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Article

Banking Ecosystems: Identification Latent Innovation Opportunities Increasing Their Long-Term Competitiveness Based on a Model the Technological Increment

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Abstract: Ecosystem business models are becoming widespread in the modern economy; their potential is increasingly understood by financial institutions. Banks become part of the ecosystems and some of them initiate their creation, seeing in this business model an opportunity for their development. However, not all the possibilities of the ecosystem business model are sufficiently recognized by banks. Meanwhile, becoming “orchestrators” of ecosystems, banks get new opportunities, taking on new management functions that require the development of new promising competencies. This aspect predetermined the goal of this article—to explore the essence and development prospects of banking ecosystems and create a model for the establishment of additional innovative and technological advantages for banking ecosystems, allowing the bank to create conditions for long-term competitive advantages. Methods of comparative analysis, statistical methods, modeling methods, and cluster and regression analysis were applied. The results: a model of technological increment that formed during the functioning of the banking ecosystem has been developed; the authors established that the orchestration of the ecosystem by the bank creates opportunities for the formation of new profit centers because of the formation’s greater number of innovative technologies and the possibility to dispose the intellectual property.

Keywords: ecosystem business models; innovative technologies; banking ecosystems; orchestrating of ecosystems



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1. Introduction

The study of entrepreneurial ecosystems is becoming an independent field of study and is considered as a special business model typical of the era of digitalization. There are opinions that this economic form was formed in the Middle Ages and is the result of the evolution of fair trade and merchant and trading communities. It is obvious that its formation has logical relationships with vertically integrated forms of management and with cluster formations of a technological nature (as we described in the article [1]).

However, despite a few similarities with other models of economic activity, what are called entrepreneurial ecosystems are not just an evolved form of partnership and collaboration. In the conditions of digitalization, they gain independent meaning and form new competitive conditions in the external and internal environment. Being a promising form, it has a few advantages that determine its originality and authenticity. This is predetermined by their manufacturability (in the context of the presence of special technologies that form the system and make it authentic, market-relevant and competitive), the implementation of

digital platform relations, the prevalence of collaborative partnerships, and the availability of financial relations (forms, methods and technologies of implementation, which should increase by including in the system not only relations related to the payment of goods and services, but also with insurance, crediting of participants, other possible forms of development of financial relations and financial services within ecosystems, including specialized ones, which should arise with their progress).

The concept of an ecosystem has become quite firmly established in all areas of modern economic science and economic activity. The paradigmatic nature of the ecosystems characterizes their significance for research and high-probability occurrence of new business conditions because of the digitalization of business processes and the transformation of consumer behavior.

The authors, developing the research at the conceptual level, also remember that the economic meaning of the concept of “ecosystem” was provided by J.F. Moore [2,3], and they believe (for a few reasons, including those indicated in [1]) that it is not quite correct to use the concept of ecosystem without a specific economic context. In this regard, the authors understand by ecosystems a special (ecosystem) business model. This position does not contradict the concept of J.F. Moore and other researchers.

Ecosystems are unique in that they create conditions for the formation of a new competition form—coopetition. In a few works devoted to the study of ecosystems, their authors note that they contribute to the development of the ecosystems theory. Perhaps this is evidence of the isolation of this phenomenon and the emergence of an independent direction of research.

We are not sure that it is expedient to form a special theory of ecosystems, but we respect this position. The theoretical concept of ecosystems is developing rapidly, and new views on the concept of ecosystems have already been formed, different from those that have become classics. It should be noted that the COVID-19 pandemic, despite its tragic character, stimulated the development of ecosystems. The increased interest of the scientific community in the study of this phenomenon has led to an increase in the number of publications and the differentiation of researcher positions. Of particular interest is that ecosystems are able to constitute new forms of cooperation and new forms of competition.

As noted, the pioneer of research of ecosystems in business was J.F. Moore. Among those who began to study this phenomenon a long time ago, we should highlight the publications of T.F. Bresnahan and S. Greenstein [4], A. Gawer and M.A. Cusumano [5], J. West [6], N. Economides and E. Katsamakas [7], R.M. Henderson and A. Gawer [8], C. Wigren [9], M. Markus and M. Silver [10], S.A. Zahra and S. Nambisan [11] and others. Many of these authors continue to develop their conceptions. Because of the impossibility of citing within the framework of this manuscript the entire significant number of reputable researchers who have studied the researched issues, we will focus on those studies whose results are especially significant within the goal of this manuscript, using several accents—understanding ecosystems, studying the mechanism of their functioning, composition and prospects, innovative opportunities and significance implementation in banking and for the development of banks. We also consider the fact that the term “ecosystem” does not yet have a generally accepted definition, but this makes their study even more interesting.

According to R. Adner, an ecosystem can be characterized as the result of the interaction and coordinated behavior of numerous partners who form a value proposition through their efforts; for him an ecosystem is a “structure that defines belonging” [12], p. 40.

S.Y. Barykin et al. argue that Adner improved J.F. Moore’s understanding of ecosystems and differentiate two types of ecosystems—Moore’s ecosystems and Adner’s economic ecosystems, each of which is subject to special specific conditions [13].

According to E. Autio et al., who have studied industrial areas and agglomerations, clusters and innovative systems single out entrepreneurial ecosystems as a separate type of entrepreneurial activity, rightly making such accents as innovative business models and “by voluntary horizontal knowledge spillovers” carried out within ecosystems [14].

It should be noted that M.G. Jacobides et al. note such qualities of ecosystems as modularity, which allows “multilateral dependences based on various types of complementarities” [15].

P. Torres and P. Godinho [16], based on the conclusions of E. Autio and L. Thomas [17] and E. Autio et al. [14], are thinking the main promising advantages of “entrepreneurial ecosystems” are “modularity”, “organization of communications”, organization of connections between participants and in relation to the availability of search capabilities and on scaling up [16].

J.T. Li et al. consider the unique advantages of ecosystems; analyzing the complexities and “bottlenecks” formed during the transformation of business models in their article, they join researchers who combine the management of multinational networks and management of platform technologies, working within the framework of the development of the theory of the ecosystem, and propose the concept of ecosystem advantages—“ecosystem-specific advantages”. The authors especially highlight the value of “firm-specific advantages” (FSAs) [18].

Pointing to the relationship with the theory of internalization, the authors J.T. Li et al. note that the use of individual firms with specific characteristics (FSA) by platform companies “follows the logic of externalization and depends on the pooling of external, additional assets owned and controlled by autonomous partners” [18–20], since this firm can share its technologies with partners, transfer rights to them (for example, Google, which shared Android code, and Baidu, which shared Apollo). The peculiarity of this situation may lie in the fact that, unlike MNCs (multinational corporations) and internalization processes, within the framework of the operation of platform ecosystems a situation may arise in which the company’s intangible assets become available to partners in host countries, which is in the interests of the platform owner, since this creates network effects (although sometimes the use of the platform becomes completely independent of the owner company), and each of the partners can use the open codes of different companies; that is, complementarities have access to alternative systems (for example, both iOS and Android) [18].

According to J.T. Li et al., additional benefits in ecosystems are created by “the generative potential of distributed innovators” and are also shaped by the sharing economy. At the same time, the owners of such platforms themselves receive unique opportunities “to recombine resources is considered MNCs”, which is possible only at high levels of development of MNCs and does not correspond to the theory of internalization, according to which MNC companies seek to obtain rent and “concerns itself mostly with the capture of rents earned in value-adding activities” [18,21]. J.T. Li et al. consider ecosystems “as a mode of cooperative governance”, noting, first, that “the ecosystem perspective better describes platform organization structures than traditional theories Ecosystems can be seen as comprising a multilateral set of autonomous firms that collaborate to realize a value proposition” (R. Adner [12]; M.G. Jacobides [15]) and, second, that “the internationalization of digital platforms largely depends on whether platforms can attract ecosystem participants in local markets and align their goals with those of the platform” [18,22].

Researchers also pay attention to the study of competing platforms (ecosystems) and find that competing platforms may have different focuses for profit [23].

A. Gupta et al., following the formation of the theory of “social inclusive open innovation”, also touch upon the importance of developing technological, as well as market and institutional adaptability, when because of open innovative platforms they create the opportunity for interaction between communities and corporations [24].

Returning to the question pointed out by J.T. Li et al. that ecosystems are not without significant bottlenecks [18], we note that the competitive advantage of ecosystems consists precisely of the fact that ecosystems have great advantages in optimizing the problems created by bottlenecks (in comparison to other business models). This is due to their openness and the possibilities of technological improvement, but at the same time, ecosystems have a drawback consisting of an extended payback period for investments in their creation and orchestration. At the same time, ecosystems are characterized by the uninterrupted

dynamism of resources traffic, and the development of partnerships into an ecosystem makes new market spaces (digital and non-digital) possible for its orchestrators at a lower cost. It is the secret of ecosystems to consist of the uninterrupted dynamic development of this system: extensive factors are transformed into intensive factors in it.

The discovery of the dynamics and prospects of ecosystems seems to be significant also. In this regard, it should be noted, first, the manuscript of A. Cozzolino et al. They studied the possibilities of developing collaboration and “competition between incumbent producers and entrant platforms”. The authors identified three groups of clusters, which are of great importance for understanding the prospects for the growth of ecosystems and new forms of competitive relations [25]. Second, one should pay attention to the ideas presented in the manuscripts, and then in the book, by C. Beaudry, T. Burger-Helmchen and P. Cohendet. First in their article and then in the book, they differentiate the forms and concepts of ecosystems. In addition, they are studying a dynamic approach to the formation of ecosystems. This is an important contribution of these authors and it finds our understanding: we also consider the dynamic character of ecosystems and show it in the model (in the section “Results” in this manuscript) [26].

R.B. Bouncken and S. Kraus discuss the evolution of ecosystems and establish that the development of ecosystems is ensured by a change in the balance of power, one of which stimulates a given company to scale it up, while the other stimulates it to use external resources to solve its business problems [27]. This position seems interesting and related to the problem of optimizing transaction costs and, of course, with institutional theory and had the correlation with R. Coases’ ideas in his famous book, *The Nature of the Firm* [28].

Y. Yi, Y. Chen and D. Li define the innovative perspectives of business ecosystems, which are born precisely because of the interaction of participants in these ecosystems. The authors also consider the problem of learning in organizations [29].

For Finnish scientists A. Bazarhanova et al., the “digital platforms are open, constantly evolving sociotechnical structures” that are sensitive to change. They study the process of evolution of the ecosystem from the “dominant phase with centralized management structures to a more federated approach to management”, and they study the problem of ownership transformation and conclude that “platforms can transform into industry infrastructures has an important implication for our understanding of the dynamics underlying digital platform” [30].

A great contribution to the systematization of ideas about ecosystems is made by L. Thomas et al. In general, the authors attempt to systematize the mainstreams that have formed in the scientific literature, describing the entire set of phenomena that describe the formation and development of platform ecosystems. They differentiate works and scrutinize the work of scientists, subdividing them into four main streams of research: (1) “Organizational”; (2) “Product family”; (3) “Market intermediary”; and (4) “Platform ecosystem”. Each of the directions is characterized by its own “level” of research—“firm”, “product”, “industry”, and “System/Industry”, respectively. “Key Concepts” are also differentiated: “Core competencies”, “real options” and “dynamic capabilities” (1); “Product family; architecture; modularity; commonality” (2); “Network externalities; standards; multi-sided markets” (3); and “Network externalities; innovation; standards; modularity” (4). They also noted that each stream will have own value creation methods: for “Organizational” (1)—“Flexibility; Superior adaption”; for “Product family” (2)—“Flexibility; cost savings; innovation”; for “Market intermediary” (3)—“Market efficiency; pricing structure; market power”; and for “Platform ecosystem”—“Flexibility; cost savings; innovation; externalities; innovation; learning; market power” [31]. L. Thomas et al. also consider that A. Gawer and M.A. Cusumano [5], T.F. Bresnahan and S. Greenstein [4], J. West [6], A. Gawer and R.M. Henderson [8] are studying platform ecosystems.

Indeed, A. Gawer and M.A. Cusumano [32] distinguish two types of platforms: “internal (company or product) platforms”, representing the structure formed by a “set of assets” (1); and “external (industry platforms as products, services, or technologies)” that provide the basis on which “external innovators” organized into an “innovative business system”

develop their own complementary products, technologies, or services. They illustrated, as in an ecosystem, that “many peripheral firms are connected to a central platform” through technology standards or software [5].

A few authors study the features and benefits of ecosystems. For example, L. Thomas et al. [31] believe that ecosystems contribute to economies of scale, and according to [33]—economies of substitution. According to the ideas of L. Thomas et al., “a platform ecosystem is typically more complex than a product family or multi-sided market because it includes concepts from both the product family and multi-sided market streams such as modularity and market simplification” [31] and it “acts as a hub of value exchanges” [7]. The advantage of platform ecosystems, according to L. Thomas et al., is form because of the loss of control over the entire product system. This facilitates the “integration of independent complementary products”, which means obtaining direct and indirect network externalities, and leads to the acquisition of market power through the coordination of buyers and sellers. In this way, platforms enable transactional leverage enhanced by the benefits of architectural openness [31]. These authors studied the in-depth issues of ownership (in ecosystems).

N. Economides and E. Katsamakos noted back in 2006 that “Technology platforms are the hubs of the value chains in technology industries”. They distinguished the advantages of “proprietary” and “open” source. They believed that firms having prioritized (closed) platforms realize “two-sided platform pricing”, which is not available for firms with open technology platforms. They asked important questions about whether it is possible for open and closed platforms to coexist in the same market (in the same industry) and what the competition is between them. Their conclusion is that in the face of competition between a “system based on an open-source platform” and a “system based on a closed source platform”, the second of them will be dominating in market share and in the profits, even if the cost of implementing open platforms is zero [7].

Raising the issue of differentiation of ecosystem types, we note that by combining the concepts of digital and entrepreneurial ecosystems, F. Sussan and Z.J. Acs introduced the concept of a digital entrepreneurial ecosystem (DEE). They studied its structure, formed by four concepts: “digital infrastructure governance, digital user citizenship, digital entrepreneurship, and digital marketplace” [34].

Moreover, the concept of “digital ecosystem” [16] belongs to P. Dini et al. [35], as well as to P. Weil and S.L. Woerner [36]. “Digital ecosystems” was also studied by G. Elia et al. [37], and in the “Digital Ecosystems” study by Z.J. Acs et al. [38], based on a systems approach, national enterprise systems have been studied [37]. An interesting position has been taken by [39] who believe that “DEE represents a combination of elements, in a particular territory, backing the growth of start-ups aiming to pursue new opportunities that arise from digital technologies” and Song’s position asking are DEE “local, global, intermediate, or all of the above?” [40], p. 583.

K. Taylor-Wesselink and F. Teulon [41] makes a serious analysis of the ecosystems literature and differentiate directions, and also rightly note the digital platform’s ability to change “quickly and unpredictably”, complicating entrepreneurial activity, and following A. Martinez et al. [42] suggest that “through the use of digital platforms, entrepreneurial opportunities and success are democratized” [41].

T. Riazanow et al. studied several types of ecosystems in the context of digital transformation in several industry areas (automotive, blockchain, financial, insurance and IoT) and identified similarities between them and created clusters formed by companies that are not part of the same ecosystem. The authors discussed the specifics of their functioning and identified those that create unique value for their ecosystems [43].

G. Baran and A. Berkowicz studied whether digital platform ecosystems create “real value for society” and what solutions contribute to their growth. Considering “the trans-functionality of the digital strategy”, the authors develop a model representing ecosystems as “Living Labs”, noting their innovative value. They believe that “Digital ecosystems are collaborative organizations that are digitally connected, modular, non-hierarchical, specialized, connected, and competing” [44].

E. Stam and A. Van de Ven, after analyzing the growth of ecosystems in the Netherlands, concluded: “We find that the prevalence of high-growth firms in a region is strongly related to the quality of its entrepreneurial ecosystem” [45].

An important issue regarding the measurement of ecosystems effectiveness was studied by J. Dul. He wrote: “since the literature has not reached a consensus on how to measure entrepreneurial ecosystems performance. Finding the necessity of each element is of special concern from a policy perspective because a necessary condition cannot be left out. A necessary condition must be present to achieve a desired outcome” [46].

P. Torres and P. Godinho raise the question of the levels and composition of entrepreneurial ecosystems and the elements that should be included in them. They take a separate state as a unit of analysis, in which “ambitious entrepreneurship” is formed, created by digital entrepreneurial ecosystems. Their creation is facilitated by various conditions that are differentiated by levels, they study “bottlenecks” that impede the development of ambitious and digital entrepreneurship [16].

An interesting view is presented by Song (the DEE structure). He proposed a reconfiguration of the DEE, highlighting three types of frameworks. The first of them is “digital user citizenship” (the entire set of users, including consumers and producers). The second structure is “digital technology entrepreneurship”—agents developing additional products and services related to digital platforms and the “digital multisided platform” itself. Song also defined the conditions that are necessary for the stability and effectiveness of the platform—“the protection of user privacy, platform efficiency, market competition not being stifled by platforms, security of the digital infrastructure, and also digital finance” [40].

Some other aspects of research are also interesting. For example, A. Hein et al. pay attention to the study of “Platform ownership”. The authors differentiated mechanisms in which “digital platforms help suppliers and consumers find each other” and noted that “decentralized ecosystems of digital platforms” are “driven by “peer-to-peer communities”. Thus, the authors consider both the ownership of the platform and the mechanisms for creating its value, as well as the independence of commentators, to be important [47].

T. Thompson et al., in their study based on the study of an ecosystem created in a single metropolis (Seattle), indicate that the main motives for the creation of ecosystems to occur under the influence of endogenous rather than exogenous causes are due to the subject’s desire with over time to a shift from distributed and fragmented activities to a more coordinated and integrated social order, patterns of more coordinated, integrated social interactions. They also believe that instrumental state policy is not a motivating factor. The authors identify 14 stages in the formation of an “entrepreneurial ecosystem” in which an alliance is created on a socially oriented initiative, which then transforms into “Social Purpose Corporations (SPCs)”, and then into a commercial structure [48].

In addition to traditionally describing the creating mechanism of the formation of platform ecosystems (which is based on platform technology (Apple)), there are other mechanisms—for example, the mechanism of transformation from a socially significant corporation into a commercial corporation (T. Thompson et al. [48]). The literature also describes the mechanism for the formation of ecosystems on the initiative of the state [16]. These authors, applying field theory, rightly insist on the prevalence of social relations in the formation of ecosystems: “We see ecosystems as relational, activity-rich spaces where actors grapple with conflicts and consensus and with institutional conformity and distinctive approaches as they strive to establish conventions that can sustain activity and support their legitimacy. Our research suggests that the nondeliberate act of creating an ecosystem by engaging in entrepreneurship-linked activities can sow the seeds of transformative institutional change when new conventions are created to name, serve, and align local needs. The ongoing task is how to sustain and amplify such conventions such that they can coexist with and potentially supplant incumbent conventional meanings and activities” [16,48].

An interesting aspect is studied by M. Kenney and J. Zysman. They analyze the established and developing environment for education and development of financing for

the creation of new firms in the United States and believe that the development of open access software, the expansion of the number of sources of financing (including through the spread of crowdfunding platforms), and the reduction in the costs of creating startups have created, since the crisis of 2000 (dot.com), conditions for regime change, when traditional firms begin to be squeezed out and industrial ecosystems are modified. They also note that new-format firms are able to sustain losses for a sufficiently long time (“unprofitable firms can continue to operate and undermine the work of existing operators”). They also suggest that “These firms may be destroying economic value” and, in some cases, “they may be destroying social value”. M. Kenney and J. Zysman consider deeper and more significant manifestations of Moore’s law and the technological opportunities resulting from the development of cloud computing technologies as an explanation for the reasons for reducing the cost of creating startups. This means that the infrastructure costs of modern startups are classified as variable rather than fixed (as they used to be). The essence of this transformation is that if, earlier, an IT startup had to buy or build the entire IT infrastructure, now there is the possibility of renting server capacities [49].

However, if, according to M. Kenney and J. Zysman, “Getting started easier than ever; getting out ever slower”, the time to market dominance has increased and other costs have increased, but the number of investment vehicles has also increased. Noting the fact of the formation of a “complex ecosystem of funding organizations and networks”, M. Kenney and J. Zysman single out “mega-funds” that “formed six ecosystems”: “angel groups or syndicates”, “super-angels”, “accelerators, of which YCombinator”, digital crowdfunding platforms (Indiegogo, Kickstarter, AngelsList) and “open-ended mutual funds and sovereign wealth funds are making massive late-stage investments” [49].

They also note the proliferation of “smaller venture capital firms”, including investing using cryptocurrencies, but they are not sure about the rise of the trend. In addition to the above, they boldly conclude that “two basic conditions in a capitalist society—labor and competition—undergo changes in their activities”. According to the author’s opinion, the consequences will vary for different types of work, but the current situation is characterized by the using of “loss-based” “market dominance strategies” that generate “capital gains without achieving even medium-term market stability”. Therefore, labor “may be seen as a commodity whose cost should be minimized rather than, but not, as an asset whose value can contribute to a firm’s long-term competitive advantage and better social outcomes” [49].

The theme of ecosystem development has been widely discussed at the World Economic Forum. On its platforms, it was noted that ecosystems are interesting not only as a new business in the digital space, but also as an addition to “established models” or even as “full-fledged replacements for them”. The dominance of ecosystems has attracted the attention of the WEF. Its experts compiled a corresponding report in 2019 [50]. The authors of the report noted that the composition of the initiators of the creation of platforms is heterogeneous both in size and in specialization; for some, this is the main activity and, for others, it is an addition to the main activity. The report reflects the growth rate of companies whose activities are based on platform technologies. A feature of their business model is that “unlike the industrial giants of the 20th century, platform companies do not just create value themselves, they organize the creation of value by external users” so value itself becomes shared. This makes joint ventures more promising, “going it alone” becomes “burdensome” (and we would add that it is also risky).

Calling such firms “flipped”, the authors of the report note the priority of the platform itself compared to its product value. This happens because of the functioning of the platform, which levels out the naturally declining value of the goods, and the digital ecosystems themselves increase their power because of the growth of the ecosystem scale (the effect of power formation was independently considered by the authors in the work [1]). The boundaries of markets and firms are blurring.

The authors of the manuscript also point out that the reliability of the ecosystem is given by a diverse composition of subjects using it and united by its (suppliers, innovative consumers and public administration bodies). Ecosystems keep the interests of the state,

society and business. Interestingly, the authors of the report see the similarity of the ecosystem with the organism, which, based on the principles of natural selection, chooses those directions “where there is more food” [50].

Of interest is another emphasis made by the authors of the article—the study of the change in the “trust landscape”, which is due to “a fundamental rethinking of institutional and public governance”. A critical determinant of the future of each ecosystem will be how effectively corporations can inspire and develop trust in their operations and their product offerings. The growing need to develop corporate trust will lead to the occurrence of a “new generation of commercial trust” and mark “the decline of many of the institutions that came of age during the 20th century managerial revolution”.

The idea of Y. Shi et al. needs to be noted; they propose a “Whirlwind Model of Business Ecosystem”, which allows them to define a business ecosystem as “an interdependent and interactive relationships between a group of diversified business communities and a business-focused and integrated industrial system, as well as their supporting infrastructures”, and in the “linking Business Ecosystem and Natural Ecosystem” they see a promising direction for “Future Industrialization” [51].

Of particular interest in our study in this manuscript are banking ecosystems. However, there are few works devoted specifically to banking ecosystems, despite the growth in the number of such ecosystems and their prospects. Given the importance of studying banking ecosystems and the prospect of including industrial enterprises in them, the importance of the article M.T. Okano et al. should be noted. They are exploring issues related to digital transformation in the manufacturing industry, starting from the premise that the study of digital transformation is associated with the functioning of two digital technologies—a digital platform and a digital ecosystem. Differentiating these aspects, they study the process of digital transformation of manufacturing companies, considering five cases that differ in the degree and depth of connection of companies in digital reality [52].

Other important aspects of banking ecosystem research are presented in [53]. The authors of this article, based on the survey, study the impact of digitalization on banking business models and study how their business models are being transformed (in the UAE).

Analyzing the innovative and technological significance of ecosystems, we highly appreciate the idea of Thompson, noting that “Digitalization facilitates the exchange of knowledge” [48].

Equally important are the ideas of P. Torres and P. Godinho. These authors argue that DEE is a necessary condition for obtaining high-quality products, but their presence in no way affects the creation of a new business. “Cultural and informal institutions” and “market conditions”, as well as “networking and support” and “knowledge creation and dissemination”, have a significant impact on the quality of entrepreneurial activity in entrepreneurial ecosystems [16].

Moreover, their study showed that “knowledge creation and dissemination” is not statistically significant for unicorns, although “Digital technologies can facilitate absorbing knowledge and materializing knowledge spill-overs” [54].

In the context of studying the possibilities that ecosystems, because of the interaction of participants, create conditions for faster creation of innovations and their accelerated diffusion, the article of D. Askarany et al. [55] aroused interest. These authors provide “practical evidence” that shows the emergence and diffusion of new technologies is facilitated by the development of interconnections between enterprises (the B2B sector) in their interconnected group. It should be noted that these authors do not insist that such a relationship is “the only effective approach for introducing new technologies”, but illustrate this process by cases; they discriminate between four diffusion channels [55]. Since ecosystems are shaped primarily by the supply of the B2B sector, the mentioned article is valuable for this manuscript.

It is debatable whether “ecosystem” and “innovation ecosystem” can be synonymized, as according to A. Gawer and M.A. Cusumano [32].

We believe that the occurrence of technological increment is the most important aspect that determines the prospects for the ecosystem's development, independent of level and specialization, which determines the prospects for commercial and social goals. Thus, we would like to point out the correctness, for example, of P. Torres and P. Godinho, who noted that "knowledge creation and dissemination seem to be more important to boost digitally-enabled unicorns rather than unicorns in general" [16].

In the end of the Introduction, the importance of the few remarks of M.G. Jacobides et al. point out: the "Ecosystem is a term used inconsistently"; it is possible that "ecosystems become a new way of organizing, distinct from both firms and markets, supply chains and hierarchies", and the "ecosystems respond to a completely new logic that has occurred as a result of major shifts" [50]. Believing that ecosystems became an independent business model, possessing their own strategies, and have prospects, we cannot exclude the fact that after some time we will be forced to agree with M. Kenney and J. Zysman that ecosystems are nothing more than "entrepreneurial experiments" [49]. However, at the same time, the authors propose the thesis that ecosystems are a special business model, formed through the influence of digitalization processes, changing forms of competition and increasing digital literacy and digital susceptibility of consumers. This business model can be implemented by the subjects as an independent one or implemented in parallel with the main type of activity of modern companies. Ecosystem business models contain a great potential for innovation generated by the technological increment generated in ecosystems because of the exchange of new knowledge and technological exchange that occurs naturally between ecosystem participants. The observations we made earlier suggested that banks have less understanding of this possibility than non-bank structures (those that are leaders in the field of building ecosystems and are included in the analysis in the "Results" section). This opportunity is very significant for banks, since the owning of an ecosystem allows bank to improve their economic effectiveness (including the effectiveness of communication provided by reputational factors), although the formation of ecosystems requires investment. In general, for everyone, but especially for banks, the possibilities of technological increment because of the exchange of information and technologies between participants (in fact, this is a technological transfer carried out by ecosystem participants operating within this ecosystem) turn out to be latent, although they have great potential, since banks have effective investment vehicles that can enable them to synthesize and commercialize the innovative technologies generated in their ecosystem. Identification of this opportunity and the awareness of banks of this prospect will create conditions for increasing their competitiveness sustainability in the development of their investment activities and opportunities for diversification of their activities. Such mechanisms, we believe, are inherent in an ecosystem (it is an ecosystem's nature) business models and must be used. Therefore, to show how successful projects for the formation of ecosystems affect the activities of banks, we compared the results of the activities of the ecosystems of banks and ecosystems of non-banking structures (orchestrating ecosystems) and proposed a model of technological increment of banking ecosystems, which is reflected in the Results and Conclusion. The Discussion section provides some discussion points that provide a basis for the development of research in this area and the application of these ideas in the practice of banking.

2. Materials and Methods

The methodological basis of the study was made up of methods of comparative analysis, statistical methods, methods of regression and cluster analysis and data envelopment analysis (DEA), which allow evaluating and comparing economic agents by several input and output parameters and studying the hypothesis of constant returns to scale, as well as the modeling method, based on dynamic programming approaches.

It should be noted that cluster analysis has been used in works on ecosystems before. A work has already been mentioned above in which this type of analysis has been successfully applied [43].

Based on the above points, the authors put forward the thesis that ecosystems are business models, since they can be implemented as independent activities of individual companies, which can be implemented by them in parallel or in combination. The ecosystem as a business model is characterized by unique approaches to the coordination of activities and the development of partnerships based on the formation of a unique cumulative offer to the market of value. With functioning based on open-source or closed-source platform technologies, the ecosystem as a business model simultaneously implements the development of both horizontal and vertical market relationships, forming private market mechanisms in its microenvironment and integrating various forms of cooperation (not managing, but orchestrating based on contractual relations the activities of the participants (complementarities)).

In general, the formation of an ecosystem business model can be explained from the standpoint of the concept of J.A. Schumpeter: an ecosystem is formed because of a special combination of technical, communication and financial technologies, which together form a special case of organizing entrepreneurial activity and can be considered as an innovative form of entrepreneurship.

The peculiarity of ecosystem business models is that they “create value in two changes” (as noted by McKinsey experts). Values that are significant for both b-2-c and b-2-b. Sharing this point of the view, we consider it necessary to add to it the following idea: we believe that the interpretation of the value created by ecosystems is also determined by the fact that because of them, new consumer, managerial and trade information, including educational innovative and technological values, are formed, regardless of whether this beneficiary of the created value is a representative of the b-2-b or b-2-c market.

All this makes ecosystems a promising business model. Banks are estimating the prospects of ecosystems more and more. This is supported by McKinsey data: more than half (60%) of the US banks they surveyed said they were likely to form their own ecosystem or join an existing ecosystem [56–58]. This research shows the interest of banks in the formation of ecosystems, but it does not guarantee that banks already intend to seek ecosystem opportunities to increase their innovation and technological potential.

According to McKinsey, which also draws on data from S&P Capital IQ, six of the top companies by market capitalization own the ecosystem. These are: Amazon—\$1.572 billion, Microsoft—\$1.614 billion, Alphabet—\$999 billion, Facebook—\$712 billion, Alibaba—\$709 billion. The seventh company that does not have an ecosystem, but at the same time is the second in the world in terms of capitalization—Saudi Aramco—\$1.855 billion (as of 5 August 2020) and does not represent an ecosystem model.

According to data of the global analytical agencies [59–83]: in 2021, the market value of the same companies was: Amazon—\$1558 billion, Alphabet—\$1,392,561.8 M (\$1.393 billion), Microsoft—\$1,778,228.6 billion, Facebook—\$838,724.2 billion and Alibaba—\$580.88 billion [84].

According to McKinsey experts, in the modern world, the Ecosystem 1.0 model is being replaced by the Ecosystem 2.0 model, which characterizes the growth of the ecosystem’s power. They formulated several principles of Ecosystem 2.0: “use strategic mapping to identify control points” and “lock in impact with precise capabilities”; designing an organization for many participants [56].

In the literature, the composition of the ecosystem has been widely studied, which includes orchestrators, complementarities and consumers. Complementing the differentiation of the ecosystems mentioned in the introduction (digital/non-digital, open/closed, platform), we note that they are also divided into solution and transaction ecosystems (and their hybrids). In our opinion, differentiation is also relevant depending on the composition of participants (b-2-b, b-2-b, b-2-g and ecosystems created by states), as well as industrial, trade, universal, financial and, finally, banking ecosystems.

Focusing on the study of banking ecosystems, we note that a bank can become an ecosystem initiator (orchestrator) or become a complementarity. However, we believe that the first option is more promising. In this manuscript, we present the results of a study of the growth opportunities for the innovative potential of banks and their economic efficiency.

However, despite the competence and availability of investment and information and communication capabilities of banks, including those related to their possession of information about customers, not all banks have yet realized the benefits of creating ecosystems. Note that in the 2019 WEF report, banking and financial institutions were not included at all among the leading ecosystems orchestrators [50].

Having identified this situation, we decided, first, to study the feasibility of forming ecosystems by banks and received conclusions that serve as proof of the prospects. This thesis is explained by the fact that ecosystems as business models have just begun to develop and the triumph of this business model can be announced no earlier than in five years. Second, we explored the possibility of additional benefits for realizing the interests of banking ecosystems and got an optimistic result, which, it should be noted, also has a universal character.

Quite rarely, experts still speak out about banking ecosystems. For example, according to Finextra Research experts, banks receive a few benefits from the implementation of banking ecosystems [85]; this information is added in [86]. They point out that banks, by forming ecosystems, create significant advantages for themselves, which consist of the fact that the level of consumer confidence in banks is higher than in other financial institutions; banks have great information capabilities (client base) and financial opportunities to maximize the expansion of the product portfolio, the necessary infrastructure.

However, according to the same source, the development of ecosystems by banks can be narrowed down because of the presence of problems, which include the difficulty of reorienting the product offering system because of the functioning historical lines, the difficulties associated with the need to restructure the banking culture, the difficulties that are due to the inflexibility of the regulatory framework for the development and marketing of banking products. However, at the same time, compared to other fintech organizations, banks have more opportunities, competencies and consumer confidence [86].

Despite all the advantages, the banking business has not yet fully realized the importance of creating its own ecosystems, but some banks have realized the totality of opportunities that ecosystem orchestration gives them, and as they understand the significance of this process and start organizing this process banks are drawn into this process and see it has great prospects.

Noting how fast and with what a high growth rate, the activity of individual banks is increasing in the creating of their own ecosystems and the fact that such ecosystems have a high degree of competitiveness, even in comparison with ecosystems formed by non-banking structures, we ventured to suggest that despite the need to bear numerous costs for the creation of ecosystems, their functioning brings significant progress to banking structures, which is expressed in the growth of profits and revenues, an increase in assets, even in the medium term, and in the long term creates conditions for sustainable profit growth through the development of its ecosystem and increasing its competitiveness and growth of sales markets in the long run.

Evidence of the fact that it is profitable for banks to form ecosystems is, for example, the statement of Sberbank, which, having carried out 1 million technological implementations and changes in 2021, including those aimed at forming an ecosystem, achieved “30% growth in the financial sector and triple growth in non-financial business”, and thanks to the use of artificial intelligence technology was able to get RUB 205 billion (USD 2,722,195,000). In total, this bank manages more than 40 companies and supports more than 20 offline mobile applications within its digital ecosystem [86].

At the same time, those banks that have not yet mastered the ecosystem business model show significantly lower efficiency, despite that those banks that build ecosystems incur additional costs for the formation and maintenance of ecosystems. However, it is precisely ecosystems that create new sources of income and conditions for banks to increase their efficiency.

To do this, at the first stage of the study, we began to study how many banking ecosystems are functioning today. It turned out that the statistical data that allow us to

correctly compare the necessary indicators have not yet been formed. The only source that allows you to identify banks that form ecosystems has become a completely authoritative source [87–89]. It highlights several financial ecosystems: Citi, Standard Chartered, Wells Fargo, mBank, Ant Financial, Rakuten, Facebook Pay, Amazon Pay, Google Pay, Android Pay, WeChat Pay and Goldman Sachs.

Agreeing with this grouping, at the second stage of the study, actions were taken to search for information in the banking statements among the selected banking structures on the financial performance of their activities. Here we encountered information limitations, which showed that comparable data for at least a five-year period at this stage in the development of banking ecosystems and an ecosystem business model cannot yet be found at all.

Based on these possibilities and limitations, as well as following the goal of obtaining a reliable result (proof or refutation of the hypothesis of this manuscript), we decided on the composition of the sample, which included banks having their ecosystems and companies that have ecosystems but are not banks (and in which they are subjected to comparative and other types of analysis). At the same time, we note that at one of first stage of our general analysis, we also studied and compared similar performance indicators of banks (having ecosystems) and other banks that do not have ecosystems and found that for the most part the latter (those banks that do not use this business model) do not show such efficiency as the first ones. The results of the study are given in the Section “Results”.

3. Results

Based on the results present in Section 2 above, Materials and Methods, we have set a task—to compare four banks that have their own ecosystems and four companies that have financial ecosystems and are “ecosystem leaders” but are not banks (Facebook Pay (Facebook) (Meta Platforms), Amazon Pay (Amazon), Google Pay (Alphabet), Android Pay (Apple), subject to their renaming). We conducted three types of studies (cluster analysis, regression analysis and applied the DEA method). At the same time, the one of the authors who carried out the calculations did not have information about the composition of the studied elements, which were only numbered. This made it possible to obtain unbiased conclusions that confirmed the hypothesis that banking ecosystems are progressive for banks and contribute to the growth of competitiveness and profitability of banks both in the industry and in the cross-industry context. For other limitations and assumptions, see the Discussion section.

For this reason, the sampling consists of:

1. Facebook Pay (Facebook) (Meta Platforms),
2. Amazon Pay (Amazon),
3. Google Pay (Alphabet),
4. Android Pay (Apple),
5. Citi (Citigroup),
6. Wells Fargo,
7. Goldman Sachs,
8. Sberbank.

For the analysis, eight DMU (decision making units) were considered, represented by banks and firms that have been creating and developing their ecosystems for more than 5 years. The analysis was carried out based on statistical data for 2015–2021 for three indicators: revenues, profits and assets (USD millions). The data sources are: [59–83,90–124]. This data is presented in the Appendix A (Tables A1 and A2). The main purpose of the study is to identify trends in the development of DMU, identifying the most effective DMU. In addition, it needs to be noted that the study of these indicators is determined both by the relevance and comparability of the data, and by the fact that we tried not to violate the rights of anyone’s interests (commercial and reputational) and therefore used data from open sources. At the same time, a comparative analysis (which was carried out at the preliminary research stage) allowed us to rely on the study of these indicators, when

we compared the indicators of banks that form or do not form ecosystems and revealed a stable relationship between the fact that the economic efficiency of banks working on the formation of ecosystems is growing faster than those that did not choose in favor of the formation of ecosystems. Moreover, the financial performance of these (ecosystem-building) banks is growing at a faster rate than other banks (and not only because of the size and influence of these banks) and is comparable to the growth rate of the ecosystem building leaders. Thus, the relationship between the financial performance of banks and the presence of their ecosystems exists, but, at the same time, there are also underestimated latent opportunities for the development of banking ecosystems.

General trends in indicators for the considered DMUs for 7 years are shown in Figure 1.

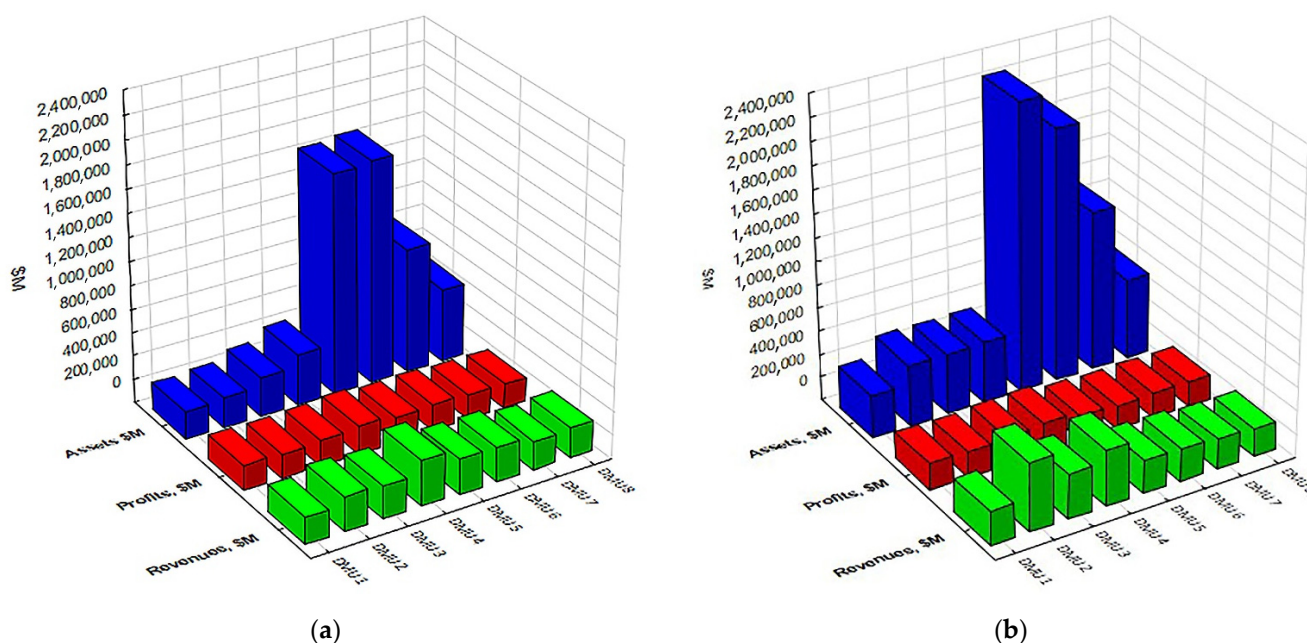


Figure 1. Characteristics of DMU by indicators of Revenues, \$M, Profits, \$M, Assets, \$M for 2015 and 2021. Source: calculated by the authors based on the data Appendix A, Tables A1 and A2. (a)—2015; (b)—2021.

As can be seen from Figure 1, the largest difference between DMUs is observed in terms of the assets indicator. The four leading DMUs in this indicator in 2015 are banks (DMU 5, 6, 7, 8) that retain their positions in this indicator after 6 years. In general, growth is seen across all DMUs in 2021. However, the largest relative increase in all indicators is observed for DMU 1, 2, 3 and 4.

The dynamics of differences in the trends of DMU activity can also be observed in Figure 2, showing the three-dimensional coordinate space of all three and the position of the DMU in it. Figure 1a is based on data from 2015, although it reflects general trends across all DMUs from 2015 to 2019. Since the considered DMUs are represented by two types of primary activities, it was interesting to study the characters of the development of ecosystems of various DMUs: whether the nature of ecosystem development depends on the primary activities of the DMU. For that purpose, the authors conducted a cluster analysis of all DMUs for each year.

As can be seen from Figure 3, the hierarchical clustering method implemented in the “STATISTICA” software environment divided eight DMUs into at least two clusters. In 2015–2019, the first cluster consists of five and six DMUs (banks), the second cluster includes all other DMUs.

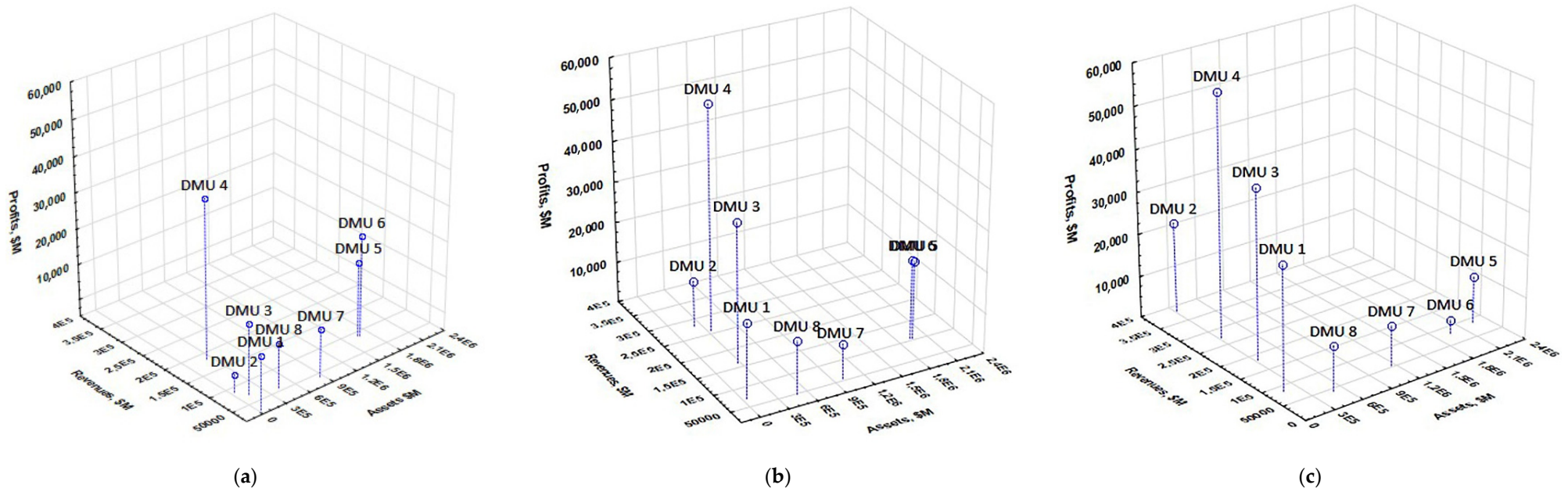


Figure 2. Dynamics of Revenues, \$M, Profits, \$M, Assets, \$M indicators in three-dimensional coordinate space. Source: calculated by the authors based on the data Appendix A, Tables A1 and A2. (a) 2015 (and beyond until 2019); (b)—2020; (c)—2021.

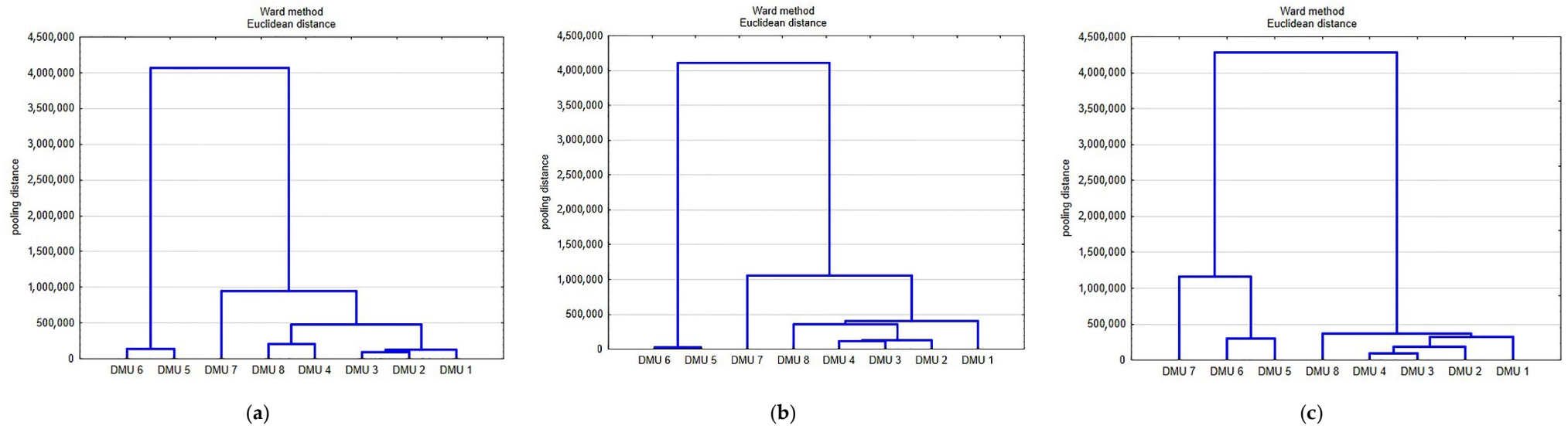


Figure 3. Hierarchical clustering of ecosystems by Revenues, \$M, Profits, \$M, Assets \$M criteria for 2015–2021. Source: calculated by the authors based on the data Appendix A, Tables A1 and A2. Dendrograms of hierarchical clustering using the Ward method and Euclidean distance are shown in Figure 3. (a)—2015–2019; (b)—2020; (c)—2021.

Moreover, the second cluster is heterogeneous. It is explicitly allocated to separate subclusters (or lower-level clusters) of DMU 7 (bank). Another subcluster is DMUs 4 and 8. The other DMUs, 1, 2 and 3, are very similar in the character of the ratios of clustering indicators. Further, in 2020, we see an increase in the distance to the center of the second cluster at DMU 8 (Banks), and DMU 7 moved to the first cluster (and replaced DMU 6 there): that is, these three DMUs have significant changes in activity, which changes the ratio of clustering criteria. In 2021, DMU 6 returns to cluster 1. At trust level 1E6, 3 clusters can be allocated. But considering that there are only 8 DMUs under consideration, we do not see the feasibility of allocating a third cluster consisting of two DMUs.

Thus, in 2021, the first cluster already consists of three DMUs-5, 6 and 7, represented by banks and the second cluster, consisting of DMUs 1, 2, 3, 4 and 8, consisting of DMUs of the IT sector and one bank (DMU 8). We can also observe that the trends in the development of the banking and IT sectors are different, and over time this difference is increasing—DMU 7 bank has moved to the first cluster. The exception is DMU 8 provided by the bank. This exception is explained by the fact that this bank has made serious progress in creating an ecosystem and is the orchestrator of one of the largest ecosystems in its country.

Due to the lack of semantic load, we did not specify the average cluster distances and the average indicators of each firm in the cluster.

Next, using regression analysis, we will consider the characteristics of the activity processes in each cluster separately.

The resulting measure of performance for commercial enterprises is profit. Based on the available data on the three performance indicators, we constructed a regression equation for each cluster. Due to the small number of DMUs in each cluster, we will consider data for all 7 years in one equation.

Data for cluster 1 for regression analysis are presented in Table A1 (Appendix A).

Before regression analysis, the data were checked for multicollinearity. The pairwise correlation coefficient for the independent variables revenues and assets for cluster 1 data was 0.63 (with the assumed collinearity equal to or greater than 0.7). Based on these data, the authors excluded the multicollinearity of independent factors in the data used.

The study used the single variable normal linear regression model and multiple normal linear regression model.

As a result of the analysis, we obtained a multiple regression equation (model 1), showing a high correlation coefficient between the dependent variable profits and the independent variables revenues and assets, while the hypothesis 1 itself about the quality of the model indicates its inadequacy to the experimental data; i.e., it cannot be used for further research and forecasting of processes according to the selected characteristics.

$$a = Y = x_1, x = x_2, x_3 \quad (1)$$

$$Y = 350.41 + 0.31624 \times x_2 - 0.00381 \times x_3, \quad (2)$$

Multiple correlation coefficient $R = 0.40748$, $R^2 = 0.16604$.

Standard error 7724.7, $F = 1.1946$, Significance $F = 0.33709$.

Hypothesis for model 1. *Regression model 1 is inadequate for the experimental data.*

Next, we considered one-factor relationships between the studied variables. The results of the analysis are presented in Table 1.

Table 1. Results of the regression analysis of the variables of the first cluster *.

N	Type of Model	Regression Equation	Multiple Correlation Coefficient R	R ²	Standard Error	F	Significance F
Variables Y = x ₁ , x = x ₂							
2	Linear Y = a ₀ + a ₁ × x	Y = -2489 + 0.2602 × x ₂	0.39426	0.15544	7468.7	2.393	0.03098
3	Exhibitor Y = EXP(a ₀ + a ₁ × x)	Y = EXP(2.1777 + 9.8724 × 10 ⁻⁵ × x ₂)	0.74548	0.55575	17,583	16.263	9.0094 × 10 ⁻⁷
4	Exhibitor Y = EXP(a ₀ + a ₁ × x + a ₂ × x ²)	Y = EXP(0.15867 + 0.00026535 × x ₂ - 1.7786 × 10 ⁻⁹ × (x ₂) ²)	0.99	0.9801	0.38822	295.57	7.0566 × 10 ⁻⁷
Variables: Y = x ₁ , x = x ₃ ,							
5	Exhibitor Y = EXP(a ₀ + a ₁ /x)	Y = EXP(3.3181 + 1.132 × 10 ⁷ /x ₃)	0.70032	0.49045	1.2419 × 10 ⁵	12.513	2.4994 × 10 ⁻⁶
6	Exhibitor Y = EXP(a ₀ + a ₁ × x + a ₂ × x ²)	Y = EXP(0.097371 + 1.0913 × 10 ⁻⁵ × x ₃ - 2.9955 × 10 ⁻¹² × (x ₃) ²)	0.9944	0.98882	0.29099	530.76	3.6504 × 10 ⁻⁷
Variables Y = x ₂ , X = x ₃ ,							
7	Linear Y = a ₀ + a ₁ × x	Y = 24448 + 0.027527 × x ₃	0.63638	0.40498	9499.3	8.8478	1.3418 × 10 ⁻⁵
8	Polynomial Y = sum{a _i × x ⁱ }	Y = 2.0453 × 10 ⁻⁵ - 0.40891 × x ₃ + 3.1563 × 10 ⁻⁷ × (x ₃) ² - 7.0841 × 10 ⁻¹⁴ × (x ₃) ³	0.8748	0.76527	6486.1	11.954	0.001184
9	Exhibitor Y = EXP(a ₀ + a ₁ /x)	Y = EXP(11.995 - 1.4049 × 10 ⁶ /x ₃)	0.74782	0.55924	8770.6	16.494	8.5766 × 10 ⁻⁷

* Source: calculated by the authors based on the data Appendix A, Table A1.

Table 1 includes equations with the highest correlation coefficient and a confirmed hypothesis about the adequacy of the model for the experimental data. The strongest relationship between the variables is exponential. The most significant (strong) linear relationship is between the variables x_2 and x_3 , which indicates a direct dependence of the DMU revenue of the first cluster on the size of fixed assets.

We have built a regression equation for the second cluster.

Data for cluster 2 for regression analysis are presented in Table A2 (Appendix A).

Before regression analysis, the data were checked for multicollinearity. The pairwise correlation coefficient for the independent variables revenues and assets for cluster 2 data was -0.201 (with the assumed collinearity equal to or greater than 0.7). Based on these data, the authors excluded the multicollinearity of independent factors in the data used.

As a result of the analysis, a multiple regression equation (model 10) was obtained, showing a high correlation coefficient (0.6499) between the dependent variable profits and the independent variables revenues and assets, while hypothesis 1 about the quality of the model indicates its adequacy to experimental data; i.e., it can be used for further research and forecasting of processes according to selected characteristics.

$$Y = x_1, x = x_2, x_3, \quad (3)$$

$$Y = 13666 + 0.082971 \times x_2 - 0.00042228 \times x_3, \quad (4)$$

Multiple correlation coefficient $R = 0.42034$, $R^2 = 0.17668$.

Standard error = $20,590$, $F = 4.0774$, Significance $F = 0.024225$.

Hypothesis for model 10. *Regression model 10 is adequate for the experimental data.*

Next, we consider one-factor relationships between the variables under study. The results of the analysis (models 11–18) are presented in Table 2.

The analysis made it possible to single out two clusters demonstrating two different trends in the development of ecosystems, described by different models of regression dependencies.

The next step of the study is to determine the most effective DMUs. The amount of profit is certainly an indicator of the resulting activity of any DMU and allows you to directly compare the absolute and relative amount of profit between the considered DMUs, but considering that all DMUs have different indicators characterizing costs, assets, working staff, etc., parametric analysis does not always give a clear and (or) exhaustive answer about the effectiveness of the DMU. In this regard, we used data envelopment analysis (DEA), which allows us to evaluate and compare economic agents according to several input and output parameters, in which the measure of efficiency is a coefficient that reflects the ratio of outputs to inputs (results to resources); i.e., DEA solves the optimum problem: minimizing inputs for actual outputs (input-oriented model) or maximizing outputs given actual inputs (output-oriented model).

This type of analysis does not require the user to specify weights for input and output parameters, does not require the formulation and testing of hypotheses about functional relationships between input and output parameters (unlike regression analysis). In addition, DEA allows us to consider the hypothesis of constant returns to scale (if we change the input parameters proportionally, then the output parameters will change in the same proportion—absolute efficiency) and the hypothesis of variable returns to scale (current or limited efficiency, when we understand that in the system has limitations, for example, technological ones, and a constant proportional change in the output parameters is technologically or physically impossible).

Table 2. Results of the regression analysis of the variables of the second cluster *.

N	Type of Model	Regression Equation	Multiple Correlation Coefficient R	R ²	Standard Error	F	Significance F
Variables Y = x ₁ , x = x ₂							
11	Polynomial Y = cyMMA{a _i × x ⁱ }	$Y = 24621 - 0.32301 \times x_2 + 2.6474 \times 10^{-6} \times (x_2)^2 - 4.22 \times 10^{-12} \times (x_2)^3$	0.55219	0.30492	19,173	5.4103	0.0037569
12	Exhibitor Y = EXP(a ₀ + a ₁ /x)	$Y = \text{EXP}(9.5623 + 656.99/x_2)$	0.50404	0.25406	19,322	13.283	1.7125 × 10 ⁻⁸
13	Logistics Y = a ₀ + a ₁ /(1+ a ₂ × EXP(a ₃ × x))	$Y = 16,133+ 27,310/(1+ 3.2855 \times \text{EXP}(-6.8381 \times 10^{-5} \times x_2))$	0.53327	0.28438	19,454	4.901	0.0059733
Variables: Y = x ₁ , x = x ₃ ,							
14	Optimum Y = x/(a ₀ + a ₁ × x + a ₂ × x ²)	$Y = x_3/(30.093 - 0.00010791 \times x_3 + 2.3963 \times 10^{-10} \times (x_3)^2)$	0.77555	0.60147	30.806	28.675	2.7832 × 10 ⁻⁶
15	Hyperbole Y = 1/(a ₀ + a ₁ × LN(x))	$Y = 1/(0.0015978 - 0.00011702 \times \text{LN}(x_3))$	0.71401	0.50981	1.6487 × 10 ⁵	40.561	7.0695 × 10 ⁻¹¹
Variables Y = x ₂ , X = x ₃ ,							
16	Polynomial Y = sum{a _i × x ⁱ }	$Y = -0.010909 + 1.4563 \times x_3 - 3.5196 \times 10^{-6} \times (x_3)^2 + 2.1342 \times 10^{-12} \times (x_3)^3$	0.49325	0.2433	1.0111 × 10 ⁵	3.9654	0.014971
17	Polynomial Y = sum{a _i × x ⁱ }	$Y = -80034 + 2.1739 \times x_3 - 5.2163 \times 10^{-6} \times (x_3)^2 + 3.2285 \times 10^{-12} \times (x_3)^3$	0.5544	0.30736	96,731	5.4728	0.0035553
18	Parabola Y = a ₀ + a ₁ × x + a ₂ × x ²	$Y = 0.02183 + 0.77783 \times x_3 - 8.3032 \times 10^{-7} \times (x_3)^2$	0.46423	0.21551	1.0158 × 10 ⁵	5.2197	0.0099489

* Source: calculated by the authors based on the data Appendix A, Table A2.

Given the limited dataset, assets were considered as inputs, and revenues and profits were considered as outputs.

Considering that the pandemic has adjusted, it is futile to consider the “pre-pandemic period”: a return to the past within the framework of current realities is impossible. Therefore, the analysis was carried out according to the data of 2019–2021. In addition, we considered a model with variable economies of scale, realizing that a direct proportional increase in revenue and profit from an increase in assets is unlikely because revenue and profits are more dependent on DMU costs, number of employees and quality of work than on the size of assets.

The DEA results are presented in Table 3. The analysis was performed in the MaxDEA 8Basic software environment (<http://maxdea.com/> accessed on 1 January 2022).

Table 3. Envelopment model output-oriented results for 2019–2021 *.

DMU	Score	Benchmark	Projection (Assets, USD Million)	Projection (Revenues, USD Million)	Projection (Profits, USD Million)
1	2	3	4	5	6
2019					
DMU 1	1	DMU 1 (1.00)	133,376	70,697	18,485
DMU 2	1	DMU 2 (1.00)	225,248	280,522	11,588
DMU 3	0.789153954	DMU 1 (0.293020); DMU 2 (0.022043); DMU 4 (0.684936)	275,909	205,101.9313	43,518.75809
DMU 4	1	DMU 4 (1.00)	338,516	260,174	55,256
DMU 5	0.351111192	DMU 4 (1.00)	338,516	260,174	55,256
DMU 6	0.356793832	DMU 4 (1.00)	338,516	260,174	55,256
DMU 7	0.153214131	DMU 4 (1.00)	338,516	260,174	55,256
DMU 8	0.247013899	DMU 4 (1.00)	338,516	260,174	55,256
2020					
DMU 1	1	DMU 1 (1.00)	159,316	85,965	29,146
DMU 2	1	DMU 2 (1.00)	321,195	386,064	21,331
DMU 3	0.71049621	DMU 1 (0.025958); DMU 4 (0.974042)	319,616	269,620.5732	56,677.29026
DMU 4	1	DMU 4 (1.00)	323,888	274,515	57,411
DMU 5	0.393427	DMU 2 (0.329096); DMU 4 (0.670904)	323,001.745	311,225.3058	45,537.22405
DMU 6	0.48647568	DMU 1 (0.777766); DMU 2 (0.222234)	195,291	152,657.1684	27,409.24214
DMU 7	0,16475937	DMU 4 (1.00)	323,888	274,515	57,411
DMU 8	0,16475937	DMU 4 (1.00)	323,888	274,515	57,411

Table 3. Cont.

DMU	Score	Benchmark	Projection (Assets, USD Million)	Projection (Revenues, USD Million)	Projection (Profits, USD Million)
2021					
DMU 1	1	DMU 1 (1.00)	165,987	117,929	39,370
DMU 2	1	DMU 2 (1.00)	420,549	469,822	33,364
DMU 3	1	DMU 3 (1.00);	359,268	257,637	76,033
DMU 4	1	DMU 4 (1.00)	351,002	365,817	94,680
DMU 5	0.28680338	DMU 3 (0.972798); DMU 4 (0.027202)	359,043.1451	250,638.612	76,540.24275
DMU 6	0.29201822	DMU 2 (0.052569) DMU 3 (0.947431);	362,489.5069	268,791.4435	73,789.9152
DMU 7	0.27385537	DMU 3 (0.840802); DMU 4 (0.159198)	357,952.0734	216,680.0703	79,001.55582
DMU 8	0.20139187	DMU 3 (0.593494) DMU 4 (0.406506)	355,907.8253	153,054.8407	83,613.10867

* Source: calculated by the authors based on the data Appendix A, Tables A1 and A2.

According to the conditions for conducting DEA, DMUs with an efficiency coefficient (Score) equal to 1 are effective. This coefficient shows the optimal ratio of inputs (costs) and outputs (results).

It can be concluded that there is a large efficiency gap (column 2) between DMUs 1, 2, 3 and 4 and DMUs 5, 6, 7 and 8, which once again confirms the different performance characteristics of these DMU groups. Unfortunately, we cannot analyze the efficiency within these groups or previously calculated clusters, since for adequate DEA results, the number of DMUs considered should be at least two times greater than the number of input and output parameters.

Table 3 shows that during 2019–2021, DMUs 1, 2 and 4 are effective (Score = 1); i.e., of all the DMUs under consideration, these three have the optimal ratio of inputs and outputs. Considering that we were looking at an exit-oriented model, the DMU data has the maximum exits (revenues and profits) at actual entries. Therefore, the MaxDEA 8Basic program recommended as the Benchmark the same values (themselves), and the parameters of the same DMUs as the design optimal parameters.

Of the other DMUs considered, DMU 3 is closest to the efficiency, with its score ranging from 0.789153954 in 2019 to 1.0 in 2021. As a benchmark, the program suggests focusing on DMU 1, 2 and 4 in 2019 and 2020 in different proportions. Recommendations for input and output parameters were obtained by calculation of optimal parameters:

- In 2019, assets—USD 275,909 million, revenues—USD 205,101.9313 million and profits—USD 43,518.75809 million;
- In 2020, assets—USD 319,616 million, revenues—USD 269,620.5732 million and profits—USD 56,677.29026 million;

When these ratios are reached (in the corresponding year), DMU 3 will reach the efficiency frontier (in the corresponding year). For DMU 5, 6, 7 and 8 in 2019, DMU 4 and all its corresponding indicators are offered as a benchmark. In 2020 and 2021, DMU 1, 2 and 4 are offered as a benchmark in various proportions for each analyzed DMU. The calculated optimal values for assets, revenues and profits are presented in Table 3 in the corresponding cells.

Starting the next stage of the study in this manuscript, aimed at studying the latent opportunities and benefits arising from the creation and functioning of banking ecosystems, it should be noted that given that ecosystems also have their own (original and exclusive) financial technologies characterized by a special organization of financial flows that form ecosystems, which together with a special combination of financial technologies used in the ecosystem that are, among other things, the know-how of the system, and noting the high potential for the development of financial technologies in the system, as well as the advanced nature of precisely those ecosystems organized by financial and banking institutions (organizations) when they play the role of an orchestrator, in this article we pay special attention to the innovative and technological potential of ecosystem business models, which, like other technologies, are among those possessed by participants, or which are used use in this ecosystem, and create conditions for the development of the ecosystems themselves, increasing their economic potential and creating conditions for the innovative development of the whole economy.

In the process of the functioning of the ecosystem, its technological capacity increases because of the regularly carried out technological exchange between the participants of the ecosystem. This process is predetermined by the nature of ecosystems and can be described as follows: the growth of technology makes it possible to increase the productivity of the ecosystem, its scale (see also [1]) and the scale of the tasks it solves and leads to an increase in competitiveness, profitability, market capitalization, market share, the number of transactions and consumer loyalty.

We have described the content of the process of technological increment of the banking ecosystem as follows.

Let there be some bank ecosystem— S , which because of the growth of technologies and participants is transformed from the state (system status) S_0 to the state (system status) S_n in time, remaining in the same ecosystem. In this ecosystem (as a system). There are m participants (A) (A_1, A_2, \dots, A_m) at the zero stage S_0 .

$$S_0 \cup \{A_1, A_2, \dots, A_m\}, \tag{5}$$

Each of these is the owner of a certain number of technologies, but for simplicity at this stage we will assume that the number of technologies (t) for all participants is the same (l):

$$T \in A,$$

Specifying that each agent A_m owns a certain number of technologies:

$$T^{A_1} \in A_1$$

$$T^{A_2} \in A_2$$

...

$$T^{A_m} \in A_m,$$

or:

$$\{t_1^{A_1}, t_2^{A_1}, \dots, t_l^{A_1}\} \in A_1,$$

$$\{t_1^{A_2}, t_2^{A_2}, \dots, t_l^{A_2}\} \in A_2,$$

...

$$\{t_1^{A_m}, t_2^{A_m}, \dots, t_l^{A_m}\} \in A_m, \tag{6}$$

That is, each A belongs to a certain technological set (combination) T .

Each A is characterized by a certain performance of technologies that allows you to perform your tasks in the best possible way. It can be a measure of profitability, the ability to handle consumer requests. In general, this is the technological capacity of this partner

organization (A), which plays the role of a subsystem in shaping the overall capacity (or productivity) of the entire ecosystem— S_0 .

If individually each of the partners (A_m) has own productivity:

$$\begin{aligned}
 y_0^{A_1} &= f(t_1^{A_1}, t_2^{A_1}, \dots, t_l^{A_1}), \\
 y_0^{A_2} &= f(t_1^{A_2}, t_2^{A_2}, \dots, t_l^{A_2}), \\
 \dots \\
 y_0^{A_m} &= f(t_1^{A_m}, t_2^{A_m}, \dots, t_l^{A_m}),
 \end{aligned}
 \tag{7}$$

However, functioning within the same ecosystem, each of the participants acquires new technologies that he receives from borrowing from other partners. Consider three stages (iterations).

The first of them is when the technology exchange did not take place and the bank ecosystem S did not change technologically. This period will be considered stage 0. Its content is discussed above, but the system operation function S (productivity (bank ecosystem)) will look like this:

$$Y_0 = F_0(T_0^{A_1}, T_0^{A_2}, \dots, T_0^{A_m}), \tag{8}$$

The system owns as much technology as before: technological growth has not occurred.

$$\{T^{A_1}, T^{A_2}, \dots, T^{A_m}\} \in S_0 \tag{9}$$

Let the technology exchange take place at stage I, when each participant of this bank ecosystem exchanged at least one technology by acquiring another. Then each of the participants already has one technology more, that is, $(l + 1)$:

$$\begin{aligned}
 \{t_1^{A_1}, t_2^{A_1}, \dots, t_l^{A_1}, t_{l+1}^{A_1}\} &\in A_1^I, \\
 \{t_1^{A_2}, t_2^{A_2}, \dots, t_l^{A_2}, t_{l+1}^{A_2}\} &\in A_2^I, \\
 \dots \\
 \{t_1^{A_m}, t_2^{A_m}, \dots, t_l^{A_m}, t_{l+1}^{A_m}\} &\in A_m^I
 \end{aligned}
 \tag{10}$$

Then in stage I, separately, each of the partners (A_m) has another individual productivity:

$$\begin{aligned}
 y_{A_1}^I &= f(t_1^{A_1}, t_2^{A_1}, \dots, t_l^{A_1}, \dots, t_{l+1}^{A_1}), \\
 y_{A_2}^I &= f(t_1^{A_2}, t_2^{A_2}, \dots, t_l^{A_2}, \dots, t_{l+1}^{A_2}), \\
 y_{A_m}^I &= f(t_1^{A_m}, t_2^{A_m}, \dots, t_l^{A_m}, \dots, t_{l+1}^{A_m}),
 \end{aligned}
 \tag{11}$$

In stage I, the system operation function of the entire bank ecosystem S and its new state S_I will look like this:

$$Y_I = F_I(T_I^{A_1}, T_I^{A_2}, \dots, T_I^{A_m}), \tag{12}$$

As well as:

$$Y_I > Y_0. \tag{13}$$

That is, the potential of the system has increased.

The S_0 system was transformed into the S_I system by the number of technologies it owns:

$$\{T^{A_1}, T^{A_2}, \dots, T^{A_m}, \dots, T^{A_{m'}}\} \in S_I, \tag{14}$$

where m' is the set of technologies that the partners received as a result of the exchange.

However, the structure of the bank ecosystem remains the same:

$$S_I \cup \{A_1, A_2, \dots, A_m\}, \tag{15}$$

That is, the bank ecosystem has changed partially.

$$S_I \approx S_0 \tag{16}$$

Suppose that at stage II a new participant ($m + 1$) is included in the bank ecosystem, the number of which will grow to some finite number (v), at some stage there will be a withdrawal of some technology t_z , which also participates in the exchange of technologies and the number of technological exchanges will increase by k (i.e.), and is formed by one new technology and each of the participants of bank ecosystem as a result of adaptation to the production conditions of each of the individual participants, as new technologies (l'), expressed as derivatives, then:

$$\begin{aligned} \{t_1^{A_1}, t_2^{A_1}, \dots, t_l^{A_1}, t_{l+1}^{A_1}, t_{l'}^{A_1}, \dots, t_k^{A_1}\} &\in A_1^{II}, \\ \{t_1^{A_2}, t_2^{A_2}, \dots, t_l^{A_2}, t_{l+1}^{A_2}, t_{l'}^{A_2}, t_k^{A_2}\} &\in A_2^{II}, \\ \dots \\ \{t_1^{A_m}, t_2^{A_m}, \dots, t_l^{A_m}, t_{l+1}^{A_m}, t_{l''}^{A_m}, t_k^{A_m}\} &\in A_m^{II}, \\ \{t_1^{A_{m+1}}, t_2^{A_{m+1}}, \dots, t_l^{A_{m+1}}, t_{l+k}^{A_{m+1}}, t_{l'}^{A_{m+1}}\} &\in A_{m+1}^{II}. \end{aligned} \tag{17}$$

Then in stage II, the individual performance of each of the partners (A_{m+1}) is determined by the functions:

$$\begin{aligned} y_{A_1}^{II} &= f(t_1^{A_1}, t_2^{A_1}, \dots, t_l^{A_1}, \dots, t_{l+1}^{A_1}, t_{l+1}^{A_1}, t_{l'}^{A_1}, \dots, t_k^{A_1}), \\ y_{A_2}^{II} &= f(t_1^{A_2}, t_2^{A_2}, \dots, t_l^{A_2}, \dots, t_{l+1}^{A_2}, t_{l+1}^{A_2}, t_{l'}^{A_2}, \dots, t_k^{A_2}), \\ \dots \\ y_{A_m}^{II} &= f(t_1^{A_m}, t_2^{A_m}, \dots, t_l^{A_m}, \dots, t_{l+1}^{A_m}, t_{l'}^{A_m}, \dots, t_k^{A_m}) \\ y_{A_{m+1}}^{II} &= f(t_1^{A_{m+1}}, t_2^{A_{m+1}}, \dots, t_l^{A_{m+1}}, \dots, t_{l+k}^{A_{m+1}}, t_{l'}^{A_{m+1}}), \end{aligned} \tag{18}$$

It goes without saying that in reality:

$$t_1^{A_1} \neq t_1^{A_2} \neq t_1^{A_m} \neq t_1^{A_{m+1}} \neq t_1^{A_{m+v}}; \tag{19}$$

$$t_2^{A_1} \neq t_2^{A_2} \neq t_2^{A_m} \neq t_2^{A_{m+1}} \neq t_2^{A_{m+v}}; \tag{20}$$

$$t_l^{A_1} \neq t_l^{A_2} \neq t_l^{A_m} \neq t_l^{A_{m+1}} \neq t_l^{A_{m+v}}; \tag{21}$$

$$t_{l'}^{A_1} \neq t_{l'}^{A_2} \neq t_{l'}^{A_m} \neq t_{l'}^{A_{m+1}} \neq t_{l'}^{A_{m+v}} \tag{22}$$

However:

$$t_l^{A_1} \cong t_l^{A_2} \cong t_l^{A_m} \cong t_l^{A_{m+1}} \cong t_l^{A_{m+v}}; \tag{23}$$

$$t_{l+k}^{A_1} \cong t_{l+k}^{A_2} \cong t_{l+k}^{A_m} \cong t_{l+k}^{A_{m+1}} \cong t_{l+k}^{A_{m+v}}, \tag{24}$$

Then:

$$Y_{II} = F_0(T_{II}^{A_1}, T_{II}^{A_2}, \dots, T_{II}^{A_m}, T_{II}^{A_{m+1}}, \dots, T_{II}^{A_{m+v}}), \tag{25}$$

However:

$$Y_{II} > Y_I, \tag{26}$$

$$Y_{II} \gg Y_0. \tag{27}$$

Acts of exchange will not always lead to the formation of a new technology.

Hence:

$$S_{II} \cup \{A_1, A_2, \dots, A_{m+v}\}, \tag{28}$$

$$\{T^{A_1}, T^{A_2}, \dots, T^{A_m}, \dots, T^{A_{m+1}}, \dots, T^{A_{m+v}}\} \in S_{II}. \tag{29}$$

Ecosystem *S* has been transformed into system *S_{II}*; further transformations will occur up to some *n* (it is inappropriate to show the growth of the system further), i.e.:

$$S_O < S_{II} > S_I, \tag{30}$$

$$S_n \gg S_0 \tag{31}$$

In terms of both scale and productivity, other things are equal. Transformation occurs with the growth of two factors—an increase in the number of technologies and the facts of their effective exchange and with the inclusion of the *v*-th participant.

However, the growth of this bank ecosystem, which is a system with open-closed access for participants, may suffer from entropy, as a process that causes the “irreversible dissipation of energy” of this system, which in the economic system of relations can contribute to the undesirable spread of exclusive organizational, technical and marketing technologies and its know-how of the system beyond its limits. In this regard, it is necessary to note the disciplining nature of the financial structures (financial infrastructure) of banking ecosystems.

As can be seen, this model, which should be characterized as a model of technological increment of the ecosystem, shows how the functioning of the ecosystem contributes to the growth of the innovative potential of the bank that owns the ecosystem and orchestrates it. The uniqueness of ecosystems as business models and the specifics of technologies and their exchange create unique conditions when, in the process of movement of goods and services, financial and logistical flows, transformation, optimization and improvement of technologies that separate companies had before joining the ecosystem, which do not exclude and even contributes to the formation of innovative technologies. This opportunity appears because of the implementation of various forms of communication between ecosystem participants. They enrich their technological knowledge and unwittingly generate innovative technologies that make the system unique. But it is not only that. The main motive for the formation of an ecosystem by a bank is the desire to maintain or increase the size of its market (its customers) and they manage to do this, but there is also a latent meaning, which consists in the fact that ecosystem business models, by their nature (as well as by the nature of information and technology), allow the generation of technology, and if banks take this into account, they can become centers of technological knowledge. The generation of technologies within the ecosystem is necessary not only to ensure the sustainability of development but can also serve to develop the functions of banks (orchestrators of ecosystems) when they cannot only have technologies for the development of new production areas by investing in their projects, but also become an independent participant in the market of innovative technologies. Thus, the influence of the nature of the ecosystem business model, technology and banking forms a unique combination that is realized in ecosystems, which is advisable for banks to use.

4. Discussion

The points of discussion relate to the fact that there is no way to obtain accurate information both about the costs of banks for the formation and development of the ecosystem, and about the growth of their profits and revenues because of the functioning of their ecosystems, caused by the lack of special reporting. This is explained by the fact that the formation of ecosystems is closely connected with the processes of digitization and with the processes of mergers and acquisitions carried out by banks. We cannot be sure that all the costs of digitization and acquisitions are directly related to building ecosystems. But we can be sure that the process of ecosystem formation is always connected with both the first and the second. Therefore, the analysis of profits, revenues and increments of assets are rather indicators reflecting the dynamics than indirect indicators, but they cannot be considered as indicators that do not reflect their dynamics. In this regard, the direction of future research will be to conduct a broader comparative analysis aimed at studying the effectiveness of ecosystem activities of banks. In addition, we do not exclude that the income from the functioning of ecosystems for banks at the first stages may be negative, which is explained by the costs of creating and developing the ecosystem. That is why we considered the dynamics of assets.

The debatable point also lies in that it was impossible to study a longer period, since the start to the beginning of the functioning of banking structures was taken recently and this is an innovative activity for banks, this also determines the directions for the development of future research.

The points of discussion are related to the limitations of the study, which are, on the one hand, considered a rather small sample size, although logically justified, which also implies considering that the number of financial institutions forming their ecosystems will grow because of the prospects of this type of business. On the other hand, the given model has a universal character and can be applied in non-financial, non-banking structures.

Limitations also determine the methods used, including those directly related to the technological increment model; insufficient attention to the totality of external factors limits the development of this ecosystem (including the presence of competition and government restrictions, as well as the need to bear marketing costs and the costs of ensuring the safety and integrity of the ecosystem, increasing the level of complexity with the development of ecosystems).

The prospects for future research are defined by us as related to the study of the boundaries of the development of individual ecosystems, the study of their institutional features and sustainability of development, the formation and development of innovative ecosystems.

For ourselves, we see the future development of research in the formation of an institutional theory of the functioning of ecosystems, designed to explain the nature of partnerships and the transforming forms of implementation of externals and internals of a positive and negative nature. An important direction will be the formation of a marketing concept for the formation and promotion of ecosystem technologies and the formation of models for the functioning of ecosystem.

5. Conclusions

Thus, the study made it possible to find out that for banking institutions the formation of ecosystems is of great interest, and many banks carry out their activities in their formation. Given that this process is investment-intensive and requires high competencies in their development of digitalization and the organization of competent management in intra-banking activities, as well as highly effective marketing activities within and outside their ecosystem. It should be noted that by forming ecosystems, banks are reaching a new level of organization of activities, expanding their competencies, and diversifying their activities. In general, one can be sure that the creation of banking ecosystems is not a tribute to fashion, but an opportunity to improve their financial performance and create additional sources of growth. In the formation of ecosystems for banks, new opportunities are formed that have a hidden form.

In addition to the above, these are opportunities to increase the number of customers, the formation of unique synthesized banking and financial products. However, the most important thing, in our opinion, is that innovative technologies are formed in ecosystems, formed through cooperation between the orchestrator and complementarities and between complementarities. The possibility of establishing control over the innovations created by the ecosystem by the orchestrator bank should allow it not only to gain access to innovations created in various areas, but also to manage and even own the intellectual property created within the ecosystem. Thus, the arranging bank becomes a strong agent of the innovative technology market and the owner of advanced intellectual property. This means both new competencies and new opportunities and prospects for growth.

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Appendix A

Table A1. Data for cluster 1 for regression analysis *.

Year	DMU	Profits, USD Million (X ₁)	Revenues, USD Million (X ₂)	Assets, USD Million (X ₃)
2015	DMU 5	17,242	77,277	1,731,210
	DMU 6	22,894	86,057	1,787,632
2016	DMU 5	14,912	70,797	1,792,077
	DMU 6	21,938	88,267	1,930,115
2017	DMU 5	−6798	72,444	1,842,465
	DMU 6	22,183	88,389	1,951,757
2018	DMU 5	18,045	72,854	1,917,383
	DMU 6	22,393	86,408	1,895,883
2019	DMU 5	19,401	74,300	1,951,158
	DMU 6	19,715	86,832	1,925,753
2020	DMU 5	11,047	75,501	2,260,090
	DMU 7	9459	44,560	1,163,028
2021	DMU 5	21,952	71,884	2,291,413
	DMU 6	21,548	78,492	1,948,068
	DMU 7	21,635	59,339	1,463,988

* Source: calculated by the authors based on the data [59–83,90–124].

Table A2. Data for cluster 2 for regression analysis *.

Year	DMU	Profits, USD Million (X ₁)	Revenues, USD Million (X ₂)	Assets, USD Million (X ₃)
2015	DMU 1	3688	17,928	49,407
	DMU 2	596	107,006	65,444
	DMU 3	16,348	74,989	147,461
	DMU 4	53,394	233,712	290,345
	DMU 7	6083	33,820	861,395
	DMU 8	3064	23,539	375,054
2016	DMU 1	10,217	27,638	64,961
	DMU 2	2371	135,987	83,402
	DMU 3	19,478	90,272	167,497
	DMU 4	45,687	215,639	321,686
	DMU 7	7938	30,608	860,165
	DMU 8	8934	32,917	418,237
2017	DMU 1	15,934	40,653	84,254
	DMU 2	3033	177,866	131,310
	DMU 3	12,662	110,855	197,295
	DMU 4	48,351	229,234	375,319
	DMU 7	4286	32,730	916,776
	DMU 8	12,998	39,364	470,693
2018	DMU 1	22,112	55,838	97,334
	DMU 2	10,073	232,887	162,648
	DMU 3	30,736	136,819	232,792
	DMU 4	59,531	265,595	365,725
	DMU 7	10,459	36,616	931,796
	DMU 8	11,972	32,998	449,067
2019	DMU 1	18,485	70,697	133,376
	DMU 2	11,588	280,522	225,248
	DMU 3	34,343	161,857	275,909
	DMU 4	55,256	260,174	338,516
	DMU 7	8466	36,546	992,968
	DMU 8	13,649	37,969	483,929
2020	DMU 1	29,146	85,965	159,316
	DMU 2	21,331	386,064	321,195
	DMU 3	40,269	182,527	319,616
	DMU 4	57,411	274,515	323,888
	DMU 6	3377	74,264	195,291
	DMU 8	10,301	33,813	487,521
2021	DMU 1	39,370	117,929	165,987
	DMU 2	33,364	469,822	420,549
	DMU 3	76,033	257,637	359,268
	DMU 4	94,680	365,817	351,002
	DMU 8	16,839	30,824	554,093

* Source: calculated by the authors based on the data [59–83,90–124].

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