ЕКОНОМІЧНА ТЕОРІЯ

UDC 330.341.1:005.21
JEL Classification: O32, L20, O38, F15
DOI: https://doi.org/10.20535/2307-5651.36.2026.360535

Smoliar Liubov
PhD in Economics, Professor
ORCID ID: 0000-0002-5626-4043
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

DYNAMIC AND META-DYNAMIC CAPABILITIES OF INNOVATION ECOSYSTEMS AS A MECHANISM OF STRATEGIC NAVIGATION UNDER GLOBAL PERMACRISIS

This article develops a theoretical approach to the analysis of innovation ecosystems in the context of global permacrisis and substantiates the category of meta-dynamic capabilities as a mechanism for strategic navigation of systems in conditions of structural turbulence. It is shown that the classical theory of dynamic capabilities, developed at the firm level, explains adaptation through the restructuring of resource configurations, but does not provide sufficient tools for analysing the transformation of the architecture of interaction within ecosystems. Based on the debate between approaches, an extension of the theory to the ecosystem level is proposed through the introduction of a three-level model of capabilities: operational, dynamic and metadynamic. Metadynamic capabilities are defined as a system's ability to alter its institutional and architectural configuration: coordination rules, actor roles, standards, interfaces, and value capture mechanisms. A system of indicators has been developed for their operationalisation, along with an integrated index of ecosystem strategic navigation. A comparative illustration of the model is provided using the example of Ukraine's high-tech defence-oriented innovation ecosystem and the institutional transformation of the European Union's innovation ecosystem within the framework of strategic autonomy (the EU Chips Act, the European Defence Fund). It is demonstrated that, in conditions of permacrisis, the resilience of ecosystems is determined not only by the speed of adaptation, but also by the capacity for architectural restructuring.

Keywords: *innovation ecosystem, dynamic capabilities, metadynamic capabilities, strategic navigation, permacrisis, strategic autonomy.*

Смоляр Л. Г.
Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»

ДИНАМІЧНІ ТА МЕТАДИНАМІЧНІ МОЖЛИВОСТІ ІННОВАЦІЙНИХ ЕКОСИСТЕМ ЯК МЕХАНІЗМ СТРАТЕГІЧНОЇ НАВІГАЦІЇ В УМОВАХ ГЛОБАЛЬНОЇ ПЕРМАКРИЗИ

У статті розвинено теоретичний підхід до аналізу інноваційних екосистем у контексті глобальної пермакризи та обґрунтовано категорію метадинамічних можливостей як механізму стратегічної навігації систем в умовах структурної турбулентності. Показано, що класична теорія динамічних можливостей, сформована на рівні фірми, пояснює адаптацію через перебудову ресурсних конфігурацій, однак не забезпечує достатнього інструментарію для аналізу трансформації архітектури взаємодії в екосистемах. На основі полеміки між підходами запропоновано розширення теорії до екосистемного рівня через введення трирівневої моделі можливостей: операційних, динамічних та метадинамічних. Метадинамічні можливості визначено як здатність системи змінювати інституційну та архітектурну конфігурацію: правила координації, ролі акторів, стандарти, інтерфейси та механізми захоплення вартості. Розроблено систему індикаторів для їх операціоналізації та інтегральний індекс стратегічної навігації екосистеми. Порівняльна ілюстрація моделі здійснена на прикладі високотехнологічної оборонно-орієнтованої інноваційної екосистеми України та інституційної трансформації інноваційної екосистеми Європейського Союзу в межах стратегічної автономії (Закон ЄС про чіпи, Європейський оборонний фонд). Доведено, що в умовах пермакризи стійкість екосистем визначається не лише швидкістю адаптації, а здатністю до архітектурної перебудови.

Ключові слова: *інноваційна екосистема, динамічні можливості, метадинамічні можливості, стратегічна навігація, пермакриза, стратегічна автономія.*

Introduction. The global economic environment at the beginning of the 21st century is characterised by a transition from cyclical instability to a state of prolonged multidimensional turbulence. In international discourse, this state is referred to as a "*permacrisis*" – a period of prolonged instability and danger caused by a series of interrelated crises [7]. The convergence of geopolitical, technological, energy, financial and security shocks is shaping a new reality in which traditional models of strategic planning are losing their predictability.

In strategic management, the theory of dynamic capabilities has become the key response to the problem of turbulence. In its classical formulation, dynamic capabilities are interpreted as an organisation's ability to integrate, develop and reconfigure internal and external competencies in response to changes in the environment [1]. 's further development of the concept through the sensing-seizing-reconfiguring triad has clarified the process-oriented nature of strategic renewal [2]. Despite a substantial body of research, most studies focus on the level of the individual firm. However, the contemporary creation of innovative value increasingly takes place within the framework of innovation ecosystems: structures of interdependent actors, roles and complementarities [5; 6]. In such systems, there is no complete hierarchical control, and coordination is achieved through an architecture of standards, interfaces and institutional rules. Consequently, a theoretical gap emerges: existing approaches to dynamic capabilities do not explain the mechanisms of transformation of the architecture of interaction within innovation ecosystems.

This issue is of particular relevance to Ukraine, where, since 2022, a high-tech defence-oriented innovation ecosystem has been taking shape, within which defence demand is becoming a system-defining driver of technological transformations. An institutional marker of this restructuring is the launch in 2023 of the BRAVE1 platform as a coordination mechanism for the state, business and military users [8; 9]. Thus, the relevance of the study stems from the need for a theoretical understanding of the mechanisms of strategic navigation of innovation ecosystems in a permacrisis environment and the development of tools for their empirical measurement.

Formulating the purposes of the article. The aim of the study is to develop the theory of dynamic capabilities at the ecosystem level by substantiating the category of metadynamic capabilities and their operationalisation.

Objectives:

1. To clarify the scope of the theory of dynamic capabilities as it applies to ecosystems.
2. Develop a three-level model of ecosystem capacity.
3. Propose a system of indicators for their operationalisation.
4. To illustrate the model's application using the examples of Ukraine and the EU.

Methodology. The methodological framework is based on works on the theory of dynamic capabilities [1–4] and the structural theory of ecosystems [5; 6]. Conceptual synthesis, structural-logical analysis, modelling and a comparative approach were employed.

Presentation of the main research material. The theory of dynamic capabilities originates from the works of D. Teece, G. Pisano, and A. Shuen [1], who developed it as a response to the limitations of the resource-based view, which focuses on static advantages. The underlying logic of dynamic capabilities is based on the premise that sustained competitive advantage in an environment of rapid change arises not only from unique existing resources, but from an organisation's managed ability to integrate, develop and reconfigure internal and external competencies in response to environmental uncertainty and instability [1].

Further theoretical refinement of dynamic capabilities relates to their process-oriented and managerial nature and the role of dynamic capabilities in shaping an organisation's competitive advantages in a dynamic environment [2]. Three micro-foundations of dynamic capabilities have been identified: sensing-seizing-reconfiguring [2], where sensing is associated with the identification of opportunities/threats, seizing with the mobilisation of resources for their realisation, and reconfiguring with the transformation of the resource base and organisational configurations [2]. This concept has also been developed in domestic academic literature, where it is adapted to the conditions of a transitional economy and used to explain the strategic adaptability of enterprises, their innovative activity and competitiveness (V. Heyets, A. Chukhno, O. Ilyash, T. Hrynko, V. Zakharchenko et al.).

However, within the context of the ongoing academic debate regarding the "nature" of dynamic capabilities, an alternative position has emerged. K. Eisenhardt and J. Martin have demonstrated that dynamic capabilities are not, in themselves, a source of uniqueness: under certain conditions, they can be replicated, and the competitive advantage stems from combinations and timing [3]. Dynamic capabilities often take the form of specific, identifiable processes/routines (new product development, strategic decisions), and their effectiveness is largely determined by the context of the environment [3]. Thus, whilst in D. Teece's approach dynamic capabilities act as a source of strategic renewal for firms through the managed reallocation of resources, in Eisenhardt and Martin's approach they take on the character of context-dependent processes that do not guarantee a long-term advantage.

The third point of contention was formulated by S. Winter [4]. He proposes distinguishing between ordinary capabilities (zero level), which allow firms to "make a living" in the short term, and higher-order dynamic capabilities as the ability to transform these ordinary capabilities themselves [4]. His argument is fundamental: higher-order capabilities do not come free of charge; their viability is determined by the ratio of investment costs in the "higher order" to the benefits derived from systematic, reproducible, institutionalised restructuring [4].

A key limitation of the classical perspective on dynamic capabilities is its focus on firm-centricity. It "naturally" assumes a centralised decision-making process and control over resources within the organisation.

In contrast, modern innovations increasingly occur in configurations where the outcome depends on the coordination of complementarities between different participants. The key unit is not an individual company, but the architecture of global collaboration between actors, knowledge and technologies. Therefore, at the level of innovation ecosystems, we are interested not only in the question of "how firms adapt", but also in "how the very structure of interactions changes", which determines the opportunities/constraints for firms and the speed of the technology cycle.

In contemporary strategic literature, an ecosystem is increasingly defined not as a "network" metaphor – which does not always have a coordinating centre and does not explain the mechanism of value capture – but as a structured architecture of multilateral, multi-level complementarities. According to R. Adner, the "glue" that compels autonomous players to cooperate and make complementary decisions is *the focal value* proposition (FVP) [5]. M. Jacobides, C. Cennamo, and A. Gawer demonstrate that ecosystems emerge where value is created through complementarity, there is no complete hierarchy of control, and the coordination of modular innovations occurs through an interface architecture [6]. In an ecosystem, the structural elements are:

– central nodes, which form the core of the ecosystem (their types: digital platform, technology core, product core, infrastructure core, data; their key function is orchestration and value capture);

– peripheral modules created by partners: application developers, component suppliers, integrators. Modularity allows the ecosystem to connect new players without disrupting the core, and to expand geographically;

– access interfaces – "connection rules". Interfaces determine who can connect, under what conditions, and with what level of access;

– interaction rules.

As we can see, an innovative ecosystem functions as an architecturally organised system, where the central core, through interfaces and interaction rules, coordinates peripheral modules, ensuring scalable creation and capture of value. An ecosystem creates value when the end result for the customer is a configuration of complements that a single firm cannot effectively create on its own. In an ecosystem, the following become key:

– *complementarity* (the diversity effect) – the more relevant complements (modules/services/integrations) there are, the broader the value proposition, the better the adaptation to segments, and the faster the innovative renewal "at the edges" of the ecosystem. Ecosystems are particularly effective when the coordination of modular innovations takes place without a strict hierarchy [6];

– *interface control* (reduction of transaction costs) – standards, APIs, certifications, protocols – this is the "coordination infrastructure" that reduces the cost of partner integration, accelerates the entry of new modules, and reduces negotiation and control costs [6];

– *systemic barriers to entry and "value capture*" – barriers are created not by the product, but by the access architecture (interfaces, entry/exit rules, control of standards, the role of the "core" and complementary players) [6]. Whoever controls the interfaces and standards controls the value flows and the "right" to scale. This is the transition from "product competition" to "architecture competition". It is not the one with the best product who wins, but the one who has created the best configuration of complements and controls the rules of interaction;

– *distribution of innovation risks* – the search for solutions is shared among many players; innovation becomes distributed, which increases the "throughput" capacity of innovation: more attempts mean faster learning, and risks become interlinked;

– *Conjunctive risk and the "bottleneck" effect* – dependence on all elements, where the failure of a single element destroys the entire value proposition. Value arises only if all critical complements are functioning. Ecosystems are particularly sensitive to situations where all parts must work simultaneously. Even if an individual firm possesses strong dynamic capabilities, the failure of a complement or breakdowns in role coordination can derail the innovation's market launch [5].

Thus, an ecosystem is not merely a network of partners. It is a structured architecture of complementarities, where success depends on the coordination of all critical elements. The primary strategic tool is the management of dependencies, working with architectural dependencies and structural coordination [5].

This raises a research gap: if an ecosystem is a structure, then its "capacity for development" must involve not only network adaptation (reconfiguring) within the existing architecture, but also changing the architecture itself: changes in roles, standards, institutional coordination mechanisms, mechanisms for transitioning to new technological trajectories, rules of participation, and modes of access to resources. Classical dynamic capabilities explain changes in organisations" resource configurations [1; 2], but do not provide sufficient tools to explain "how to change the very rules of change" at the ecosystem level of analysis.

An ecosystem's ability not only to "recover" but also to restructure in response to structural shifts and new constraints is of fundamental importance in conditions of permacrisis. In public discourse, the term "permacrisis" has become established as a state of prolonged instability and danger, where crises "flow" into one another without returning to a stable state [7]. This definition is methodologically significant: it implies that the "norm" is not a return to equilibrium, but a constant readjustment to new constraints (logistical, regulatory, technological, security, staffing, and climatic).

Drawing on Winter's idea of higher-order capabilities as the ability to alter other capabilities [4], as well as on the structural logic of ecosystems [5; 6], we propose the introduction of the category of metadynamic capabilities of an innovation ecosystem. The *metadynamic capabilities of an innovation ecosystem* are higher-order capabilities that enable the controlled modification of the ecosystem's institutional and architectural configuration (rules, roles, coordination mechanisms, standards/interfaces and value capture regimes) in response to structural shocks and long-term shifts in the environment. This definition differs from "dynamic capabilities of an ecosystem". We interpret dynamic capabilities at the ecosystem level as the ability to rapidly change *interaction configurations* (alliances, resource allocation between modules, intensity of co-development) without altering the basic *rules of the game.* Metadynamic capabilities are viewed as the ability to change the rules of the game (architecture and institutions), i.e. to ensure *strategic navigation*.

Three analytical implications follow from this.

Firstly, in a permacrisis, the resilience of an ecosystem is determined not only by buffers/reserves and the rate of recovery, but also by the potential for structural restructuring, which reduces systemic dependencies and bottlenecks.

Secondly, metadynamic capabilities are linked to power and architectural control: the ecosystem must generate mechanisms for the legitimate amendment of rules (new institutional frameworks, new standards, new access regimes); otherwise, changes will remain fragmented and informal.

Thirdly, dynamic and metadynamic capabilities have different time horizons: dynamic capabilities operate within the horizon of rapid adaptation cycles; metadynamic capabilities – within the horizon of trajectory shifts and the restructuring of coordination regimes.

Based on [4–6], a three-level hierarchy of capabilities within an innovation ecosystem is proposed:

1) Operational capabilities of the ecosystem (O-level) – institutions and infrastructure ensuring routine functioning (standard formats of cooperation, basic rules of participation, communication channels, procedural testing mechanisms, basic support programmes).

2) Dynamic capabilities of the ecosystem (D-level) – the ecosystem's ability to rapidly reconfigure interaction patterns (formation of new alliances, reallocation of resources between modules, restructuring of partnership chains) within the existing architecture.

3) Metadynamic capabilities of the ecosystem (MD-level) – the ability to restructure the architecture and rules of interaction (standards, interfaces, roles, coordination mode, institutional mechanisms, value capture principles), which sets the ecosystem on a new trajectory.

Thus, there is a transition from the logic of adaptation (dynamic capabilities) to the logic of navigation (metadynamic capabilities), which entails a change not only in resource configurations but also in the rules governing their interaction.

To illustrate this distinction, it is useful to consider innovation ecosystems, in which value creation occurs through the integration of complementary modules and the coordination of actions by a multitude of actors. In such systems, effectiveness is determined not only by the ability to rapidly reconfigure interaction patterns (which corresponds to dynamic capabilities and is reflected, in particular, in indicators D1–D3), but also by the ability to change institutional rules, the architecture of interaction, and coordination mechanisms. It is precisely these processes that go beyond adaptation and are reflected in the indicators of the metadynamic level (MD1–MD5), which characterise changes in the logic of the ecosystem's functioning.

Thus, whilst dynamic capabilities capture the intensity of opportunity identification, resource mobilisation and the restructuring of network connections, metadynamic capabilities reflect deeper transformations – changes in access rules, the redistribution of roles, the restructuring of architecture and the reorientation of the development trajectory. This is precisely why it is appropriate to consider them as a systemic mechanism for the strategic navigation of an innovation ecosystem.

Metadynamic capabilities can be broken down into five interrelated components (in line with the structural logic of ecosystems [5; 6]):

(MD1) Institutional reconfiguration – the ability to change the rules and instruments that set incentives/constraints for actors (regulatory regimes, rules for access to testing, procurement/certification procedures, data/security regimes, financial support mechanisms).

(MD2) Architectural flexibility – the ability to reconfigure the "core – modules – complementary components" structure and the distribution of roles/centres of influence, whilst maintaining compatibility through interfaces.

(MD3) Coordination restructuring – transition to other coordination regimes (new forms of orchestration, different entry/exit rules, different mechanisms for collective selection/prioritisation).

(MD4) Strategic reorientation of trajectory – the ability to change the dominant technological/market course (portfolio reallocation, change of technological core, reconfiguration of the ecosystem's "core value proposition').

(MD5) Working with structural dependencies and bottlenecks –

the ability to identify critical control points/dependencies (supply, standards, data, components, funding, testing) and restructure the architecture to reduce systemic concentration risks.

These components enable us to move from the general concept of "the ecosystem is changing" to the operational question of "what exactly is changing and how can this be empirically measured". To operationalise these opportunities, we have developed a three-level model and a system of indicators. Since the ecosystem is a structure of interdependencies [5; 6], the operationalisation of opportunities must capture three types of change:

- *behavioural/portfolio* (what actors do and how investment priorities change);
- *network-related* (how the configuration of interactions changes);
- *architectural-institutional* (how rules, roles, standards and access regimes change).

Therefore, a combined system is proposed: (a) indicators of pace/frequency; (b) indicators of network structure; (c) indicators of institutional change; (d) indicators of trajectory reorientation.

Indicators of ecosystem dynamic capabilities (D-level):

D1. Sensing (ecosystem "scanning" and opportunity identification)

- D1.1. Rate of emergence of new technological directions in the ecosystem portfolio: proportion of new directions/sub-directions over a period (e.g., a year) out of the total number of R&D directions.
- D1.2. Intensity of "external signals': the number of new external partnerships/contacts (international teams, corporations, laboratories) over the period.

Rationale: in a dynamic environment, sensing manifests itself in the ecosystem's ability to quickly recognise the emergence of a technological "window" and to draw upon relevant knowledge/competencies [2].

D2. Seizing (mobilisation for opportunity)

- D2.1. Time from opportunity identification to the launch of a joint project (lag in weeks/months).
- D2.2. Share of joint R&D/pilot projects in the overall innovation portfolio (as a proxy for the ability to "seize" opportunities through collective investment and experimentation).

Rationale: seizing at the ecosystem level implies not merely the decision of a single firm, but the coordinated mobilisation of complementary players [5].

D3. Reconfiguring (reconfiguring interaction patterns)

- D3.1. Network turnover rate: the proportion of new/departing actors in key projects over the period.
- D3.2. Frequency of restructuring of partnership ties in strategic modules (number of revisions to cooperation chains).

Logic: reconfiguring at the ecosystem level involves the rapid reconfiguration of the network of interactions, but without changing the "rules of the game".

Point of contention: if we follow Eisenhardt and Martin [3], these D-processes should be described as recurring mechanisms (ecosystem routines): for example, regular selections/pitches/demo days, testing sprints, modular co-development. They can then be tracked and compared across ecosystems.

Indicators of an ecosystem's metadynamic capabilities (MD level):

MD1. Institutional reconfiguration (changes to rules/tools)

• MD1.1. Frequency of updates to access rules and procedures (e.g., regulations on testing/certification/procurement/participation) per year.

• MD1.2. Diversification of support instruments: the number of instrument types (grants/contracts/joint programmes/incubation/sandboxes/vouchers) and their respective shares.

Practical significance: the ecosystem "learns" to adapt its institutional framework to the pace of innovation; otherwise, high-tech solutions become "stuck" between R&D and scaling.

MD2. Architectural flexibility (restructuring of the core/modules/roles)

• MD2.1. Change in the roles of the core and complementary players: the proportion of projects where the "core" actor changes or the role of the integrator is redistributed.

• MD2.2. Architectural control concentration index (proxy): if control over standards/interfaces is overly concentrated, the ecosystem may be agile in the short term but fragile in a permacrisis (risk of deadlock).

Theoretical basis: ecosystems are coordinated through modularity and interfaces; control over them forms architectural power [6].

MD3. Coordination restructuring (change in orchestration mechanism)

• MD3.1. Transition between coordination modes: from predominantly hierarchical to platform-based/hybrid (marked by the emergence of a coordination platform, standard selection "pipelines", test loops, "fast-track procurement" mechanisms, etc.).

• MD3.2. The proportion of decisions made through collective selection/prioritisation mechanisms (councils, committees, joint expert panels).

Meaning: in a permacrisis, when technologies change rapidly, coordination becomes a "bottleneck"; the ability to change the coordination regime is a marker of metadynamism.

MD4. Strategic reorientation of the trajectory (change of course)

• MD4.1. Change in portfolio structure: the proportion of resources/projects shifting to a new technological core.

• MD4.2. Pace of "rewriting" priorities: the number of strategic reviews of roadmaps/priorities over a period.

Rationale: strategic navigation is the ability to change the dominant trajectory, rather than merely adapting within the confines of the old one.

MD5. Working with structural dependencies and bottlenecks (architectural resilience)

• MD5.1. Diversification of critical dependencies: the number of alternatives for critical components/channels (supply, testing, funding, data).

• MD5.2. Number of "blocking nodes" eliminated: instances where the ecosystem creates an alternative circuit (alternative standards, alternative testing channels, alternative procurement mechanisms).

This area relates to competition between ecosystems as architectures of power and control [6].

Integrated indices for empirical verification. To ensure the comparability of indicators and the possibility of their subsequent aggregation, it is proposed to normalise the indicators within the range [0; 1] with the subsequent formation of integrated indices.

Dynamic Adaptation Index (DAI)

$$DAI = w_1 D_1 + w_2 D_2 + w_3 D_3, \quad (1)$$

where D_1, D_2, D_3 – the aggregated values of the sub-indicators corresponding to the micro-foundations of sensing, seizing and reconfiguring, respectively.

w_1, w_2, w_3 – weighting coefficients reflecting the re lative importance of the respective components,

$$\sum_{i=1}^{3} w_i = 1.$$

Meta-dynamic *Navigation Index* (MNI)

$$MNI = w_4 MD_1 + w_5 MD_2 + w_6 MD_3 + w_7 MD_4 + w_8 MD_5, \quad (2)$$

where MD_1 – institutional reconfiguration;

MD_2 – architectural flexibility;

MD_3 – coordination restructuring;

MD_4 – strategic reorientation of the trajectory;

MD_5 – addressing structural dependencies;

$w_4 \ldots w_8$ – weighting coefficients of the relevant components,

$$\sum_{1=4}^{8} w_i = 1.$$

Ecosystem Strategic Navigation Index (ESNI)

$$ESNI = \propto \cdot DAI + \beta \cdot MNI, \quad (3)$$

where $\propto, \beta$ – weighting coefficients reflecting the relative role of adaptive and metadynamic processes, $\propto + \beta = 1$.

Theoretical justification of weighting coefficients. In the classical logic of higher-order capability theory (Winter [4]), investments in higher-level capabilities are not always effective, as they are associated with high transaction costs and uncertainty regarding the outcome. This implies that in stable or moderately dynamic environments, the dominance of dynamic capabilities (i.e. $\propto \geq \beta$) may be appropriate.

At the same time, in conditions of a global permacrisis, characterised by frequent "structural breaks', disruptions in value chains and changes in institutional frameworks, there is a shift towards metadynamic opportunities. In such conditions, it is precisely the ability to restructure the ecosystem's architecture that determines its long-term viability.

Consequently, for environments of permanent crisis, the following ratio is justified: $\beta > \propto$, reflecting the dominant role of metadynamic capabilities in ensuring the strategic navigation of the ecosystem.

In the absence of a priori grounds for differentiating weights, it is advisable to apply an equal distribution (for example, $w_i = 1/3$ для *DAI* та $w_i = 1/5$ для *MNI*). For empirical studies, weighting coefficients can be determined using: expert assessment, the Analytic Hierarchy Process (AHP), and factor analysis. The proposed system of indices allows for inter-system comparisons, as well as the analysis of changes over time.

To operationalise dynamic and metadynamic capabilities, a system of indicators is proposed (Table 1). To ensure the comparability of indicators, normalisation within the range [0; 1] is used according to the min–max procedure. For "the lower, the better" indicators (in particular, time lags), inverse normalisation is applied.

Indicators of dynamic capabilities reflect the ecosystem's ability to identify opportunities, mobilise resources and restructure interactions. In particular, the network renewal coefficient can be formalised as:

$$D3 = \frac{|A_t \,\Delta\, A_{t-1}|}{|A_t \cup A_{t-1}|} \tag{4}$$

Metadynamic capabilities, in turn, characterise an ecosystem's ability to change institutional and architectural parameters. A change in the development trajectory can be represented as:

$$MD4 = \frac{1}{2}\sum |\, 8_{k,t} - 8_{k,t-1} \mathrm{I} \tag{5}$$

This form of indicator corresponds to the metric of structural changes and allows for a quantitative assessment of changes in the ecosystem's development trajectory. Other indicators follow a similar logic and are presented in Table 1.

To summarise the proposed approach, we note that integral indices allow us to move from a conceptual description to a formalised assessment of an ecosystem's capabilities, which is critically important for further empirical studies.

To demonstrate the practical application of the proposed model, we present an illustrative example of calculating the ecosystem strategic navigation index (ESNI).

Suppose that the following values are obtained from the normalisation of indicators:

$$D_1 = 0{,}70, D_2 = 0{,}65, D_3 = 0{,}60;$$

$$MD_1 = 0{,}75, MD_2 = 0{,}70, MD_3 = 0{,}70,$$
$$MD_4 = 0{,}80, MD_5 = 0{,}60.$$

Assuming a uniform distribution of weighting coefficients:

$$DAI = \frac{D_1 + D_2 + D_3}{3} = 0{,}65$$

$$MNI = \frac{MD_1 + MD_2 + MD_3 + MD_4 + MD_5}{5} = 0{,}68$$

In conditions of a permacrisis, where metadynamic processes play a decisive role, we assume the following weight ratios $\alpha = 0{,}4. \beta = 0{,}6$:

$$ESNI = 0{,}4 \cdot 0{,}65 + 0{,}6 \cdot 0{,}68 = 0{,}668$$

Table 1

System of indicators for operationalising the dynamic (D) and metadynamic (MD) capabilities of an innovation ecosystem

Indicator code	Component	Indicator content	Metric	Calculation formula
D1 (Sensing)	Scanning for opportunities	The ecosystem's ability to identify new technological directions	Proportion of new trends in the portfolio	$D1 = \frac{N_{new}}{N_{total}}$
D2 (Seizing)	Resource mobilisation	Ability to rapidly launch joint projects	Average time from signal to launch	$L = \frac{1}{m}\sum_{j=1}^{m}(t_j^{start} - t_j^{signal}$ $D2 = 1 - norm(L)$
D3 (Reconfiguring)	Restructuring interactions	Ability to change the partnership network	Network renewal rate	$D3 = \frac{\lvert A_t \,\Delta\, A_{t-1}\rvert}{\lvert A_t \cup A_{t-1}\rvert}$
MD1 (Institutional reconfiguration)	Institutional reconfiguration	Changes to rules, procedures and tools	Frequency of updating institutional mechanisms	$MD1 = \frac{K_{updates}}{T}$
MD2 (Architectural flexibility)	Architectural flexibility	Redefinition of roles and ecosystem structure	Proportion of projects involving a change in roles	$MD2 = \frac{R_{shift}}{P}$
MD3 (Coordination restructuring)	Coordination restructuring	Changes in coordination mechanisms	Index of diversity of coordination mechanisms	$MD3 = \frac{M}{M_{max}}$
MD4 (Strategic reorientation)	Strategic reorientation	Change in the ecosystem's development trajectory	Portfolio structure change index	$MD4 = \frac{1}{2}\sum_{k=1}^{n} \mathrm{I}8_{k,t} - 8_{k,t-1}\mathrm{I}$
MD5 (Working with structural dependencies)	Working with structural dependencies	Reduction of critical dependencies	Dependency diversification index	$MD5 = \frac{1}{Q}\sum_{q=1}^{Q}\frac{S_q}{S_{q,max}}$

The resulting value indicates a relatively high level of strategic navigation of the ecosystem, in which metadynamic capabilities make a decisive contribution, which is consistent with the logic of system functioning in a permacrisis environment.

This confirms the possibility of using the proposed model as an analytical tool for assessing the strategic navigation of innovation ecosystems.

The developed model of metadynamic capabilities acquires particular analytical value when applied to systems operating under conditions of profound structural shifts. In this context, two cases are illustrative: the formation after 2022 of a high-tech defence-oriented innovation ecosystem in Ukraine and the institutional transformation of the European Union's innovation ecosystem within the framework of strategic autonomy policy.

Full-scale war triggered a radical restructuring of Ukraine's innovation ecosystem, as a result of which defence demand became the key driver of technological development. Unlike classical models, where demand is shaped by the market, in this case it is security needs that determine the structure, pace and direction of innovation activity.

The institutional marker of this transformation was the launch in 2023 of the BRAVE1 platform as a coordination mechanism for interaction between the state, business and military users [8; 9], reflecting the transition from a fragmented to an integrated ecosystem architecture.

From the perspective of the proposed model, this allows the Ukrainian case to be interpreted through the prism of a combination of dynamic and metadynamic capabilities. In particular, at the D-level, there is a high intensity of identifying technological capabilities, accelerated mobilisation of resources and rapid restructuring of network interactions. At the same time, at the MD level, deeper transformations are recorded, linked to changes in institutional rules (simplification of procedures and new funding mechanisms), coordination mechanisms (integration of users into the innovation cycle), strategic trajectory (focus on defence tech) and partial diversification of critical dependencies. This indicates the growing importance of MNI components within the structure of the ESNI composite index.

Thus, the Ukrainian case demonstrates a situation where the ecosystem is not merely adapting to changes but is undergoing an architectural re ation under the influence of an exogenous shock, which is a characteristic feature of the activation of metadynamic capabilities.

In contrast to Ukraine, the transformation of the EU's innovation ecosystem is more institutionally driven and takes place within the framework of a strategic autonomy policy. The key instruments of this policy are the EU Chips Act [11] and the European Defence Fund [12], aimed at strengthening technological sovereignty and reducing dependence on external suppliers.

In this case, dynamic capabilities manifest themselves in the development of research programmes, the formation of technology consortia and the support of new areas of innovation. At the same time, metadynamic opportunities are realised through institutional reconfiguration (new regulatory and financial instruments), architectural restructuring (transnational alliances), coordination integration (policy harmonisation) and systematic work on structural dependencies. As a result, a more balanced structure of indices is observed, where the growth of the MNI is strategically managed.

A comparative analysis of the two cases (Table 2) allows us to draw a general conclusion: regardless of the nature of the shock (exogenous or institutional-strategic), it is metadynamic capabilities that act as the key mechanism for ecosystem restructuring. The differences lie in the manner of their activation: reactive (Ukraine) or proactive (EU), which determines the configuration and dynamics of the DAI and MNI indices within the ESNI framework.

Conclusions. The article demonstrates that classical theory of dynamic capabilities requires extension to analyse innovation ecosystems in an environment of global permacrisis. The category of metadynamic capabilities is proposed as the ecosystem's ability to deliberately alter its own institutional and architectural configuration in response to structural shifts.

The developed three-level model (operational, dynamic, and metadynamic capabilities) and system of indicators facilitate the transition from a conceptual description to a formalised assessment of the strategic navigation of ecosystems. The proposed integrated indices (DAI, MNI, ESNI) allow for the analysis of both adaptive processes and the depth of architectural transformations. In environments of permacrisis, given the logic of higher-order capabilities [4], the dominance of metadynamic components ($\beta > \alpha$) is justified, reflecting their decisive role in ensuring long-term sustainability.

A comparative analysis of the cases of Ukraine and the EU confirmed the universality of the proposed model and established that:

1) metadynamic capabilities are activated in response to structural ruptures and the transformation of the institutional environment, regardless of their nature;

2) the resilience of ecosystems is determined not only by the speed of adaptation, but also by the capacity for architectural restructuring and the reduction of critical dependencies;

3) institutional orchestration mechanisms are a key factor in strategic navigation.

Thus, in the modern economy operating under conditions of a permanent crisis, metadynamic capabilities become a system-forming factor in the competitiveness of innovation ecosystems. Further research should focus on the empirical validation of the model and the refinement of the parameters of the integrated indices depending on the type of ecosystem.

Table 2

Comparative analysis of Ukraine's high-tech defence-driven innovation ecosystem and the EU's institutional transformation

Criterion	Ukraine	EU
Type of shock	Exogenous (war)	Structural-strategic
Nature of transformation	Reactive, accelerated	Proactive, institutionally driven
Dominant MD components	Coordination, trajectory	Institutions, dependencies
Role of the state	Orchestrator in a crisis	Strategic architect

References:

1. Teece D. J., Pisano G., Shuen A. Dynamic capabilities and strategic management. *Strategic Management Journal.* 1997. Vol. 18, Iss. 7. P. 509–533. DOI: https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z
2. Teece D. J. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance // *Strategic Management Journal.* 2007. Vol. 28, No. 13. pp. 1319–1350. DOI: https://doi.org/10.1002/smj.640
3. Eisenhardt K. M., Martin J. A. Dynamic capabilities: what are they? *Strategic Management Journal.* 2000. Vol. 21, No. 10–11. pp. 1105–1121. DOI: https://doi.org/10.1002/1097-0266(200010/11)21:10/11<1105::AID-SMJ133>3.0.CO;2-E
4. Winter S. G. Understanding dynamic capabilities. *Strategic Management Journal.* 2003. Vol. 24, No. 10. pp. 991–995. DOI: https://doi.org/10.1002/smj.318
5. Adner R. Ecosystem as structure: an actionable construct for strategy. *Journal of Management.* 2017. Vol. 43, No. 1. pp. 39–58. DOI: 10.1177/0149206316678451
6. Jacobides M. G., Cennamo C., Gawer A. Towards a theory of ecosystems. *Strategic Management Journal.* 2018. Vol. 39, No. 8. P. 2255–2276. DOI: https://doi.org/10.1002/smj.2904
7. Permacrisis. Collins Dictionary. Available at: https://www.collinsdictionary.com/dictionary/english/permacrisis (accessed: 19 February 2026).
8. Ukraine launches BRAVE1 defence tech cluster to stimulate development of military innovations and defence technologies // Cabinet of Ministers of Ukraine. 26 April 2023. Available at: https://kmu.gov.ua/en/news/v-ukraini-zapustyly-defense-tech-cluster-brave1-iakyi-stymuliuvatyme-rozvytok-viiskovykh-innovatsii-ta-oboronnykh-tekhnolohii (accessed: 19 February 2026).
9. BRAVE1: Defense Tech Cluster // Official website of the BRAVE1 platform. Available at: https://brave1.gov.ua/en/ (accessed: 19 February 2026).
10. Bilousova O., Omelchenko E., Makarchuk M., Mylovanov T. Ukraine's Drones Industry: Investments and Product Innovations. 4 October 2024. 23 p. Available at: https://kse.ua/wp-content/uploads/2024/10/241004-Brave1-report-v.1.pdf (accessed: 19 February 2026).
11. Regulation (EU) 2023/1781 of the European Parliament and of the Council establishing a framework of measures for strengthening Europe's semiconductor ecosystem (European Chips Act). *Official Journal of the European Union.* 2023.
12. Regulation (EU) 2021/697 of the European Parliament and of the Council establishing the European Defence Fund. *Official Journal of the European Union.* 2021.
13. European Commission. Strategic Autonomy and the European Defence Industrial Strategy. Available at: https://commission.europa.eu (accessed: 19 February 2026).
14. Regulation (EU) 2021/694 establishing the Digital Europe Programme (2021–2027). *Official Journal of the European Union.* 2021.

Дата надходження статті: 24.02.2026
Дата прийняття статті: 16.03.2026
Дата публікації статті: 02.06.2026