WHEN AND WHY REGIONAL CLUSTERS BECOME BASIC BUILDING BLOCKS OF MODERN ECONOMY

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In this paper, we examine the modern cluster theory and the specific features of regional innovation clusters as complex adaptive systems. Clusters have become a typical pattern of industrial organization in national economies under their transition to innovation-driven model of growth. We provide an overview of the contribution of various theoretical frameworks (evolutionary theory, spatial development theory, theory of technological change and system innovation, and Porter's competitiveness theory) to the cluster concept and consider the latter from the perspective of complexity economics. On this basis, we differentiate true clusters from their nominal counterparts and propose three analytical dimensions to explore clusters, namely, as a special class of industrial agglomerations, as a special class of innovation ecosystems, and as a special class of economic projects (cluster initiatives). We examine the properties of clusters corresponding to each class and demonstrate their role in the geographical and functional fragmentation of production, in the integration of local exporters into global value chains, and in bridging communication gaps and developing collaboration among economic agents. We show that clusters occupy a central place among various types of business networks and have a comparative edge making them key building blocks of the modern industrial landscape. Further, we explain how the innovation capacity of clusters is affected by network synergy effects arising from the triple-helix pattern of collaboration among their participants. Finally, we draw conclusions regarding national cluster supporting policies, including those applied in modern Russia.

***Keywords*:**
innovation clusters, cluster initiatives, collaboration, innovation ecosystems, triple helix model, complex adaptive systems, global value chains

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Digital transformations combined with rapid technological progress and global competition challenge sustainable growth prospects of countries, so that economic systems now have to rely on exclusively endogenous sources of development. This challenge necessitates the transition of both developed and developing economies towards an innovation-driven type of growth based on a continual innovation activity of businesses or, plainly speaking, on continual innovation. To manage this process of transition, countries and regions are launching extensive reforms that would enable the adaption of domestic economic contexts to fundamental global changes.

Firstly, the development of information and communication technologies (ICT) leads to the *emergence of a network-based innovation model*, where the creation of innovations as well as the innovation-driven production process become non-linear, decentralised and interactive [1]. New ideas and knowledge are now generated not only in academia or business sectors but in all institutional sectors. The transformation of this knowledge into innovations (new products, technologies and services) results from a collective action of multifarious actors united into common communication networks.

Secondly, globalisation leads to *the emergence of a distributed model of production* [2]. The manufacturing of a final product is no longer done by one large firm or group of firms from the same country but rather by several exporting firms from different countries, operating within the global value chains. The traditional production chains had ultimately gone beyond the national boundaries and transformed into joint international projects uniting autonomous network partners from wherever in the world. The literature describes this process as the globalisation of production [3].

Thirdly, both the technological progress and the globalisation of production lead to *the re-arrangement of national economic landscapes* so that the organisation of economic activities in countries and regions gains a network-based and a cluster-based design. The growing complexity of technological systems generates a complementary growth in the complexity of economic systems: the latter are re-arranging themselves from a set of hierarchical firms into a complex variety of business networks, or ecosystems, which are better tailored to a collective creation and a mass diffusion of innovations than hierarchies [4]. Of all forms of ecosystems shaping the new economic landscape, *regional clusters* are becoming the basic model since they better fit into the digitalised and globalised context as compared to other business networks.

This article aims to reveal the specific features and advantages of regional clusters, which enable them to provide a continual innovation. Why are clusters considered the most efficient organisational model of modern economic and industrial activity?

We focus mostly on existing theoretical findings rather than on empirical research. In the first part, we provide a literature review summarising the contribution of various streams of theoretical thought to the cluster concept. On

that basis, we highlight the nature of clusters as complex dynamic systems and propose three analytical dimensions to study them. Following the proposed methodology, we analyse modern clusters first as a special type of industrial agglomerations (the second section), then as a special type of innovation ecosystems (the third section), and finally, as special economic projects often referred to as cluster initiatives (the fourth section). The final part of the article contains conclusions regarding the policy of supporting clusters, including Russian cluster efforts.

1. The Origin and Evolution of the Cluster Concept. Literature Review

The cluster concept began to gain momentum in the economic theory and practice a quarter of a century ago, which reflected the growing interest of academics, policy-makers and business in both the very phenomenon of clusters and their advantages in achieving a more dynamic economic growth. Cluster concept first appeared in the well-known book by Michael Porter *The Competitive Advantage of Nations* [5] in 1990, where Porter defined the term 'industrial cluster' as a group of companies from related industries having common business tasks and communication channels. Before Porter's cluster idea, the economic literature was focused on discussing a similar idea of 'industrial districts.' The latter had been introduced by Marshall as early as in the 19th century, reflecting the contemporary British phenomenon, but it re-emerged in the late 1970s, in the works of Becattini on similar agglomerations of small and medium-sized companies in Italy [6].

Until the mid-1980s, the Marshall-Becattini concept of industrial districts [7] remained on the periphery of theoretical research since economists kept to more popular theoretical findings on industrial markets introduced by the future Nobel laureate Williamson [8]. However later, this concept incorporated some of Williamson's approaches and Granovetter's idea of embeddedness, which laid the foundation for the *European cluster research tradition* that leans toward spatial analysis in studying business agglomerations and business networks [9]. A similar thing happened to Porter's cluster concept. Originating from the Harvard Business School studies on corporate strategies, it was initially developing on the periphery of economic theoretical thought. However later, it formed the core of the *American cluster research tradition* which relies largely on Schumpeterian innovation theory [10] and focuses on regional analysis in studying national competitiveness and innovativeness.

Almost until the mid-1990s, these two traditions of cluster research evolved independently — the European one was based on the Marshallian idea of industrial districts, and the American one — on Porter's cluster concept. Thereafter, they gradually integrated into a common research stream, often referred to as *cluster literature*. Interestingly, this integration had been spurred by two

interdisciplinary works in the field of comparative territorial analysis, which were increasingly cited in the 1990s by both European and American scholars [9]. They were Saxenian's book of 1994 on institutional advantages of the California Silicon Valley as compared to the Boston innovation ecosystem *Route 128* [11], and Scott's book of 1988 on comparing new industrial districts in North America and Western Europe [12].

By the 2000s, the term 'cluster' had been widely used in the economic literature on industrial organisation, regional development and innovation, while the cluster concept had taken a pronounced cross-disciplinary nature [6]. Yet, until now, there is still no generally accepted definition of a cluster that would distinguish this concept from other spatial forms of industrial organisation. Contemporary cluster literature reflects a variety of theoretical approaches gleaned from different areas of economic thought (economic theory, management, economic geography, regional studies etc.) and different disciplines (economics, sociology etc.). As a result, the term 'clusters' is often mistakenly applied to typologically different entities ('new industrial districts', 'innovative milieu', regional innovation systems, 'knowledge regions' etc.), and the cluster concept remains rather vague and eclectic [13]. An overly broad interpretation of clusters or a simplified interpretation of a cluster concept often leads to failures in economic policy and cluster programmes in both developing and developed economies [14; 15].

At this background, a significant part of *Russian cluster literature* focuses rather on the issues of reliable cluster mapping, as well as on the elaboration of more effective cluster policies and their coordination with other national economic strategies [16—18]. However, this does not mean that Russian scholars do not address the development of the cluster concept itself. As an example, consider Shastitko [19] or Gareev [20] who analysed a number of key institutional properties of clusters. Markov [21] showed that clusters should be viewed as self-organising regional production systems. Smorodinskaya [1] proposed three analytical dimensions to study clusters as complex systems. At the same time, important theoretical subtleties of the cluster concept, which directly affect the transition of economies to innovation-driven growth, have not yet been pronouncedly generalised. This article seeks to fill this gap by and large.

The modern theoretical thinking of clusters and their role in the evolution of economies has been shaped and is further polished under the influence of several large literature streams. Among them, we have chosen a number of complementary streams that seem most close to the objective of this article in terms of their contribution to the cluster concept.

Contribution of the evolutionary theory and literature on spatial development (geographers and economists — Asheim, Boschma, Feldman, Fornahl, Menzel)

As an independent research subject clusters have firstly become a priority among evolutionary scholars in economics and economic geography [22]. The

evolutionary literature opposes itself to the traditional neoclassical theory and is closely connected with the ideas of institutional economists. Cluster studies implemented by evolutionary scholars mostly follow the European cluster tradition going back to the Marshall-Becattini concept of industrial districts [7]. Such studies largely rely on spatial and regional development theories, stressing the advantages of localisation, i.e. concentration of a large group of small and medium firms in a particular territory, especially when these firms are united in a horizontal network.[1] Another source for such studies is the network theory, originating from Granovetter [23]. The contribution of evolutionary literature to the modern cluster concept can be summarised in the following findings.

Firstly, this literature emphasises the advantages of geographically concentrated business agglomerations as compared to geographically dispersed business networks (e.g. value chains). It also highlights the contribution of the regional institutional environment into the success or failure of local clusters. On the whole, the *quantitative results and dynamics of clusters' economic activity depend on three qualitative parameters related to the efficiency of interactions among cluster firms* [24; 25]. The first parameter is heterogeneity (degree of diversity) of cluster actors, which affects the diversity of knowledge generated in the cluster and its adaptability to changes in the external environment. The second one is the development of network linkages (between cluster firms and with their external partners), which makes it possible for the cluster to improve its growth pattern and successfully upgrade its specialisation. The third one is the quality of local institutional environment, which facilitates or, on the contrary, hampers the emergence and further development of new networks and clusters in the given region. Indeed, the experience of Silicon Valley shows that it was the development of institutional relations and network linkages that had become a decisive factor of its unique success in innovation [11].

Secondly, this literature analyses *the patterns and factors of a cluster evolution during its life cycle* — how and why groups of companies become clusters by developing network linkages, then grow further, and thereafter, decline or, conversely, transform into new clusters by changing the profile of their economic activity [26]. The key driver of this evolution is seen as the advancement of interactions at the microlevel, among the cluster firms themselves (rather than shifts in the production structure of the cluster). And the most important conclusion is that each cluster at each stage of its life cycle needs a specifically tailored package of government regulatory measures aimed at improving the above-mentioned

[1] According to Marshall's concept based on the experience of a number of English regions of the late 19th century, localisation of a significant number of small and medium-sized firms increases their efficiency to the level of a large-size firm due to the agglomeration effects of cost reduction. According to Becattini's concept based on the experience of the Emilia-Romagna region and other industrial districts of Northern Italy in the 1970—1980s, the unification of such group of firms into a network lends them further competitive advantages beyond agglomeration effects.

qualitative parameters — increasing heterogeneity of cluster actors, developing their network linkages, and improving the regional institutional context [25]. Although the emergence of new clusters is market-driven, their transformation into mature competitive entities requires a well-designed policy pursued by regional authorities, which ultimately promotes the advancement of collaborative activities in clusters.

Thirdly, the evolutionary literature *leverages the concept of path dependency,* a key idea of institutionalists, implying that new trends, technologies or industrial activities are generated through a creative recombination of previously existing ones. In particular, it highlights the necessity of supporting *a dynamic balance between specialisation and diversification in clusters* so that a group of cluster firms could, on the one hand, continually deepen its industrial specialisation, and on the other hand, maintain the diversity of competencies and economic activities by attracting new firms from related industries [27]. When this diversity is narrowed, a cluster may become dependent on the previous development trajectory thus getting in an institutional or technological lock-in. Such lock-ins imply interruptions in a cluster's technological upgrading, which eventually leads to its stagnation and the following decay.

The evolutionary geography should not be confused with the ***new economic geography*** **(NEG)** launched by Paul Krugman, which has also made an important contribution to the cluster concept [28; 29]. Applying mathematical modelling, this discipline elucidated the very process of clusterization of economies: it explained the underlying factors in geographical localisation of industries and in formation of clusters primarily in large cities. At the same time, in contrast to the evolutionary economic geography, the NEG adheres to a narrow interpretation of clusters. It views them not as a new model of organising economic activity in the era of innovation, but solely as a type of industrial agglomerations generated by the spatial concentration of tangible resources and the possibility of cost reduction [30]. In other words, the NEG focuses only on the advantages of clusters that arise from Marshallian externalities of geographic proximity without taking into account the role of network linkages and other qualitative parameters emphasised by the evolutionary theory.

Contribution of literature on technological change and system innovation (the line of Lundvall, Cooke, Freeman, Braczyk, Malerba, back to Schumpeter's ideas)

Unlike neoclassical theory resting on models of exogenous economic growth, this literature proceeds from the idea of endogenous growth, interpreting technological change and innovation (the process of technological upgrading) as an internal factor of industrial development, according to Schumpeter. It considers innovation not as a linear process (basic research — applied research — production) but as the result of non-linear and interactive relationships among economic

agents, leading to the generation and spillovers of knowledge flows. The contribution of this literature to the cluster concept is associated with the development of the following ideas.

Firstly, the *drivers of economic growth arise from the effects of knowledge spillovers, or externalities* that can be achieved not only in traditional agglomerations uniting firms from a single industry (Marshall's externalities observed within industries) but also in clusters uniting firms from related industries (Jacobian externalities observed between industries and leading to industrial diversification) [31]. Moreover, of special importance are the effects of tacit knowledge spillovers among networked firms and, particularly, among cluster firms (Marshall described such effects as a 'special atmosphere').

Secondly, *the innovation process has a systemic nature* — it requires a system of networked agents, enabling a collective action in the field of creation and diffusion of innovations. In the 1980s, this concept of system innovation resulted in the idea of national innovation systems built by governments in a top-down way. By the mid-1990s, this approach had transformed into a similar idea of building regional innovation systems since it was recognized that the innovation potential of national economies could be primarily developed at the regional level [32; 33]. In addition, parallel findings of regional studies made it obvious that competitive advantages of regions depend not just on their labour or natural resources but also on resources of tacit knowledge embedded in the local industrial and institutional contexts [34]. Therefore, literature on system innovations started to develop alternative concepts of *innovation territories emerging in a bottom-up way* (learning regions, innovation milieu, etc) [35; 36]. Among them, there was also the concept of clusters that came from Porter [37], which initially interpreted clusters as an exclusively market-driven phenomenon, not requiring (according to the US experience) any organisational efforts. All these concepts have been used interchangeably.

Thirdly, a systemic approach to innovation suggests not only the geographical proximity of networked actors but also their cognitive proximity and closeness of their activities in both industrial sectors (a network of firms from related industries) and institutional sectors (a network of industrial firms, research centres, universities, and government agencies). This gave rise to the concept of *sectoral innovation* systems proposed by Malerba [38]. Since the emerging networks are multifarious in type and scale [39], the sectoral innovation systems can appear at any level, from transnational to local, including business agglomerations in the form of clusters [33]. These findings led to a more precise concept of *innovation clusters* implying a group of firms and organisations localised in a certain geographical and institutional context and engaged in collective creation of innovations in a given field of activity. As a result, various countries, including USA and Russia, started to introduce a more generalised term *regional innovation clusters* in their official cluster programmes [17; 40].

Finally, it was in this literature that the concept of innovation ecosystems began to take shape. This concept embraces innovation clusters and all other

types of innovation-oriented network communities that constitute an organisational alternative to traditional hierarchic systems. In contrast to hierarchies, these communities emerge in a bottom-up way and have a heterarchical design, implying that networked agents rely on a decentralized pattern of coordination and form an ecosystem of linkages for collective action [41; 42]. The concept of innovation ecosystems emphasises the non-linear nature of innovation process, its reliance on interactive relationships (feedback connections) among networked agents, and the importance of a continual enhancement of such interactions [43]. It also highlights a relatively higher stability of inter-firm linkages within localised ecosystems that have a specific life-cycle, such as regional clusters, than within dispersed business networks, such as value chains, formed just for the period of creating a certain product [44].

Since the 2010s, academic research on innovation ecosystems has been accompanied by relevant studies on the part of different expert communities of both national (USA and European countries) [40; 45] and international level (the World Bank) [46]. These studies acknowledged innovation ecosystems of various configurations and complexity as new building blocks of the post-industrial economy, while viewing clusters as a key variety among them.

The theoretical thought on technological change and system innovation is often adjacent to ***sociological and economic literature on business networks***, both inter-firm and inter-organisational ones [47]. This literature views business networks, including clusters, as a hybrid model between a classical firm and the market [48]. It contributes to the cluster concept by exploring the diversity of networks in terms of their organisational and governance design, with the purpose to identify the most effective patterns. Meanwhile, unlike the stream of cluster literature, literature on networks does not focus on aggregate cluster externalities but rather on individual motives and benefits of cluster firms [49].

Contribution of Porter's competitiveness theory and cluster literature (the line of Porter, Delgado, Ketels, Lindqvist, Sölvell et al.)

The most significant contribution to developing the cluster concept, and particularly to explaining the advantages of clusters over isolated firms and industries in a global economy, was made, admittedly, by the cluster literature that originates from Porter's competitiveness theory [5; 37; 50].

Elaborating this theory, Porter found that competitive advantages of firms largely depend on the local economic environment where they operate, and the quality of that environment could be assessed through a set of indicators constituting the Diamond model [5]. One of the Diamond's facets denotes the presence in a given location of specialised business agglomerations which Porter called clusters. Although Porter introduced the idea of clusters just for analytical purposes, it began to gain popularity among both business managers and government bodies worldwide as a practical economic policy tool — independently of

the Diamond model itself.[2] A decade later, reckoning with the already achieved international experience in cluster building, Porter significantly expanded his interpretation of clusters, and this renewed approach formed the framework for the American cluster research tradition.

Firstly, Porter reaffirmed his *descriptive definition of clusters as business agglomerations,* viewing them as 'geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate' [51, p. 197—198].

Secondly, Porter formulated an *analytical definition of clusters as complex dynamic systems* typical for the era of innovation. Allowing for Saxenian's findings on the success story of Silicon Valley [11], he proposed to describe clusters from three interconnected perspectives — as a localised agglomeration having a certain territorial scope; as a non-hierarchical network of agents from various institutional sectors; and as a special economic milieu (an ecosystem), where agents benefit from sharing their resources (from 'commonalities and complementarities') [51].

Thirdly, Porter warned against limiting the cluster idea to the benefits of a new type of business agglomerations. Rather he stressed the decisive role of clusters and their ecosystems in fostering inter-firm competition, enhancing productivity growth, and raising the dynamics of firm and product turnover in the economy [51].

This complex thinking of clusters was followed by Porter's upgrading of the initial 1990 version of the Diamond model itself.

Porter's competitiveness theory argues that a territory can enjoy sustainable economic growth if it maintains sustainable competitive advantages through enhancing total factor productivity (TFP). In the era of ICT and innovation, the enhancement of TFP is based on a perpetual innovation activity of businesses [37], which demands a relevant, innovation-inducing quality of microeconomic environment, where firms operate. The modern version of the Diamond model, upgraded by Porter in the late 2000s [52], assesses this quality by means of the following four groups of indicators (four 'diamond facets') [46]:

1) input conditions for innovation;

2) demand conditions for innovation;

3) the level of inter-firm competition (rivalry) encouraging companies to innovate;

4) the level of inter-firm cooperation enabling the firm clustering — integration of companies from technologically related and supporting industries into business agglomerations.

[2] This situation is known in literature as 'the Porter paradox'. The idea of clusters sparked the interest of policy-makers and managers as an advanced, network-based form of organising industrial activity, which can lend businesses extra competitive gains and generate additional growth in respective territories. In addition, for the first time, macroeconomic competitiveness of countries and regions was pronouncedly put into dependence on microeconomic conditions where businesses operate [1].

Although favourable conditions for the firm clustering is only one of the Diamond facets, the formation of innovation clusters in the given territory depends on the growing quality of local economic context throughout all the four assessment parameters. A simultaneous dynamic interaction of all the four quality factors contributes to inter-firm networking and collaboration in the economy, and promotes the transformation of newly emerging agglomerations into effective innovation ecosystems tailored for interactive co-creation of innovations by networked agents [52]. To become a knowledge-based economy, a territory must continually improve its economic context in line with the Diamond model estimations, i.e. it should apply policy efforts that dynamize the formation of new ecosystems and *accelerate the cluster-oriented restructuring of its industrial landscape*. In its turn, the cluster-based organisational design helps markets to reallocate resources and technologies to the most productive sectors, and within them, to the most innovative companies, thereby supporting the TFP growth, and hence, sustainable economic growth in the territory [53].

Modern cluster literature exploits both the descriptive Porter's definition of clusters as business agglomerations and their analytical Porter's interpretation as complex dynamic systems.

Economists recognised the *descriptive definition* as classical, and it is variably reproduced in various cluster research since it is suitable for cluster mapping (identification of the emerging cluster agglomerations) [54; 55] and for comparing clusters by quantitative parameters (e.g., by a number of employees). Today, clusters are regularly mapped in the United States (within the frames of the Harvard's initiative '*The US Cluster Mapping Project*'), Canada (*Canadian Cluster Map*), in the EU (*European Observatory for Clusters and Industrial Change*) and some other countries. However, the classical interpretation of clusters does not allow revealing their qualitative parameters that enable their transformation into network-based innovation ecosystems.

Therefore, the *analytical definition* helps to view clusters as complex holistic entities, where a dynamic interplay between geographical and functional proximity of networked agents, as well as between their competition and cooperation, generates externalities that strengthen competitive advantages of both the cluster firms and the territory of their location [50]. Within this complex approach, the cluster concept is being constantly upgraded and enriched. The cluster research tradition close to Porter's thinking seeks to accumulate the up-to-date empirical and theoretical findings of other literature streams, while giving top priority to exploring the cluster collaboration effects associated with aggregate gains in competitiveness and innovativeness [56].

Of special note is differentiation of *true clusters* from other business networks and innovative milieu. In Europe and worldwide, cluster studies that follow Porter's findings identify as true clusters only those innovation ecosystems, where the existing pattern of collaboration among agents ensures them a continual productivity growth (so called '*competitiveness upgrading*') and enables them to function as growth poles for the given local economy [57].

Cluster concept from the perspective of complexity economics

In studying clusters as complex dynamic systems, cluster literature echoes not only the evolutionary and institutional approach to innovation but also the approach of *complexity economics*, a modern alternative to traditional economics. This is a relatively new stream of thought, a specialised branch of the interdisciplinary theory of complexity, which explores the significantly modified standards of organisation and behaviour of economic systems in the age of digital technologies and non-linear innovation [22; 58].

According to the complexity theory, complex dynamic systems, more often pronounced as complex adaptive systems (CAS), evolve as heterarchical and heterogeneous communities of legally independent (autonomous) but functionally inter-dependent agents who have self-united into a common network and are developing in the course of their interactions an ecosystem of relatively sustainable linkages, shared rules, and shared assets [59]. Complex systems differ from traditional linear systems by a typical set of specific generic properties. Their most essential features include an emergent (non-deterministic) behaviour, reliance on feedback loops, self-organisation and self-development (without any external or central governance), adaptability to unpredictable changes in the environment, ability to generate self-similarities on any scale (fractal nature), holistic nature and synergy [60].

As a key variety of innovation ecosystems generated by collaborative networks, clusters admittedly display similar properties as envisaged in CAS, which suggests their learning from the perspective of complexity economics [4; 61]. From this perspective true clusters appear to rely on *endogenous growth sources* — they evolve and advance through continual renewals, or internal structural transformations enabled by network interactions. Due to synergy effects occurring in complex systems, the results of a cluster economic performance will always be greater than the sum of individual achievements of its participants. Besides, in true clusters, agents always adapt to each other and to the cluster environment through feedback loops, which means they act interactively, accounting for the behaviour of other agents. These self-adjustments (adaptability) inform agility to cluster firms in terms of managing with unpredictable external changes, be they rapid technological or market changes of the day. Within clusters, agents can do better in decision-making and functioning under any emergence and uncertainty, which, as a result, improves functional parameters and aggregate performance of the ecosystem as a whole [4; 61].

Indicatively, in all streams of literature discussed above, findings on clusters in one or another way get close to the assumptions of complexity economics. Following these assumptions, we further describe the nature of clusters by three interconnected analytical dimensions, as a special type of industrial agglomerations, a special type of innovation ecosystems, and a special type of economic projects called cluster initiatives.

2. Clusters as a Special Type of Industrial Agglomerations

As industrial agglomerations, regional clusters could be seen as non-hierarchical business communities fitting into the emanating model of globally distributed production and the relevant system of global distribution of labour.

The growing distribution and dispersion of the production process, which especially intensified after the global economic recession of 2007—2009, has two inter-related formats — geographical and functional [2].

Geographically, business operations for producing new final goods are no longer confined to a single country, but are dispersed across the world and distributed among many firms from many countries. This leads to the formation of global value chains (GVCs), treated in literature as basic tools of globalization [3]. Within a GVC, export products of certain countries are purchased by other countries as intermediaries meant for further processing and subsequent re-export to third countries. This process generates an increasing flow of value added — from the stage of research and elaboration of a new product idea to the stage of sales and after-sales services [62].[3]

Functionally, the production process is no longer divided into three large stages (resource extraction — processing — services). Rather it is fragmented within those stages into increasingly granular and technologically complex business tasks, each of which corresponds to a certain node in the GVC [64]. In this context, diversification of economic systems is increasingly associated with their growing structural complexity, i.e. with the growing share of more complex, higher specialized and higher value-added activities in the composition of GDP [65]. Moreover, since trade through GVCs (so called 'trade in value added') is export-oriented, the prospect of maintaining competitive advantages under the global competition challenges countries to increase the complexity of their export basket, rather than just the overall complexity of domestic industrial structure.[4]

Proliferation of GVCs, while covering manufacturing since the 1990s and services since the 2000s [67], has led to an increasingly complex and granular division of labour at both the national and international levels. Nowadays, firms and countries are abandoning the strategy of producing final goods by themselves (within completed national value chains) in favour of producing and exporting innovative, narrowly specialised intermediate products, which they can create more efficiently than their competitors worldwide. Accordingly, economic systems are also moving towards a more subtle, cluster-based orga-

[3] As compared to similar terms (supply chain, production chain, commodity chain), the concept of GVCs, introduced by Gereffi et al. in the late 1990s (see the literature review in [63]), emphasises the uneven generation of additional amounts of value at different stages of the production cycle.

[4] This approach provides the basis for the Harvard's Economic Complexity Index [65] and other economic complexity indicators, elaborated to assess competitive potential and growth prospects of economies [66].

nizational design. New clusters with sophisticated specialization emerge at the junction of several technologically related sectors. Describing this phenomenon, cluster literature distinguishes 51 cluster categories, i.e. typical patterns of co-location of firms from related industries [68].[5] Mapping these patterns allows decision-makers to identify emerging cluster agglomerations.

Although each cluster evolves in its own dynamics, there is still a common logic of such evolution, which ensures adaptability of a cluster to ever changing environment through the process of *configuration — deconfiguration — reconfiguration*. This process is predetermined by four stages of the cluster life cycle (Fig. 1) that does not coincide with the life cycle of industries presented in the cluster [25; 56].

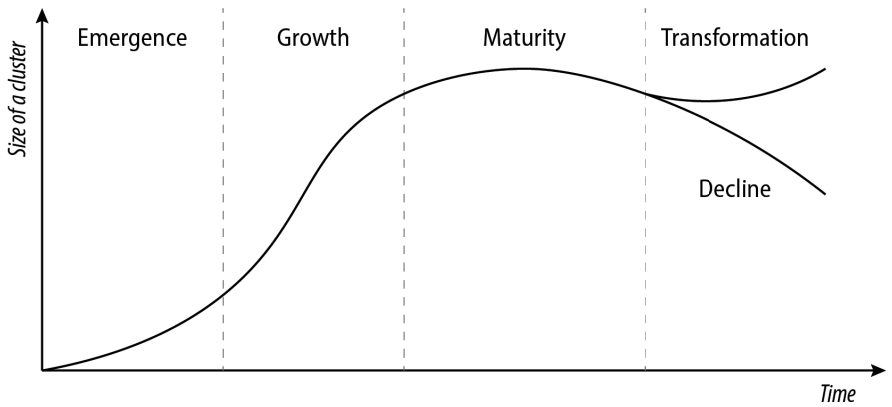

Fig. 1. Cluster life cycle: from emergence to transformation

Source: elaborated by the authors on the basis of [25; 56].

At the stage of cluster *emergence*, cluster-specific features are almost completely absent. The cluster has neither a pronounced specialisation, nor an obvious local structure of institutions for inter-firm collaboration. However, by this moment, the region has usually accumulated certain experience in organising production, generating knowledge, training staff, and other areas of economic activity, which can be used for further cluster development.

At the *growth* stage, the generation of new firms and spinoffs of incumbent firms intensifies, nascent inter-firm linkages and institutions for collaboration emerge and take various forms — from conventional inter-firm alliances to specialized cluster organisations. Cluster starts to accumulate unique knowledge assets (mostly tacit) and competencies.

[5] The concept of cluster category was introduced by Porter in 2003 in reckon with the US economic survey results [54]. Nowadays it is applied by cluster observatories worldwide as an alternative to conventional input-output analysis of industrial structure [69]. Statistically, the same industry, as introduced in traditional classification systems (e.g., in Russian OKVED), may be included simultaneously in different cluster categories, since it is taken as fragmented into more specialized and sophisticated types of activity.

At the *maturity* stage, the quantity and variety of cluster participants reaches a certain critical mass, so that the generation of new firms and spinoffs slows down. Firms begin to develop inter-firm linkages outside the cluster, which often leads to the emergence of new multinational enterprises (MNEs). In the course of a cluster engagement in global production (through GVCs), tacit knowledge is subject to codification and standardisation. Although incumbent firms retain the ability to upgrade their competitive advantages, they rarely generate radical innovation, only a small part of clusters are able to generate them at this stage. Generally, a mature cluster has a pronounced and often unique specialisation not only at the national but also at the global level, which attracts both domestic and foreign investors.

At the *final stage* of the life cycle, the cluster may evolve according to two alternatives. In a *negative scenario*, it gets technologically locked-in due to inability to generate further knowledge for the purpose of upgrading its specialisation and meeting the new global market demands. It starts facing stagnation and may eventually vanish. In a *positive scenario*, the cluster gains new momentum by attracting new knowledge from outside. As a result, it either upgrades its specialisation, or transforms into several new clusters that focus on new products or even on a completely different type of economic activity.

In contrast to agglomerations of the industrial age, clusters operate under open global competition and ever-changing demands of customised markets. This compels them to constantly improve their production capacities and develop a smart specialisation, i.e. produce unique goods in terms of quality, cost or special features. Cluster firms are therefore more specialised, more productive and more innovative than firms locating outside the clusters [70]. Moreover, *clusters themselves become export-oriented structures that act as local nodes of global value chains* (Fig. 2).

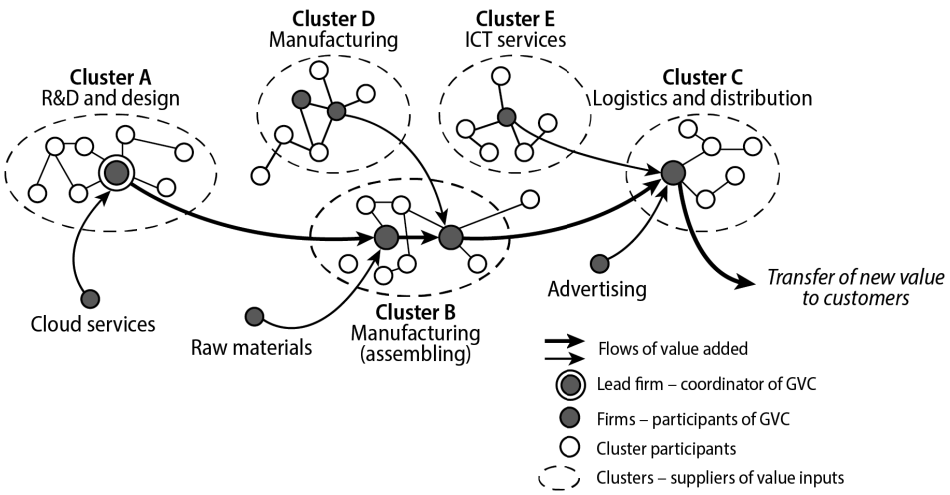

Fig. 2. Organisation of a global value chain (a typical schema)

Source: [2].

GVCs are built by global firms as a joint international project that has its own time frame and operational sequence, both determined by the process of co-production of a new final product. They represent distributed and geographically dispersed networks of legally independent but functionally related firms. Each firm acts as a supplier that performs its individual business task (a unique of its sort within the common project) corresponding to a particular node in the GVC, with this task usually executed within a regional cluster of one country or another. Interactive cooperation among numerous networked project partners turns GVCs in sophisticated business ecosystems [43].

Nowadays, global firm organising a GVC neither participates in every node, nor seeks to control the key nodes. Rather it acts as an effective project coordinator, or just a *project leader* through its branch-offices in one of the regional clusters, and additionally, as an ordinary supplier of certain intermediaries.[6] In the course of co-production, lead firm locates and regroups value chain nodes in such configurations that allow to reduce costs and create new products with the highest value added. Lead firm usually selects specialised contractors on terms of *smart-sourcing*: it picks up a supplier for each narrow business task from that very local cluster, where this task can be performed most effectively as compared to all other clusters across the world [72]. As a result, most innovative clusters with a smart specialisation become highly specialised local nodes in GVCs. This turns clusters into agile and *glocal* entities that take advantage of the dynamic combination of local and global resource flows.[7]

As nodes of global chains, clusters localize parts of the globalized production process inside various geographical areas and, thus, lend the world economy a *glocal structure*. On the one hand, value-added flows generated by GVCs permeate through over the world economy, which enables its growing diversification. On the other hand, these flows shape specialised cluster nodes in various localities across the world economy, which deepens its specialisation [1]. In turn, the regions, where promising clusters have emerged, acquire unique comparative advantages to attract global investors who lead GVCs and may locate next business-tasks within the given clusters. In this case, local cluster firms can successfully join GVC, while the region can gain access to global technologies and global markets [72].

To sum up, the specificity of regional clusters as industrial agglomerations stems from the increased complexity of economies and production process. First of all, it concerns 'trans-industrial' specialization of clusters, emerging at the junction of several technology-related sectors. Secondly, clusters are highly specialised local nodes of globally distributed production, and in this role, they help the world economy to keep a dynamic balance in enhancing both diversification

[6] Interactive coordination of activities within GVCs, usually through digital platforms and modular solutions, increases the total gain in value added and, as a result, individual gains of each participant, including the lead firm itself [71].

[7] The circulating in clusters flows of financial and physical capital run global mobility, the social capital flows (a source for tacit knowledge spillovers) run local mobility largely determined by local institutional environment, and flows of human capital have mixed mobility [73].

and specialisation. Thirdly, clusters are export-oriented business communities and key components of GVC's ecosystems, which makes them crucial regional channels for a better integration of national economies into global markets.

3. Clusters as Special Innovation Ecosystems

To identify the specifics of clusters as innovation ecosystems, we first define their place in the larger family of business networks that develop ecosystems.

Business networks can emerge both on the basis of dispersed value chains and on the basis of agglomerations of co-located firms. In both cases, the economic activity is not rooted in the individual agents themselves, but rather in the ecosystems they form in the course of interactions. Such ecosystems are just a space of relatively sustainable business linkages and shared assets, arising from even, multilateral and regularly recurring communications among networked agents. This implies that autonomous agents self-unite in a common network and develop its ecosystem in order to achieve economic goals that none of them can achieve individually [44].

Among various criteria to classify business networks, which can be found in modern evolutionary and innovation literature, a key one, in our view, is the pattern of interactions among participants [47]. As follows from the idea of adaptability of CAS (and also from Porter's findings on collaboration [5]), the more complex the configuration of linkages and the pattern of agents' interactions in the ecosystem, the higher its innovation dynamics and, hence, its economic robustness and resilience [74]. Applying this criterion, namely the dependence of innovation dynamics in an ecosystem on the complexity of interactions between its agents, we distinguish three types of entities within the modern family of business networks. These types are cooperation networks, collaborative networks, and collaborative networks with a triple helix design (Fig. 3).

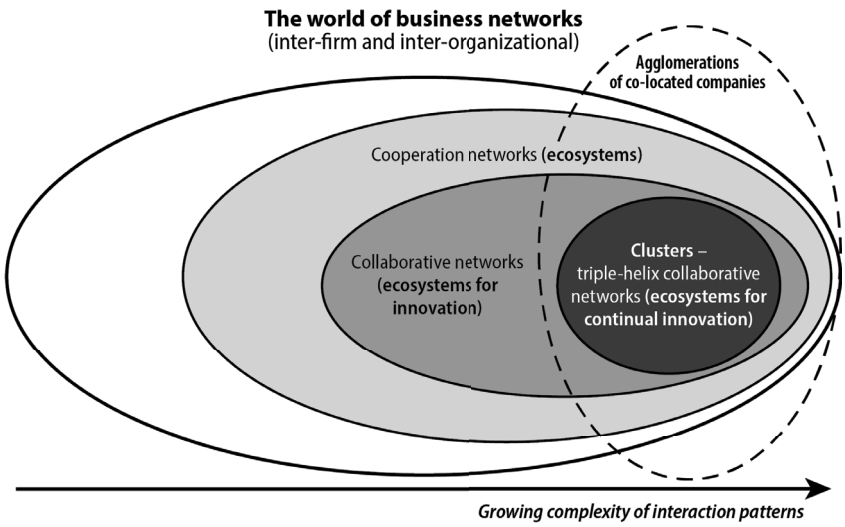

Fig. 3. The place of innovation clusters in the world of business networks

Source: [4].

Cooperation networks include a wide variety of business networks where agents form an ecosystem of relatively sustainable linkages and rely on soft coordination of economic activities, not necessarily applying to joint commitments or joint action plans. Such networks create a favourable supportive milieu for the existing or the future innovation clusters and alike innovation partnerships in the given area. However, they usually run a rather low level of organisational complexity for building a true innovation ecosystem suitable for a collective innovation activity. As a result, they play a limited role in producing and diffusing innovation, as well as only an auxiliary role in stimulating innovation-driven growth in the local economy.

The family of cooperation networks contains a subset of *collaborative networks* with a more developed and complex pattern of interactions. Typically, such networks are described in literature as collaborative innovation networks, which emphasizes their involvement in modern, network-based innovation model.[8] The concept of *collaboration* implies the highest form of cooperation, in which agents are involved not only in knowledge exchange but also in a continuous interactive coordination of activities through feedbacks. In the course of collaboration, agents use to develop a common identity (formation of an integrated and institutionalised business community), shared rules of conduct (joint commitments), and procedures for co-production, i.e. they interactively plan, implement and update a programme of collective action (rather than just coordinate individual actions) [79]. Collaboration leads to the formation of true innovation ecosystems designed for a direct co-creation of innovative products.

Recent literature on innovation ecosystems [4; 80; 81] affirms their identity with CAS. It pronouncedly connects their emergence with collaboration of a meaningful quantity of autonomous (not controlled by any superior authority) agents that have complementary competencies and resources. A continuous sharing and re-combination of these assets through collaboration bring to the market new goods and values that cannot be produced by each individual agent independently.

As noted above, agglomeration-based ecosystems differ positively from geographically dispersed value-chain-based ecosystems in terms of generating innovation synergies and boosting innovation dynamics. The family of collaborative networks formed on the basis of agglomerations contains, in its turn, a subset with an even more complex pattern of interactions, where collaboration is built in accordance with the Triple helix model. *Triple-helix collaborative*

[8] A decisive role of collaborative networks in bringing innovative products to the market was empirically confirmed in the second half of the 2000s [75; 76]. Later, economists incorporated this type of networks into the open innovation concept [77] and the concept of global innovation networks [78].

networks involve no less than three functionally different types of economic agents, usually representing the private sector (business), knowledge sector (universities and research institutions) and public sector (different levels of government, government agencies).[9] In the course of collaboration, these three groups of agents start co-evolution by drawing together and intertwining their complementary functions, which creates sustained interdependences and incentives for a continual innovation activity [83] typical for a knowledge-based economy. In such ecosystems, firms and organisations acquire the highest dynamics in innovation and growth, while the effects of knowledge transfer and collective action are maximized [42]. Therefore, eco*systems for a continual innovation* are becoming a new standard in organising economic activity, vitally important for countries and regions in the age of non-linearity and post-industrial transition.[10]

In world practice, triple-helix collaborative networks are most widespread in the form of *innovation clusters*. As cluster literature asserts [56; 57; 69; 72; 84], it is mature innovation clusters that generate the effects of continual productivity growth on the basis of continual innovation. In addition, they are the most convenient tools for diffusion of innovations across the economy. That is why cluster literature classifies as true innovation clusters only those networks that fully realise synergy effects of triple-helix pattern of collaboration. Of importance here is not only the geographical proximity of agents that leads to agglomeration effects of cost reduction, but above all their special functional interdependence and complementarity, leading to collaboration effects of growing innovation activity [56]. On the contrary, *business networks not able to achieve the aggregate effect of continual productivity growth are considered only nominal similarities of innovation clusters*. In other words, irrespectively of industrial specialisation of clusters, their innovative capabilities are rather determined by institutional and organisational factors, particularly, by specific synergy effects achieved in the ecosystem they form. The complexity of this ecosystem largely depends on a sophisticated combination of functional linkages embracing a wide range of autonomous but economically interdependent agents from different sectors (Fig. 4).

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[9] The triple helix pattern of collaboration first emerged in Silicon Valley and was later described by sociologists [82] as a special model of non-linear and interactive communication, resembling linkages in a DNA chain. Formalization of the model shows that collaboration of at least three functionally different agents brings along a complex synergy of forward and feedback linkages, which makes the economic system resilient to radical uncertainty and allows it to switch to a higher development level through self-restructuring [74].

[10] Since the 2000s and especially since the 2010s, the idea of facilitating triple-helix partnerships has been put high on economic agenda not only within OECD or the EU but also in developing and transition economies of Asia and Latin America [1].

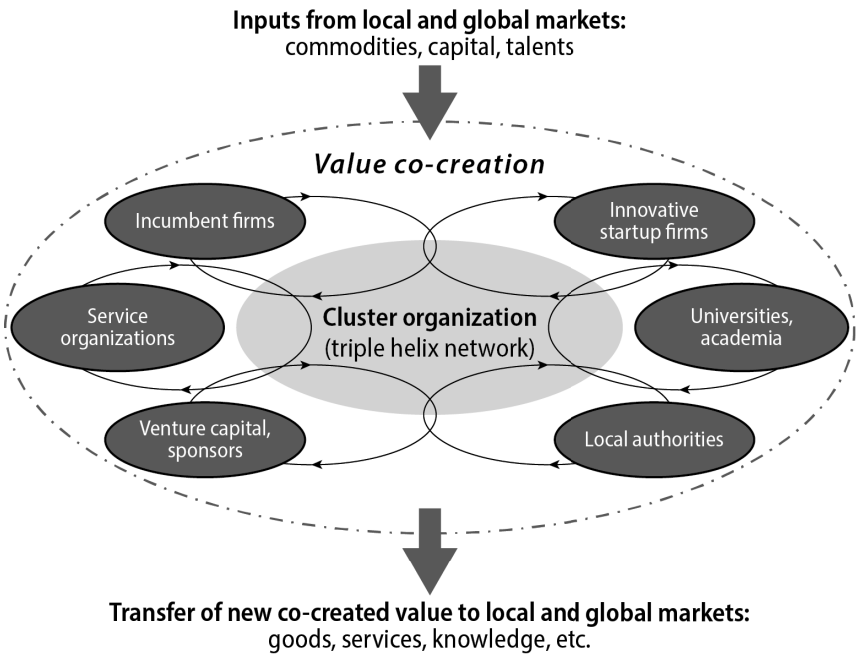

Fig. 4. Ecosystem of an innovation cluster

Source: elaborated by the authors, based on [85].

Although clusters greatly vary by composition, which depends on the stage of a cluster life cycle and the specifics of the local economic context, each mature cluster relies on a critical mass of agents in terms of their quantity and variety. An available evidence suggests that to achieve synergy effects, a cluster should involve no less than 50 and no more than 200 networked firms [86]. And from the point of variety, *three major categories of agents* make up the critical mass [87].

Firstly, these are *agents embracing all the three triple helix sectors:* firms, universities (research organisations) and government agencies, all located in close geographical proximity (within a radius of less than 200 km according to OECD) [88]. Government agencies can be engaged in a cluster as sponsors, venture investors, consultants or cluster development co-coordinators.

Secondly, it is a *cluster organisation*, a specialised internal network that acts as a cluster coordinator. It brings together representatives of the triple helix sectors and other key cluster agents on a membership basis. In contrast to free accession of new participants to an open-end cluster community, such membership is not automatic and implies regular fees. The cluster organisation provides the cluster with a proper institutional form and a platform for collaboration, while coordinating its activities in a way of collective self-governance. Its task is to create and support a 'special atmosphere' within the cluster, favourable for enhancing mutual trust, accumulating social capital and developing collaboration.

Thirdly, a successful cluster should involve a variety of private, public or international *investors and sponsors*.

Our findings from cluster literature and other research streams cited above suggest that mature innovation clusters with the triple helix design can achieve the following *synergy effects*:

– *significant cost reduction* resulting from co-location of agents;

– *minimization of various possible risks* and acquiring resilience to unpredictable changes in the globalised environment [11];

– *capacities for overcoming technological lock-ins related to path-dependence*. In the course of collaboration, each pair of agents representing triple-helix actors (government-business, business-academia, academia-government) may bring their growth trajectories too close together, resting on previously developed technologies. But every third triple-helix actor plays a counter-balancing role, thus pushing cluster firms towards further technological upgrading. This prevents the entire ecosystem from interruptions in innovation activity and ensures its further productivity growth;

– *innovation-driven growth*. The effect of continual innovation backing this model of growth is largely supported by the process of reshuffling. In the course of collaboration, complementary assets, technologies and competencies of cluster agents are not just shared but arranged and rearranged in an unlimited variety of creative combinations for the purpose of co-creating new products constantly. As a result, cluster firms get ready to upgrade their competitive advantages. Due to collective action, they can engage in any risky business projects, join new value chains, and meet rapidly changing market demands, including the market for new technologies itself;

– *endogenous sources for self-development*. Collaboration leads to an increase in knowledge and in 'common-pool resources', including the resources of social capital accumulated during communications [90]. Accordingly, the greater is the complexity of collaboration, the larger is the ecosystem's resource pool, including technological knowledge. A continual rearrangement of these resources and an agile reconfiguration of linkages lends cluster the necessary dynamic sustainability: new sources for growth are generated through continual structural transformations that further increase the ecosystem's economic complexity;

– *growth pole effect*. The growing complexity of network linkages within clusters facilitates the emergence of start-ups, spinoffs and new inter-firm alliances, which in turn promotes the spillover of knowledge, new technologies and innovative business practices into the local economy, thereby dramatically enhancing its competitive and production capabilities.

Along with the triple helix effects, adaptability and self-supporting growth in innovation clusters can be explained in terms of *dynamic and constantly changing structural balances* emerging in complex systems. Among key dynamic balances observed in clusters, cluster literature usually highlights the balance *between specialisation and diversity* (see section 1) and the balance

[11] Resilience denotes the capacity of economic system to maintain core performance despite unpredictable shocks by adapting its structural and organisational features to a changed environment [89].

between cooperation and competition. While cooperating with each other and with external agents within the frames of a range of business projects, cluster firms simultaneously compete within the frames of other projects. This combination enables clusters to attract the most competitive agents while pushing the less effective ones out of the ecosystem. As a result, cluster firms are engaged in hybrid relationships, known as co-opetition, which is typical for knowledge-based economies [51].

Overall, the world of business networks that develop various ecosystems is much broader than the family of collaborative networks that generate innovation ecosystems. This family, in turn, is much broader than a more complex variety constituted by innovation clusters. As a special type of innovation ecosystems, clusters are open-end communities of autonomous, geographically proximate and functionally diverse partners. They can achieve dynamic sustainability in a non-linear emergent environment, elaborate unique collaborative mechanisms of innovation-driven growth, and realize common development projects through collective action. Similar advantages of complex systems can be obtained at the aggregate level of national economies upon their transition to a heterarchical, cluster-based organisational design [4].

4. Clusters as Special Economic Projects (Cluster Initiatives)

The emergence of new cluster agglomerations in the form of co-located firms of a certain profile is a purely market-driven process. However, transformation of such agglomerations into ecosystems and innovation-inducing growth poles, requires deliberate initiatives on the part of both government and non-government actors. Today, the growing number of countries and regions put cluster initiatives at the heart of their innovation and economic growth programs [45]. Cluster literature defines cluster initiatives as *projects that are jointly elaborated by business, authorities and / or research organisations, and aimed at collective action on nurturing and developing clusters* as future powerful innovation ecosystems [73].

Since the early 2000s, cluster initiatives have evolved from projects promoted by individuals (clusterpreneurs) into complex projects implemented by specialised cluster organisations. A cluster initiative can be proposed by representatives of one, two or all the three triple-helix actors at once. It can be solely private, coming from companies and/or research institutions. Or it can be public, launched under a call for proposals and/or under implementation of a certain government program. However, the very coordination and implementation of such initiatives is a joint work of all three groups of actors, constituting the most important function of the cluster organisation.

Inherently, cluster initiatives are *complex economic projects* that differ much from traditional projects of the past [91].

Firstly, unlike classical market or production infrastructure projects (e. g. industrial parks), they serve as a tool for communication and coordination, or just

as means for developing network interactions. Secondly, they are always open-end projects for attracting new participants (clusters revealing signs of closedness are considered degrading). Thirdly, in terms of duration, cluster initiatives depend on the life cycle stage of a cluster. Particularly, a cluster organisation aims to develop the cluster to the maturity stage, and to help in renewing its specialisation at the stage of its transformation. Finally, cluster initiatives are realised on the *collaborative governance* principles, which implies a collective self-governance (without any centralized body) and a horizontal way of consensus-building backed by mutual economic benefits of the cluster agents.

Cluster initiatives put evolution of a cluster within the framework of a *joint development strategy* which is elaborated by the cluster organisation and approved by all cluster agents. Such a strategy usually pursues *three inter-related goals* [87]:

1) stimulating growth of a cluster by involving new agents into its ecosystem and network interactions;

2) promoting internationalization of a cluster, which implies a consecutive rising of the cluster significance in the given area of specialisation from local to global level;

3) enhancing and sustaining competitiveness of a cluster through continual improvements in the ecosystem economic environment, through facilitation of triple-helix collaboration, and through involvement of cluster firms into global value chains.

Implementation of a cluster's long-term development strategy, as well as day-to-day plans of collective action, are based on a unique combination of two inter-related frameworks of relationships among cluster agents. They are the production framework, implying joint implementation of concrete business projects, and the social framework meant for targeted advancement of the triple-helix-based collaboration. Importantly, the success of the former crucially depends on the success of the latter.

Within the *production framework*, cluster firms build both vertical and horizontal ties based on traditional market contracts for the purpose of co-creation of particular goods or services. Market incentives of cost saving promote vertical integration of firms by stages of production, and simultaneously, the development of horizontal intra- and inter-industry ties at each step of the value chain (outsourcing of certain activities, generation of spinoffs, allocation of non-core assets, etc.).

Within the *social framework*, cluster agents support each other as collaborating partners by developing horizontal network linkages. For this purpose, they rely on relational contracts — a system of long-term agreements on the general rules of conduct and interaction, backed by high mutual trust.[12]

[12] Under such agreements, formal business functions of cluster agents and their personal social roles are barely distinguishable and can condition one another. Everyday interpersonal communication penetrates here from the level of top managers inside companies, down to the level of middle managers, thereby forming horizontal professional networks [92]. This ensures equal positions in decision-making among all cluster agents, enabling them to have an equal say in elaborating common action for each concrete business project.

Ultimately, these agreements concern optimization of the cluster development strategy and a range of corresponding joint commitments for its implementation, which usually require interactive coordination of stakeholders' decisions. For the first time, this multifaceted dynamic model of relations had spontaneously emerged in Silicon Valley in the mid-1990s [11], and today it is purposefully supported in most successful innovation clusters worldwide.

The social format of cluster initiatives is associated with specific managerial functions of a cluster organisation. Firstly, its initial aim is to transform the local industrial agglomeration into a full-fledged community of networked firms ready for a joint innovation activity. This is achieved by building mutual trust and developing collaborative co-production skills. Recent empirical literature [93; 94] confirms the significant contribution of cluster initiatives in promoting networking and knowledge exchange among stakeholders of a nascent cluster. Secondly, when configuration of a cluster ecosystem has already taken shape through involvement of all the three triple-helix sectors, the cluster organisation turns to its next task of sustaining this very pattern of collaboration between these groups. Thirdly, of crucial importance is further continuous enhancing of triple-helix collaborative interactions among all cluster agents by means of eliminating inter-personal barriers and bridging communication gaps. This process of deepening collaboration towards higher complexity is described in cluster literature as 'bridge building', and is carried out by two units within the cluster organisation — the cluster governance team and the cluster management group.[13]

Since communication gaps impede the continuity of the innovation process, cluster literature equates them to *innovation gaps*. There are seven types of such gaps divided into two categories [90]:

– *gaps in internal cluster environment,* embracing five gaps: business — academia; business — education; business — financial institutions; business — government (including both administrative bodies and other government agencies, for example, development institutions); business — business (for example, gaps in relationships of small firms with majors, whether they are national companies or the branches of MNEs);

– *gaps in the cluster's interactions with external environment*, implying two gaps: cluster — cluster; business — global market (global value chains).

It needs emphasising that cluster organisations are *collaborative public-private partnerships*, where government bodies behave according to the rules established by a relational contract, and act as an equal partner to the other triple helix actors. It is also noteworthy that in the most successful national cluster programmes, the government focuses on financial support of specific functions of

[13] The cluster governance team consists of representatives of all three triple helix spheres who elaborate cluster development strategies to be subsequently agreed among all cluster agents. Operational management is carried out by a small group of professionals (four people on average), who are engaged in daily tasks of developing interpersonal ties and other activities needed for reaching strategic goals of the cluster development project [91].

cluster organisations, particularly on their functions as collaboration promoters and coordinators of cluster development strategies. In other words, governments are in the first place supporting the social format of cluster interactions rather than investing into concrete business projects of cluster agents [95].

However, in many countries, including Russia, governments heavily subsidise production activities of cluster firms themselves, which often results in distortion of competitive market context and favours certain interest groups to the detriment of other regional businesses. Such selective pattern of support often leads to paradoxical results, when initiatives aimed at enhancing competitiveness of the local clusters reduce the competitiveness of the given region as a whole. Take, for example, recent findings on the cluster supporting policy in Germany [96], where the majority of clusters had been created in a top-down way, on the initiative and at the expense of local or/and federal governments. It was found that while selectively subsidised German firms benefit from engagement in cluster initiatives, the rest of the region's business milieu is being harmed — while left without subsidies, firms and industries faced with acute shortages of human, financial and social capital.

* * *

Hopefully, our analysis of regional innovation clusters contributes to an observed evidence that agglomerations of a different type, also titled 'clusters', no longer meet the historical challenges of the time. The described specifics of clusters are meant to demonstrate the level of organisational complexity as well as functional advantages of those economic entities that are evolving as new principal building blocks of the modern industrial landscape. Regardless of different dynamics of this process across the world, the transition of economies towards cluster-based design (as well as overall proliferation of collaborative networks) is an objective global trend determined by the course of technological progress, the digital revolution and the strengthening of global competition. We argue that only those regional clusters that meet the criteria of complex adaptive systems, can help both developed and developing economies to achieve sustainable growth in a non-linear environment, as well as to successfully transform into knowledge-based systems.

Synergetic effects achieved in clusters following a triple helix pattern, and hence, effects that could be reached in economies with a completed cluster-based landscape, concern the reinforcement of all known agglomeration externalities and the increased adaptability of economic agents to radical uncertainty in the globalised markets. Innovation clusters can help economies a lot in overcoming their dependence on previous technological trajectories, in building efficient mechanisms of collaborative governance and, most crucially, in enhancing productivity growth through continual innovation.

Successful clusters capable of generating such effects and diffusing growth impulses to surrounding areas are complex and self-sustainable innovation eco-

systems that take advantage of both the factor of agents' diversity and their collective action. At the same time, they are sophisticated partnership projects where autonomous agents are constantly enhancing complexity of collaboration, relying on joint initiatives, high mutual trust and long-term relational contracts. Finally, clusters are industrial agglomerations with a smart specialisation, designed for attracting global investors to the region and for involving the local export-oriented SMEs in global value chains, and hence, in the global division of labour. The emergence and proliferation of innovation clusters across a national economy requires systemic improvement of its institutional and business environment in line with the post-industrial standards, rather than a selective promotion of certain types of agglomerations.

Noticeably, the very idea of engaging three triple helix sectors in a cluster ecosystem had been embedded in national cluster supporting programmes long ago. Many developed and developing nations, including Russia, started offering priority support to those alliances which distinctly include representatives of business, academia and government. However, a formal presence of these actors in clusters does not contribute to their success, the more so, to the transformation of a business agglomeration into a true innovation ecosystem. Rather, it is the pattern of network interactions that matter. Clusters with a triple helix configuration are able to generate synergy effects of continual innovation and, hence, of sustainable growth only upon reaching a special level of complexity in the triple-helix collaborative relationships. Therefore, official cluster programmes turn to be effective and can reach macroeconomic goals of enhancing productivity and growth only in those countries where cluster building is backed by a well-directed promotion of both inter-firm competition and collaboration, of constantly growing quality of institutional environment. In case of inappropriate institutional context, governments' attempts to borrow best international practices in cluster building, let alone the idea of building new 'Silicon Valleys' in a top-down way, will hardly lead to increased innovation activity in the economy. Rather such efforts will motivate businesses to artificially unite into certain cluster agglomerations that only nominally resemble true cluster networks.

Theoretical aspects of developing cluster supporting strategies, the stories of success or failure of such strategies in different countries, as well as the ways of exploiting clusters as effective growth policy tools — all these issues deserve their separate research attention and can be a subject of further discussion. In this paper we just tried to draw attention to the complexity and advantages of clusters as the emerging standard format for organising economic and innovation activity as a whole.

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