understanding and the body of knowledge (including scientific, political and popular texts) devoted to the bioeconomy is very heterogeneous. The diversity comes from the evolution of perception and different objectives imposed for the bioeconomy as a concept. There can be distinguished two epistemological approaches. First recognizes bioeconomy from classical and neoclassical points of view. Second is applying the hetorodox economics approaches. The later point of view seems to be more appropriate. This is because, using the relativist assumptions, it enables to answer the urgent questions about the bioeconomy by applying evolutionary, ecological, post-Keynesian or institutional traditions.

The emergence of the bioeconomy concept is directly linked to the problems of scarcity of resources and their sustainable use. The rational and promising alternative was spotted in the bioeconomy due to the exhausting natural resources as well as socio-economic and environmental problems associated with their use, including both climate change on the global scale and several regional and local challenges. For such decision speaks the level of technological and biological progresses, which were achieved particularly in the life sciences as well as the exceeded minimum threshold of implemented innovations.
It can be argued that in the developed countries the first wave of bioeconomy, that took place at the turn of XX and XXI century, was associated with the biological and technological progresses, which laid the groundwork for product and process innovations in various industries. Genetic modifications and transgenic techniques, associated with the precision productions and extensive use of innovative biological processes resulted in emergence and development of the bioeconomy as a one of the sectors of the economy [Maciejczak 2012a].

As a result, it was confirmed by Piotrowski et al. [2016] that in 2013 in the European Union (EU) the bioeconomy showed a turnover of 2,1 trillion EUR, roughly half of which were responsible the food, feed and beverages sectors. The so-called bio-based industries, such as chemicals and plastics, pharmaceuticals, paper and paper products, forest-based industries, textile sector, biofuels and bioenergy – contribute with 600 billion EUR. The European bioeconomy sector contributed with the employment of 18,3 million jobs with primary biomass production (agriculture, forestry and fishery) as the biggest contributor (58%). The analysis showed different situations among Member States. Eastern European countries such Poland, Hungary, Romania and Bulgaria are strong in primary production and their commodities' sectors have a high employment/turnover ratio. Western and Northern European countries generate a much higher turnover compared, hence have lower employment/turnover ratios. Frontrunners for bioeconomy in Europe are Germany, Italy and France, which share the highest turnover and employment in the EU-28. Accordingly, most recent analysis based also on 2013 data for the United States of America showed that bioeconomy sector contributes to the national economy with 369 billions of USD of value added and 4 million of jobs [Golden et al. 2015].

As the bioeconomy sector matures, it also changes in order to adjust to changing conditions of growth, both internally and externally. These changes can be recognized as a second wave of bioeconomy development. Analyzing this momentum one should perceive the bioeconomy from the complex adaptive system perspective, as a system that binds together natural resources, technologies, markets, people and policies. Maciejczak [2015a] pointed out that the bioeconomy as a concept established already links between industries, both old, that for a long time form a chain of added values and new, that previously had no connections, within a new, symbiotic relationship where one industry utilizes the by-products of another. Additionally, the bioeconomy putted together processes that have far been disparate: business and sustainability, ecosystem services and industrial applications, innovations and technologies, biomass and products, all in order to meet growing public and private expectations. Thus it can be concluded that the complexity of bioeconomy resulted from the inter-relationship, inter-action and inter-connectivity of elements within a system and between a system and its environment [Levin 2000; Cham 2001]. It is important to realize that in case of the bioeconomy there is no separation between a system and its environment. The bioeconomy is closely linked with all other related systems of the economy making up an ecosystem. Within such a context, as argued by Vanberg [2004] change will take place in terms of co-evolution with all other related systems, rather than adaptation to a separate and distinct environment.

The co-evolution of the bioeconomy within the economic system can be observed in case of the focus on circularity approach [Maciejczak 2015b], contextual approach [Maciejczak 2016] as well as changes of development, implementation and use of innovations [Nabradi 2010; Lencses et al. 2014]. The second wave of the bioeconomy development is challenged for new industrial organization of the bioeconomy as a sector. The challenges comes from two main synergetic factors which are shift from close to open innovations and network organization. This thesis is supported by the research done by Besi and McCormick [2015]. They analyze twelve strategies of bioeconomy development produced by national governments, regional agencies and industry groups in Europe. The findings show that the different strategies focus on the same key priority areas. These include fostering research and innovation; promoting collaboration between industry, enterprises and research institutions; prioritising the optimized use of biomass by implementation of the cascade principle and by utilising waste residue streams; and providing funding support for the development of bio-based activities.

There is also high pressure paid on the inter-regional collaboration that shall have a particularly important role, especially when the region is highly contextualized and specialized in terms of its bioeconomy focus [Golebiewska 2014]. Collaboration amongst them will be necessary in order to create a holistic and functioning European bioeconomy.

Objectives, materials and methods

The paper main objective is to present how the shift from closed innovations based on the linear models to open innovations based on non-linear models drive the development of the bioeconomy sector being in the second wave of its development. The presented researches are based on the heterodox assumptions of deductive and descriptive reasoning as well as the constructivism paradigm. The analyzis will be conducted based on the region of the European Union. There will be used secondary data coming from the Eurostat as well as Bioeconomy Observatory using the data management tool DataM2, which is capturing statistics related to bioeconomy [European Commission 2016]. In order to present a comprehensive picture of the situation in the analyzed region, the time frame was limited to the years 1990-2014. It is worthwhile however to mention after the European Commission's Joint Research Centre staff that documenting the bioeconomy is a challenge for science as official statistics only report on traditional sectors with no distinction between synthetic and bio-based production (e.g. manufacture of synthetic textile vs. bio-based textile [Ranzon 2014]. Therefore, indicators for the bioeconomy shall be estimated using a combination of multiple sources.
In the paper was used the case of liquid biofuels, as an example of developments in the bioeconony sector in Europe. The detailed estimations were made based on the descriptive statistics and the model of diffusion of innovations developed by Rogers' [1995]. His classical model of innovation diffusion can be expressed by the differential equation:

$$\frac{dN(t)}{dt} = g(t)(m - N(t))$$

where: $N(t)$ – the cumulative numbers of adopters at time t, m – ultimate ceiling of potential adopters, $g(t)$ – the coefficient (rate) of diffusion. This equation points out that the diffusion rate is a function of the number of the potential adopters and the rate of diffusion. The rate of diffusion, $g(t)$, reflects the likelihood that potential adopters will adopt the innovation in some small interval of time around time t. The value of $g(t)$ depends on such characteristics of the diffusion process as the type of innovation, communication channels, time and the traits of the social system.

In the paper was applied the extended version of Rogers' model proposed by Bass [1969]. This model, called also mixed-influence model, includes both internal and external factors affecting the diffusion of innovation. For this mixed-influence model, the diffusion coefficient $g(t)$ is equal to $p + q\ N(t)$. In view of its great degree of generality, due to the accommodation of both internal and external influences, mixed-influence models are the most frequently employed in analyses [Mahajan et al. 1995; Kot et al. 1993]. The mixed-influence model can be expressed using the following equation:

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

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 methods of estimating the parameters of models of innovation diffusion play a leading role in fitting models to empirical data and using these models. After Mahajan, Srinivasan and Mason [1986] there was applied the ordinary least squares procedure.

Results and discussion

First wave of bioeconomy development.

Esposti [2001] as well as Douthwaite et al. [2003] argue that in the dynamic and evolutionary perspective, bioeconomy is in a stage of evolutionary process from the old to the new technological paradigm. Its inception was characterised by the time when bioresources changed their classical role towards development of new products and services using innovation. The studies of bioeconomy's innovation adoption has always emphasized the complexity of such a process [Viaggi et al. 2012]. As explained by Swinnen and Weersink [2013] in bioeconomy's evolution especially the agricultural-based outputs role have changed. They show that they have expanded beyond the traditional food, feed, and fiber to include fuel and other nonfood applications as well as environmental goods, which is also true for other, more advance sectors, as chemical. Viaggi [2015] argues that different technologies and sustainability pathways co-existed (worldwide at least) in such applications with traditionally derived products. On the other hand, attention has moved from choosing between existing technologies to a focus on new technological developments through innovation. At the same time, the concept of sustainability changed - initially it was focused mainly on environmental effects, then enlarged to economic and social sustainability and resource efficiency. This is partly due to technical issues, such the practical difficulties in proving the linkage between research and productivity change. Making this linkage has also become more difficult over time due to the increased variety of technology pathways.

Taking into account the above conditions the first wave of the bioeconomy development was characterised by the linear modes of the innovation process, which included: basic research, applied research, development works, implementation works and diffusion [Maciejczak 2012d]. In this model the main role was played by the development of science and technology. In such science-push model, was assumed that innovation starts with new scientific research and in next stages it will convert to development of production, manufacturing and marketing and at the end, new good, service or process will be sold successfully. According to this model for creating pioneer innovation, scientific researches should be improved and expanded [Takács-György 2012]. Success secret for innovation is in massive investment in research and development and emphasizing on them. That was characteristic a.a. for biodiesel production [Knothe 2005]. In this case the model of innovations diffusion was characterized by close use of the progress, mainly due to the need of the return of made investments [Haas and Foglia 2005].

Second wave of bioeconomy development

As identified by van Lacken et al. [2002] due to the multidisciplinary nature of bottlenecks that hinder innovation adoption in the bioeconomy, there was required a nonlinear, flexible, iterative research approach with intense stakeholder interaction. Diversified needs of different stakeholders created the tension for a model to provide a rationale to evolve from an innovation impulse to a technologically sound and supported innovation. Such a rationale helped to structure the complex process of progress development and innovation diffusion and gave guidance and support to every stakeholder involved [Takácsné György 2015]. With this respect the linear models were replaced with more modern interactive models that accurately present innovation processes. As argued by [Maciejczak 2010] new models have incorporated feedback processes operating within and between firms, which captured the high level of integration between various elements of the system.

In this point it needs to be stress out that this process was speeded by the development of informatics, business management methods and dynamic growth of new forms of cooperation between enterprises, governments, academia and society. Maciejczak [2012b] has shown that the challenges called attention to the quadruple helix model of innovation where civil society joins with business, academia, and government sectors to drive changes far beyond the scope of what any one organization can do on their own. He argued also that there was needed a new paradigm based on principles of integrated collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies, and extraordinarily rapid adoption with the greatest attention on speed and efficiency in diffusion of innovations, which became one of the most important factors in competitive struggle on global markets [Maciejczak 2012c, 2013].

Russel et al. [2011] as well as Hobday [2005] pointed out that while closed innovation did not disappear, they were dwarfed by the efforts of teams that enable a wide spectrum of stakeholders to take on active roles. The adoption of the new paradigm become the catalyst that unleashes an explosion of innovation in bioeconomy [Bigliardi and Dormio 2009]. It shall be emphasized that in this respect the companies changed their prespective and role. Instead of gravitating to become a dominator in the competitive system, they drive to co-create it by leveraging innovation ecosystems assembled from a multitude of participants together creating novel products and services that are quickly adopted.

This approach fitted into the idea of open innovation conceptualized by Chesbrough [2003]. The open innovation in bioeconomy therefore comes about as a result of the companies coming together to utilize on the common knowledge that has been achieved in the specific areas. Companies have realized that with time, it becomes effectively cheaper to share on some of the common knowledge and skills that are being applied in their production processes, and thus the coming together has proved to be cheaper in the long run from the activities being carried out by the company.
Tolhurst and Brown [2013] showed that the sharing of such information by companies has however certain protections, once the company has their research innovations in place, then they are entitled to ownership of the innovation, and thus they will be responsible in any form of sharing or distribution of those ideas to the other companies. This means that such ideas

will be highly protected from any form of unauthorized sharing. As argued by Zaraychenko et al. [2016] the future of the open innovation trends tend to focus more on the open innovation models and how they would apply in helping improve on the relationships and an eventual productivity of the companies.
In the EU, as shown in the report State of the Innovation Union 2015 [European Commission 2015], there is still need to improve knowledge circulation, open innovation and to foster further cooperation between industry and academia. The eco-system for innovation has been greatly improved by putting in place measures focusing on cooperation. Also closer involvement of society has proven to be essential in fostering a wider innovation culture in Europe. Ketels and Protsiv [2014] argue that European emerging industries, including bioeconomy, thrive on cross-sectoral linkages, combining narrow activities in new ways that generates economic value. Nevertheless, inconsistencies of rules and practices remain and are hampering the development of high growth innovative firms, which often find it too burdensome and risky to operate in several European markets. Not all citizens and firms are on an equal footing with regards to innovation capacities and access to the benefits of innovation.

Improving the inclusiveness of innovation appears to be increasingly important, including through further mainstreaming of actions and simplification of access rules. Having this challenges in mind it is needed an orchestration [Curley and Formica 2013]. The orchestration shall develop the capacity to create conditions where the diverse parties can work together with the right balance of inner and outer focus, and thus reinforcing both their own work and benefiting the ecosystem as a whole, as well as the provision of supporting service infrastructure to help sustain effective operation within the system. Such approach is now most promising European sector of the bioeconomy – biorefineries [Schieb 2015]. As shown by Maunula [2012] the so far functioning of this sector in Europe is on the direct path to develop the open innovation based ecosystems of biorefineries, with the highest potential of the industrial bioeconomy. The biorefinery concept based on open innovation allows companies to renew their business strategy and to maximise their value creation from the resources brought to the mill and to produce multiple bioproducts in an efficient manner.

Innovations in European biofuel market – a case study

The European Union's renewable energy directive [2009] sets a binding target of 20% final energy consumption from renewable sources by 2020. To achieve this, EU countries have committed to reaching their own national renewables targets ranging from 10% in Malta to 49% in Sweden. They are also each required to have at least 10% of their transport fuels come from renewable sources by 2020. All EU countries have adopted national renewable energy action plans showing what actions they intend to take to meet their renewables targets. These plans include sectorial targets for electricity, heating and cooling, and transport; planned policy measures; the different mix of renewables technologies they expect to employ; and the planned use of cooperation mechanisms. With regard to the transport sector in 2003, the European Union established a biofuels support policy, primarily with the aim of lower ing CO2 emissions in the transport sector. Critics have accused this policy of inducing indirect land use change. Therefore in 2015, the European Commission presented a legislative (Directive (EU) 2015/1513) to capping conventional biofuels and promoting advanced biofuels. Additionally in 2014, the European Commission set out its vision for EU climate and energy policy up to 2030 wich focus on biofuels and inform that the policies that have driven biofuel uptake and attempted to mitigate their consequences would be altered dramatically post 2020 [IEEP 2014].

Today's European policy is focusing on the advanced biofuels. The term advanced biofuels may is used to describe biofuels produced by advanced technology from non-food feedstocks (e.g. wastes, agricultural and forestry residues, energy crops). The end product (e.g. cellulosic ethanol or biodiesel) is the same as that produced by first generation technology. However, these products are considered more sustainable as they generally offers greater levels of green gass reduction and/or do not use food crops as a feedstock.The could have also advanced properties, such as biopetroleum, bio jet fuel, biobutanol, etc.. These end-products may be more compatible with exisitng fuel infrastructures or offer other technical benefits.

As indicate Pacini and Strapasson [2012] with regard to the biofuels in the EU there was reached a compromise between the policy requirements, the industry´s status quo and the society expectations. With the design of policy agenda and support of public sources it was possible to develop in the EU an system that holds the signs of open innovation [Belkema 2015].

Production of liquid biofuels in the European Union increased significantly from almost nothing in 1990. There were rapid increases — especially after 2002 — producing an average annual growth rate between 2000 and 2010 of 32 %. However, production decreased in 2011 by 10 % compared with 2010. Since then it is increasing at around 10% each year. Production of liquid biofuels in 28 Member States of the UE is shown in figure 1.

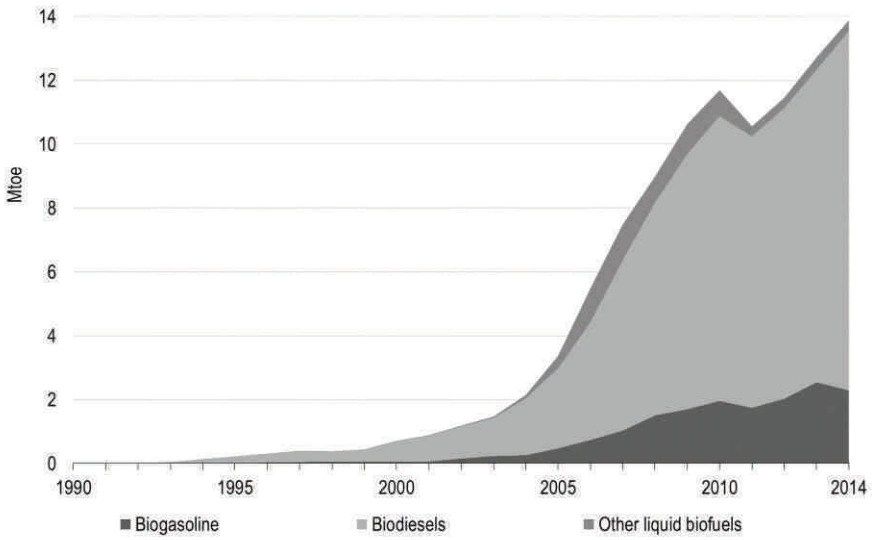

Figure 1. Primary production of liquid biofuels, EU-28, 1990-2014
Source: own calculations based on data from Eurostat

Upham et al. [2013] and Sognen-Haugsbo [2012], both argue that the in the European biofuel market the diffussion of innovations to the years 2000-2004 as dominated by the closed model based. It was based on the linear development of progress and low rate of the initial stages of the diffusion. Since that time, due to the policy changes, especially the renewable energy directive and its consequences in financing the research and development activities the model was changed into more open modes. Using this findings there was applied the concept of Rogers et al. [1999] in which the diffusion of innovations, on the biofuels example, and complex adaptive systems, such bioeconomy, can be employed together in the construction of applied hybrid model of induced change in population behavior. In such interventions, differentiated heterogeneous zones may act as catalysts for the adoption of innovation. In

cultivating network ties the innovator may prompt and, to an extent, guide the complex emergence of innovation adoption in social systems.
There was calculated diffusion of biofuels in the EU for two periods 1990-2005, assumed as period of closed and linear innovation diffusion, and 2000-2014 as a period of open and non-linear innovation diffusion. The results are presented in the figure 2. As can be drown from this figure the difussion of innovations based on the closed model, especially because of low technology transfer and the high presure for the retourn of investment, resulted in relatively lower acceptance of the biofuels on the market, while compared to the period of open innovation. It was found that due to open innovation characteristic model of biofuel difussion, which took into account the co-evolution of the approaches of the diferent stakeholders (policy designers, business, academia, technology providers, society, etc.), the market has driven into the eco-system that different expectations are met. In the second from analyzed periods the innovation difussion resulted in 5 times higher intake of biofuels then the first one.

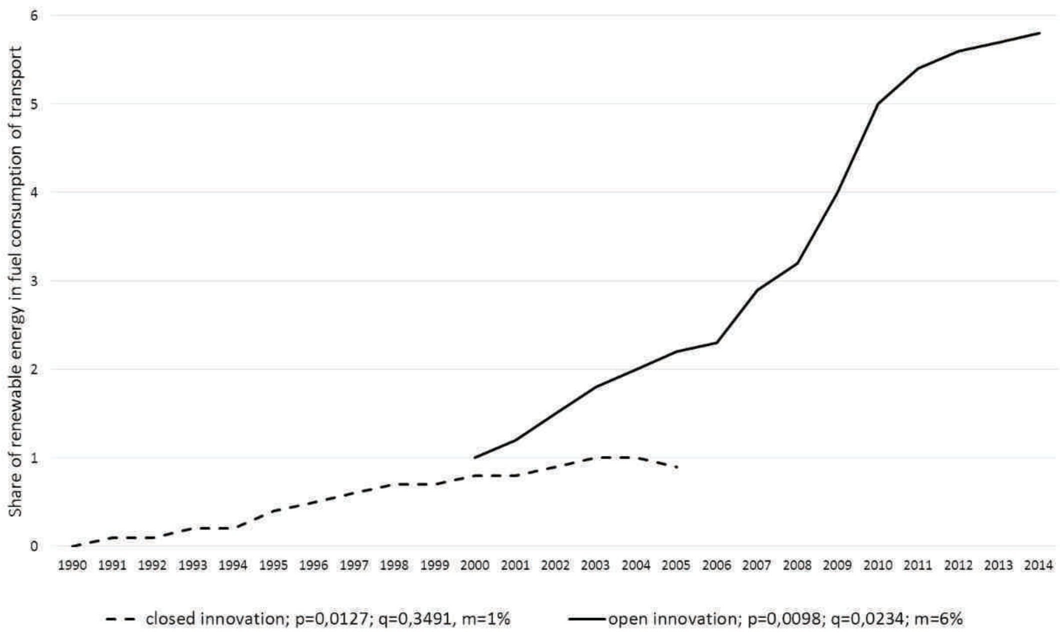

Figure 2. Difussion of closed and open innovation in biofuel market, EU-28, 1990-2014
Sources: own calculations based on the data from Eurostat and European Bioeconomy Observatory

Conclusions

There is no doubt that innovation is the most important economic force underlying improvement in the human condition and that today more inputs are being provided to the innovation process than ever before [Brander 2009]. That is also true for the case of the bioeconomy. Today's bioeconomy is dominated by projections concerning production needs of food, fibres, bioenergy and biomaterials (biodegradable plastics, bio-based polymer, biopharming), and related trade-offs.
The findings of this paper indicates new industrial organization of the bioeconomy sector, mostly through linking companies into innovative value chains, as well as clustering different socio-economic processes of several sectors of economy. This approach enables to obliterate the boundaries between a firm and its environment, making them more permeable, and thanks to that, transfer innovations inward and outward.

Based on the case study of the biofuel market in Europe there was confirmed that the open innovations drive the development of bioeconomy. Thus the transition from the classical linear model of innovation's development towards the application of open and non-linear models is a turning point in the diffusion of bioeconomy concept.

From the most recent foresight studies executed under Kovacs [2015] come that the main objectives for bioeconomy development are to deliver of food security, sustainable resource management, reducing dependency on non-renewable resources, tackling climate change and creating jobs and maintaining competitiveness. There were identified two major uncertainties. The first one is the demand growth for biomass for materials and energy. The second is the supply growth of biomass, which depends on the development and implementation of new technologies and the rate of intensification in the primary sectors. It is therefore important in the research agenda to focus on the new orchestration of the bioeconomy and analyze, not only in classical dimentions such effectivenes, but also in more contemporary's ways, i.e. institutional, how bioeconomy could coexist with other sectors.

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