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Expert insights into mesolevel industrial ecosystems: pathways for economic transformation

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ABSTRACT

This study introduces a novel framework for classifying mesolevel industrial ecosystems, focusing on their roles in reindustrialization and proactive import substitution. The research aims to address the gap in existing literature by offering a detailed categorization of these ecosystems, considering various dimensions like sectoral composition, geographic scope, and nature of linkages among participants. The study employs an expert survey methodology, targeting 180 specialists across different sectors to identify industrial ecosystems with the highest potential for fostering economic transformation. The hierarchical classification methodology used is meticulously detailed, and the rationale behind the selection of survey participants and questions is explained. The survey findings revealed that inter-sectoral and open ecosystems are particularly effective in promoting reindustrialization and proactive import substitution. The results also emphasized the significance of network-structured ecosystems and highlighted the preference for digital and strategic networks business models, alongside half-open innovation models. The study concludes that mesolevel industrial ecosystems play a pivotal role in economic transformation, particularly in the context of reindustrialization and import substitution. Openness, networking, and inter-sectoral collaboration are identified as key traits of ecosystems that significantly contribute to these goals. The paper also suggests potential areas for future research, such as the integration of digital technologies and environmental sustainability considerations in ecosystem classifications.

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1. Introduction

In the dynamic landscape of contemporary markets, there is a pressing necessity for market actors to proactively adapt to emergent challenges. This exigency underscores the imperative for innovating novel models, methodologies, and mechanisms to drive the economic evolution of industrial ecosystems [1], [2]. In this vein, collaboration and strategic alignment among developers of technology and equipment have become essential to optimize the efficacy of innovations [3].

Recent years have witnessed a growing interest in the ecosystem approach to industrial development. This paradigm fosters unique partnerships through the voluntary collaboration of diverse stakeholders within the socio-economic environment [4]. The ecosystem framework in industry enables collective resilience against external challenges by combining resources, expertise, technologies, and competencies.

The ecosystem perspective contextualizes the industry within its broader environment, examining the interplay and interdependencies among various stakeholders [5]. It acknowledges the symbiotic re-

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lationship between the system and its external milieu, considering aspects of risk, sustainability, and the complexity of systemic interrelations [6]. Under this paradigm, ecosystems evolve within a unified environment, representing a confluence of research, engineering, production, assembly, and service activities. Disruptions in any segment of the ecosystem invariably impact the entire system, highlighting the extended scope of the ecosystem approach compared to the traditional system approach.

The formulation and evolution of industrial ecosystems have been extensively explored in academic literature [7]-[12]. While various categories and characteristics of industrial ecosystems have been established, a definitive reference classification remains elusive [13]. Scientifically categorizing industrial ecosystems into distinct subgroups is instrumental in pinpointing primary challenges and opportunities for each, crafting sector-specific reindustrialization strategies, and identifying potential growth trajectories within the industry.

The objective of this study is to introduce a novel classification of mesolevel industrial ecosystems. This classification serves as a vital instrument for shaping national industrial policy, managing reindustrialization, and cultivating proactive import substitution strategies in the context of the national economy's industrial development. Employing this classification, an expert survey was conducted to ascertain which ecosystems are most conducive to addressing challenges of reindustrialization and proactive import substitution in the industrial sector. To further elucidate this classification, Table 1 provides a comparative overview of various types of mesolevel industrial ecosystems, highlighting their unique characteristics, strengths, weaknesses, and their potential impact on reindustrialization and proactive import substitution:

This table encapsulates the diverse nature of mesolevel industrial ecosystems, underscoring the importance of understanding their distinct attributes and implications for effective industrial strategy formulation and implementation.

2. Materials and Methods

2.1 Industrial ecosystem concept

This research delves into diverse scholarly approaches towards defining the economic construct of an “industrial ecosystem”. Conceptually, an ecosystem is characterized as a network of interrelations among various entities, unified by a common challenge and collaboratively pursuing intricate solutions [14]-[17]. These ecosystems are fostered by organizations with a mutual commitment to joint sustainable advancement through innovation [18], [19]. Importantly, such systems are distinguished by a symbiotic amalgamation of technical components and resources, encompassing knowledge and developmental opportunities [20]-[22].

A pivotal characteristic of industrial ecosystems is the network-oriented interaction among participants [23], [24]. Harala et al. [25] underscore the necessity of this network structure in facilitating a circular production model, whereby waste products from one industry become resources for another.

Considerable research focuses on the digital platform-based organization of ecosystems, characterized by adaptable multi-tier management systems [26]. Industrial ecosystems may revolve around product supply chains or specific geographic locales [27]. The concept of industrial symbiosis describes the

Table 1. Comparative analysis of mesolevel industrial ecosystems (source: literature review)

Type of Ecosystem	Characteristics	Strengths	Weaknesses	Impact on Reindustrialization & Import Substitution
Circular	Emphasizes recycling and resource efficiency	Sustainable resource use	High initial investment	Promotes sustainable reindustrialization
Innovative	Focuses on R&D and technological advancements	Drives industry innovation	Relies on constant change	Encourages technological leadership in industries
Cooperative	Built on collaboration between various sectors	Synergistic benefits	Complexity in coordination	Facilitates integrated industrial development
Global	Worldwide interconnected industries	Access to global markets	Vulnerable to global risks	Enhances global competitiveness
Localized	Focuses on local resources and needs	Tailored to local conditions	Limited scale and scope	Supports local economic growth and self-sufficiency

collaborative sharing of energy, materials, or information among geographically proximate industrial plants [28], often extending to co-management of shared utilities or infrastructure [29].

Russian researchers have also explored varied interpretations of the industrial ecosystem concept. For instance, Molchan et al. [30] highlight the ecosystem's diversity of participants. These ecosystems are conceptualized as supporting industrial projects with shared missions, such as the advancement of durable materials, digital platforms, and robotic process automation. Kleiner [31] posits that industrial ecosystems are sustainable socio-economic structures, exhibiting traits of clusters, holdings, financial and industrial groups, technological clusters, and business incubators. Our literature analysis reveals that mesoeconomic industrial ecosystems exhibit several defining characteristics:

- Dynamism, openness, and self-developmental capacity.
- Creation of an environment conducive to innovation and sharing of energy, products, and production waste among interested entities.
- Organization of business processes for resource sharing on a common platform, coordinated by a lead entity for process optimization.
- Interaction driven by a shared vision, defining a collective mission for the advancement of all participating entities in alignment with their interests.

Consequently, the industrial ecosystem is recognized as an open, self-organizing system that unites a diverse array of actors and stakeholders, fostering an environment that facilitates synergistic outcomes. Participants in this ecosystem may include manufacturers, suppliers, innovators, customers, and regulators, collaborating through network partnerships and a cognitive approach to achieve strategic objectives.

Key to understanding the ecosystem dynamics is the distinction between stakeholders and actors. Stakeholders, encompassing entities like government agencies or purchasers of the ecosystem's output, may influence the ecosystem without being directly involved in its operational processes. In contrast, actors are actively engaged in the ecosystem's activities, including production, supply, innovation, and service delivery.

The contemporary specialized literature identifies various forms of industrial associations, such as alliances, clusters, industrial symbioses, networks, industrial parks, associations, and unions. The industrial ecosystem represents an evolutionary advancement of these models, adapting to new technological conditions with distinct features and advantages. Unlike clusters and networks, ecosystems are uniquely characterized by the absence of a central governing entity and operate on principles of self-organization within a cognitive intellectual environment.

In summary, the industrial ecosystem is a network of interconnected and interdependent enterprises, organizations, and institutions. It exhibits a complex structure and operates collectively to achieve shared objectives and outcomes. The industrial ecosystem is defined as an assembly of economic entities within the real economic sector, including clusters, technological platforms, and technology parks, functioning within a specific geographic or industrial domain. These ecosystems encompass the entire value chain, ranging from nascent startups to major corporations. The concept encapsulates a multifaceted array of relationships and interdependencies among economic agents within a unified market.

2.2 Hierarchical classification methods

Effective management in industrial ecosystems necessitates a rigorous classification system. Within this study, we establish a scientifically grounded classification framework for industrial ecosystems. This framework is pivotal in concentrating on targeted developmental areas, thereby mitigating risks and augmenting the efficacy of strategic management processes.

Classification methodologies encompass strategic techniques essential for segmenting a diverse array of entities into systematic subgroups. Predominantly, the scientific literature recognizes two principal classification methods: hierarchical and facet methods. These methodologies are distinguished by their respective approaches in applying classification characteristics.

Our study primarily utilizes the hierarchical method for categorizing industrial ecosystems. This method is characterized by the sequential segmentation of a broad population of entities into distinct subpopulations. Each division, formulated through this method, is an integral component of a comprehensive classification system. The system encompasses interconnected and subordinate divisions, establishing a coherent and hierarchical structure. Implementing this hierarchical classification approach in the context of industrial ecosystems enables a more nuanced understanding of their structure. It aids in identifying priorities to enhance efficiency and in developing tailored strategies that are specifically attuned to different levels within this hierarchy.

In our classification of mesolevel industrial ecosystems, we have confined the analysis to a single hierarchical level. Future research endeavours could potentially expand this framework, incorporating a greater number of hierarchical levels for more detailed analysis. Overall, hierarchical classification offers a structured and comprehensible method for data organization, making it a valuable tool across various disciplines.

2.3 Expert survey methods

In this study, we employed the expert survey methodology to ascertain industrial ecosystems with significant potential to foster reindustrialization and proactive import substitution across various industry sectors.

A structured questionnaire, comprising nine meticulously designed questions, was developed for this purpose. Each question in the questionnaire was formatted as a single-choice item, enabling experts to pinpoint the industrial ecosystems most conducive to reindustrialization and proactive import substitution.

In selecting participants for the study, it was crucial to adhere to specific criteria to ensure a representative sample. Ideally, the chosen subset of individuals should align closely with the social and demographic characteristics of the broader population under investigation. Determining the optimal sample size, however, can be a challenging endeavour. Guided by the findings of Memon et al. [32], we determined that a sample size ranging from 100 to 250 participants is generally sufficient for a preliminary survey within a larger-scale study. Consequently, our survey comprised 180 experts, including esteemed representatives from higher education institutions, academic research centres, and various sectors of industry and business.

The primary criterion for expert selection was based on their expertise and recognized authority in the relevant field. Consequently, the assessment of the sample's adequacy and representativeness was anchored not in quantitative metrics, but rather in qualitative aspects. To enhance the survey's accuracy and relevance, experts were provided with additional methodological explanations regarding the author's classification of industrial ecosystems. This approach ensured a more informed and nuanced understanding among participants, thereby enriching the quality and validity of their responses.

2.4 Classification of industrial ecosystems

Kleiner [31] asserts that, within the economic hierarchy, social and economic ecosystems predominantly align with the mesoeconomic level. Kleiner emphasizes that these ecosystems primarily aim to effectively fulfil key economic functions such as production, distribution, exchange, and consumption. These functions are crucial in supporting the survival and development needs of specific socio-economic entities, such as industries within settlements or larger complexes.

In our analysis, we propose that industrial ecosystems can be stratified into four distinct levels: mega, macro, meso, and micro (as depicted in Table 2). These levels are intricately interlinked, as illustrated in Figure 1. It is imperative to recognize that each level of the ecosystem possesses its own unique structure and dynamics, along with specific challenges and characteristics.

The interplay between these hierarchical levels is complex and influential. At the mega level, alterations in global geopolitics, regulatory frameworks, or infrastructure significantly reverberate through the lower levels of the hierarchy. Similarly, shifts in

Table 2. Industrial ecosystems of various levels

Ecosystem level	Representatives
Mega level	Global networks and relationships between companies in global industry, multinational corporations, international logistics companies, etc.
Macro level of the ecosystem	National companies, government authorities and regulators, professional and trade associations, educational institutions, investors and financial institutions, logistics companies
Meso level	Enterprises operating in a certain region, regional and municipal authorities, educational institutions, industrial parks and zones, universities and research centers in the region, etc. Industry associations and organizations, companies and enterprises in the industry, suppliers, distributors and industry customers.
Micro level	Internal departments and business units, employees and management of the company, suppliers, partners and clients. Production lines and areas, workers and engineers, suppliers and distributors. Ecosystems around specific technologies.

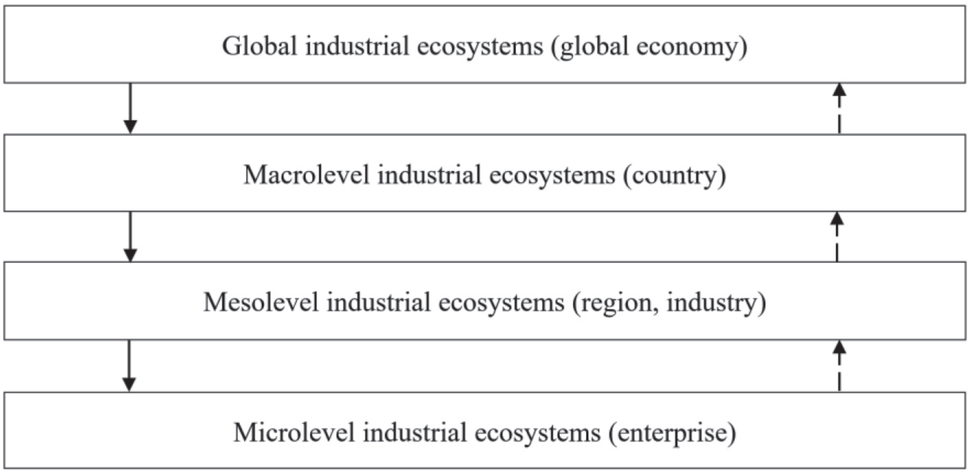

Figure 1. Interrelation of industrial ecosystems on various hierarchical levels

industry trends, technological innovations, or regulatory changes at the macro level have direct ramifications for ecosystems operating at the meso and micro levels. The interaction between the meso and micro levels is primarily governed by the dynamics of cooperation and competition among companies and conglomerates at the meso level, which in turn shape the micro-level ecosystems.

Notably, the interaction is not unidirectional. As indicated by the dotted arrow in Figure 1, the influence also percolates upwards from the lower levels to the higher ones. These lower levels contribute to shaping the overarching ecosystem through the dissemination of their resources, strategic approaches, and innovative practices.

This segment outlines the author's conceptual framework for classifying mesolevel industrial ecosystems. Contemporary mesoeconomic research encompasses a broad spectrum of study areas, one of which is the mesoeconomics of structures with definitive localization. These structures, often manifested as regional or sectoral systems, are integral in analysing object-based structures and their role in the operation of multi-sectoral complexes. Within the economic literature, the mesolevel system is typically categorized into four distinct levels: sectoral, inter-sectoral, regional (territorial), and interregional (inter-territorial).

A fundamental aspect of our classification framework is the sectoral basis. This categorization facilitates a deeper understanding of the relationships and interactions within and between industries, or across various platforms and technologies.

The territorial basis of classification is crucial for comprehending the organizational form, geographic nature, and productive force distribution of ecosystems. Ecosystems confined to a specific territory often exhibit more robust spatial integration, whereas interterritorial associations open avenues for broader cooperation.

Another key classification criterion is the direction of interconnections within the ecosystem. This aspect is central to grasping the interaction processes among various ecosystem participants. The diverse directions of these interconnections yield varying benefits and challenges, aiding in the identification of potential strategic partners, balancing participant interests, and conflict management.

Classification by the degree of centralization sheds light on the organizational structure and roles of participants within an industrial ecosystem. For instance, hierarchical structures feature top-down management processes, whereas market structures are characterized by independent decision-making based on market dynamics.

The openness of industrial ecosystems is another critical dimension. Assessing the degree of openness aids in identifying barriers to entry, opportunities for co-innovation, and other strategic elements.

Innovation is the lifeline of industrial ecosystems. Understanding the innovation model employed within an ecosystem is pivotal for selecting the appropriate innovation approach, analysing cooperation potential, assessing required changes in innovation culture, and more.

Furthermore, the classification based on the business model used is instrumental in understanding and analysing the ecosystem's organizational structure and functionality. This classification helps gauge the system's development level, adaptability to economic realities, potential advantages, challenges of each business model, and crafting effective management strategies.

The degree of coordination among ecosystem participants is another significant classification basis. It determines the intensity of interactions within the ecosystem, the prevalent types of engagements, and the required cooperation level, each bringing its own set of benefits and risks.

Lastly, classifying industrial ecosystems based on their operating area scale is vital for defining ecosystem boundaries, identifying potential competitors and partners, and formulating development strategies. This basis assists in understanding the geographical context of the studied ecosystem, leading to scientifically grounded conclusions and management recommendations.

It is important to note that the classification bases presented here have been developed based on the authors' subjective interpretation of the industrial ecosystem phenomenon. These bases can be further refined or expanded depending on the specific problem addressed and evolving understandings over time.

3. Results

3.1 Classification of industrial ecosystems at mesolevel

The classification of mesolevel industrial ecosystems proposed in this study is based on a comprehensive review of existing literature on industrial ecosystems and their characteristics. The classification bases were selected to provide a multidimensional understanding of these ecosystems and their potential roles in reindustrialization and proactive import substitution.

The bases for classification include sectoral composition, geographic scope, nature of linkages among participants, degree of centralization and openness, innovative development models, business models, depth of cooperation, and operating area scale. These bases were chosen based on their prominence in the literature and their relevance to the study's objectives.

The sources used in the study were evaluated based on their relevance, credibility, and quality. We primarily relied on peer-reviewed academic journals, conference proceedings, and reputable industry reports. The sources were assessed for their methodological rigor, the expertise of the authors, and their contribution to the understanding of industrial ecosystems. We also considered the recency of the sources to ensure that the study incorporates the latest developments in the field.

The classification process involved a systematic analysis of the selected sources, focusing on the identification of key characteristics and dimensions of industrial ecosystems. The findings from the literature review were then synthesized to develop the proposed classification framework for mesolevel industrial ecosystems, as presented in Table 3. This table is structured to enhance understanding and clarity. On the left, various types of ecosystems are delineated, each categorized according to specific classification attributes (bases). Correspondingly, the right column provides concise methodological explanations for each classification type.

Table 3. Classification of mesolevel industrial ecosystems

By sectoral basis	
Intra-sectoral	Groups of interconnected organizations, companies and institutions within a given industry sector that interact with each other and the external environment to create, produce and distribute goods and services in this sector
Inter-sectoral	It is characterized by interaction between organizations in different industry sectors, sharing resources, knowledge and experience, as well as creation of innovations and new business opportunities
Cross-platform	Cross-platform industrial ecosystems are a number of interconnected enterprises and organizations in different industries and sectors of the economy. In such ecosystems, connections between participants are usually built on the basis of interaction and collaboration on a specific platform. An example of a cross-platform ecosystem is an e-commerce platform, where different sellers can sell their goods and services on the centralized platform
By territorial basis	
Intra-regional	Networks of organizations, businesses and institutions that interact and collaborate with each other in a specific area (region or territory)
Inter-regional	Networks of related production enterprises, organizations and authorities that cooperate with each other at the interterritorial level

By direction of connections between participants	
Vertical	It involves cooperation between enterprises that are at different management levels and performing various functions and operations
Horizontal	It involves cooperation between enterprises that are at the same economic level and perform identical functions.
Diagonal	Diagonal industrial ecosystems involve the interaction of companies, organizations and individuals at different stages of the value chain and across industry boundaries. They are a combination of horizontal and vertical ecosystems
By degree of centralization	
Hierarchical	In such ecosystems, industrial activities are controlled and regulated by a single central authority or leader. Decision making, resource allocation and process organization are organized from the top down
Market	The ecosystem is based on the principle of market relations and free competition. In such ecosystems, industrial activities are carried out based on market supply and demand. Participants interact with each other through market mechanisms such as prices, competition, and the exchange of goods and services. Decisions are made on the basis of the rational choice of each participant in line with their own interests.
Network	Industrial activities in such ecosystems are organized through networks and relationships between actors who collaborate and share resources and knowledge. The main goal is to create and maintain long-term partnerships between network participants. Decisions are made collectively based on discussion and consensus
By degree of openness	
Open	In an open model of ecosystem, competing suppliers of goods and services have access to it, and their access is based on criteria publicly disclosed by the ecosystem
Closed	A closed ecosystem forms a limited number of partners and does not publicly disclose the rules of access for participants.
By innovative development model	
Open innovations	It assumes that when developing new technologies and products, the company relies not only on its own innovative developments, but also actively attracts innovations and competencies from outside.
Closed innovations	In such ecosystems, organizations tend to develop and apply internal innovative ideas. They strive to control the entire development and implementation process in order to maintain confidentiality and protect their intellectual rights
Half-open innovations	This type of innovation is a combination of open and closed innovations. Ecosystems with open innovations share some of their knowledge and ideas with external stakeholders, but retain control over a key part of the innovation process or technology
By business model used	
Traditional	They create value through the linear processes – value chains. Input (raw materials, materials, components from suppliers), passing through a series of stages (value chain), turns into output (finished product) with the greater value than input
Interconnected	In this model, ecosystem participants collaborate at all levels, from development to delivery and maintenance of the product or service. The special feature of this model is identification of logically consistent, functionally separate, but interacting and interdependent stages. Its advantage is the complementarity of the technological capabilities of ecosystem participants.
Integrated	The most important features of the model are the integration of R&D with production (for example, connected computer-aided design and flexible manufacturing systems), closer cooperation with suppliers and major purchasers, creation of joint ventures, strategic alliances, and the formation of cross-functional working groups
Strategic networks model	It represents an ideal development of an integrated model and closer strategic integration of interacting companies. Industrial activity has not only cross-functional, but also multi-institutional and network nature
Digital	In this model, digital technologies and platforms are the basis for cooperation and interaction between ecosystem participants. This may include sharing data, using analytics and artificial intelligence to optimize operations and create platform-based business models.
By target setting (depth of cooperation between participants)	
Joint engagement	Ecosystems where participants actively collaborate with each other, share information, knowledge, experience and resources to achieve joint results and stimulate innovation activities. Participants interact with each other based on market transactions. Each company is independent and makes its own production and sourcing decisions

Partnership	In such ecosystems, participants collaborate and coordinate their actions to achieve common goals, but without deep integration and sharing key resources and competencies
Cooperation	Ecosystems are characterized by the prevalence of cooperation over competition between participants. At the same time, competition between individual ecosystem participants for resources and clients remains
Collaboration	In collaborative ecosystems, participants work on joint projects and initiatives, pooling their resources and skills to achieve common goals and create new value.
Integration	It is the highest degree of coordination in ecosystems where participants interact deeply, pool their resources, competencies and processes, creating a strong and interdependent network to ensure common results and successful functioning of the system. Full integration may include mergers, acquisitions or joint ventures to achieve the maximum degree of synergy and efficiency, working together under a single strategy and management structure
By operating area scale	
Local	They operate locally and serve a specific geographic area or city. They bring together local manufacturers, suppliers, customers and other stakeholders at the local level.
Regional	These ecosystems cover a wider area, such as a region or microregion. They connect manufacturers, suppliers and customers operating within a specific region and may include joint projects and initiatives
National	They work on a national level and bring together national manufacturers, suppliers and customers. They can be created with support of national industrial development programs
International	They operate on a global level and bring together participants from different countries

3.2 Expert survey results

The results of the expert survey are shown in Figure 2. The survey included responses from 180 experts, comprising 40% representatives of higher education institutions, 33% representatives of business and non-governmental organizations, and 27% representatives from academic research institutions.

The survey results suggest that successful mesolevel industrial ecosystems possess several key characteristics that enable them to effectively promote reindustrialization and proactive import substitution:

(1) *Inter-Sectoral Ecosystems*: Nearly half of the survey participants identified inter-sectoral industrial ecosystems as particularly effective in promoting reindustrialization and proactive import substitution.

(2) *Inter-Regional Ecosystems*: A significant majority of respondents highlighted that inter-regional ecosystems in the industry play a pivotal role in driving proactive import substitution and reindustrialization within the economy.

(3) *Direction of Connections*: Expert opinions were evenly split regarding the classification of ecosystems based on the direction of connections between participants.

(4) *Network Structures*: The findings indicate that network-structured mesolevel industrial ecosystems are predominantly conducive to reindustrialization and proactive import substitution. Network-structured ecosystems, characterized by the interaction of companies, organizations, and individuals across different stages of the value chain and industry boundaries, are more successful in promoting economic transformation. These ecosystems enable the creation of long-term partnerships and the sharing of resources and knowledge among participants.

(5) *Open Ecosystems*: An overwhelming majority of respondents agreed that open ecosystems are crucial in facilitating reindustrialization and proactive import substitution. Open ecosystems, which allow for the participation of competing suppliers and publicly disclose access criteria, are more conducive to reindustrialization and proactive import substitution. Openness encourages competition, innovation, and the sharing of ideas among ecosystem participants.

(6) *Innovative Development Model*: In the context of innovative development, half-open innovation models were most favored by the experts.

(7) *Business Models*: Regarding the business model employed, the digital model and strategic networks model received notable preference from the experts. Ecosystems that employ digital platforms and strategic networks as their primary business models are more effective in fostering reindustrialization

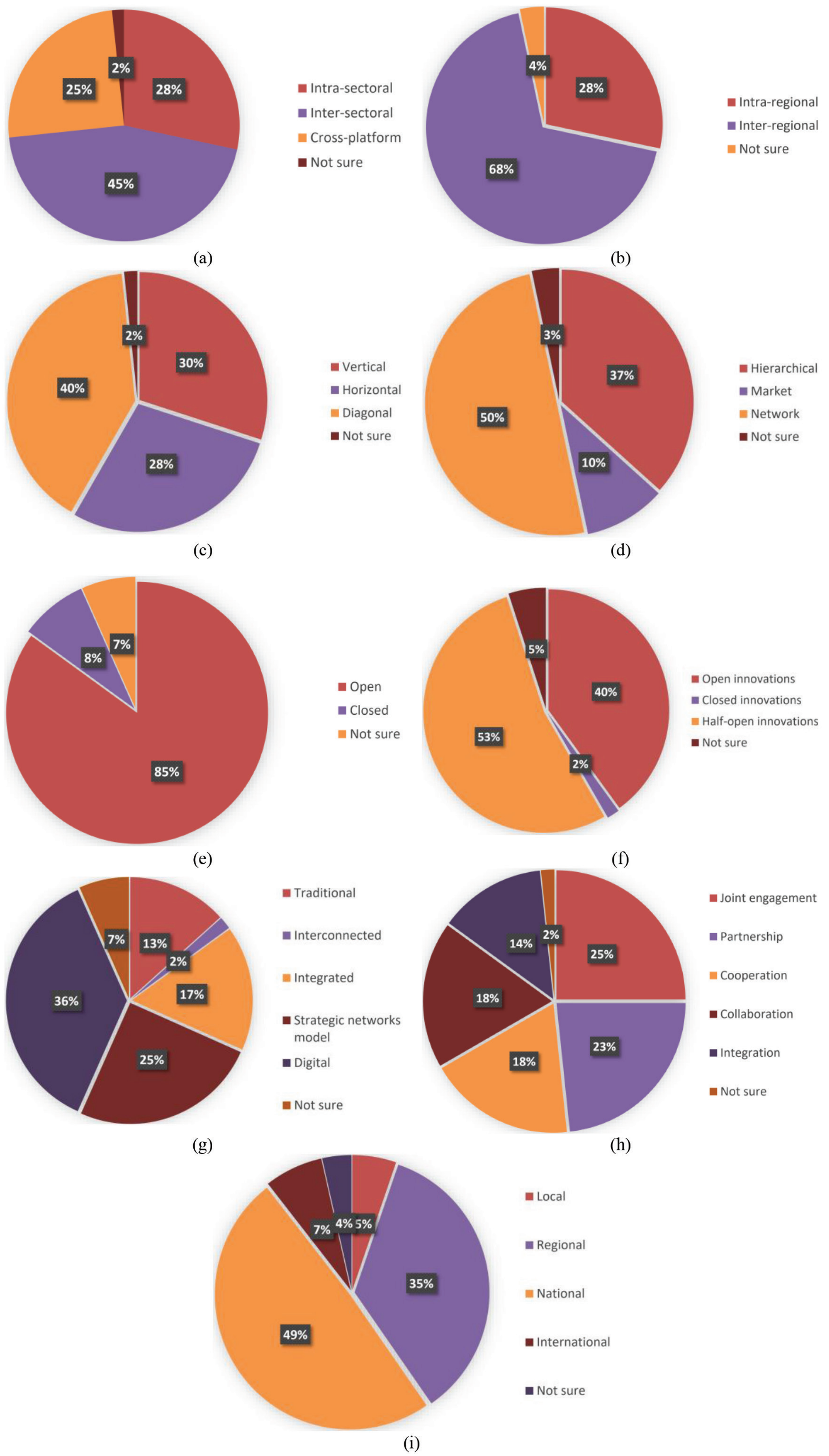

Figure 2. A breakdown of experts' responses in the classification category of (a) sectoral basis, (b) territorial basis, (c) direction of connections between participants, (d) degree of centralization, (e) degree of openness, (f) innovative development model, (g) business model used, (h) depth of cooperation between participants, and (i) operating area scale

and proactive import substitution. These models facilitate collaboration, data sharing, and the optimization of operations through digital technologies.

(8) *Depth of Cooperation*: Opinions varied concerning the classification based on the depth of cooperation between participants. However, all identified models of cooperation were deemed capable of contributing, to varying degrees, to reindustrialization and proactive import substitution in the industry.

(9) *National Orientation*: The survey results suggest that ecosystems with a national focus are key contributors to reindustrialization and proactive import substitution.

4. Discussion

While the classification system presented in this study provides a structured approach to understanding mesolevel industrial ecosystems, it is important to acknowledge its evolving nature and potential limitations. First and foremost, the rapid pace of industrial change and technological advancement may render some classification bases less relevant over time, as new forms of production, technologies, and business models emerge. Additionally, our classification does not account for the variances in regional ecosystems across different countries, which can be significant.

Furthermore, the current classification system may not adequately encompass the diversity of existing hybrid business models and ecosystems, which often defy conventional categorization. Also, certain unique or niche ecosystems may challenge the general criteria due to their specialized nature or unpredictable elements. Lastly, the methodology of the expert survey can be expanded to include a wider range of question types and a larger pool of experts, alongside the incorporation of rating systems or scales for a more quantitative assessment of each industrial ecosystem.

The classification of mesolevel industrial ecosystems proposed in this paper introduces a novel framework, expanding upon existing literature in several key areas. Our findings emphasize the significance of inter-sectoral and inter-regional collaborations in promoting reindustrialization and proactive import substitution, aligning with studies like those of Zhang et al. [14] which highlight the importance of networked structures in industrial ecosystems. The emphasis on inter-sectoral collaboration aligns with the work of Kleiner [31], who underscored the value of diverse participant integration for sustainable socio-economic structures. This is a pivotal deviation from traditional single-sector focused studies, suggesting a broader, more integrated approach. The preference for network-structured ecosystems resonates with the findings of Mikhailidi et al. [3], who emphasized the necessity of adaptable, multi-tier management systems in digital platform-based ecosystems. This underscores the evolving nature of industrial ecosystems towards more open, interconnected models. Our study's inclination towards half-open innovation models finds support in the work of Oliveira et al. [16], who pointed out the balance between internal innovation and external collaboration in ecosystems.

These findings contribute to the growing body of literature on industrial ecosystems and their role in economic transformation. Future research endeavours should aim to refine this classification by integrating considerations such as the role of digital technologies and environmental sustainability. It will be beneficial to explore emerging and evolving business models in the industry, examine the impact of international relations and social accounting, and study the influence of geographical factors. Adapting classification criteria to align with technological shifts, changing business practices, and the dynamic economic landscape will be crucial. Additionally, developing metrics and indicators to evaluate the efficiency and sustainability of industrial ecosystems across various categories will provide a more comprehensive and nuanced understanding of their impact and effectiveness.

5. Conclusions

This paper introduces a novel framework for the classification of industrial ecosystems at the mesolevel. Central to this study is a comprehensive analysis of diverse conceptualizations of the "industrial ecosystem." We have developed and presented a methodology for the hierarchical classification of these ecosystems, elucidating the relationships across various hierarchical levels. Our approach proposes the categorization of mesolevel industrial ecosystems based on a multifaceted set of criteria. These include sectoral affiliation, territorial considerations, the direction of connections between participants, the degree of centralization, openness, the model of innovative development, the business model in use, the depth of cooperation among participants, and the scale of their operating area.

A crucial component of this study was the execution of an expert survey. This survey aimed to identify ecosystems that hold substantial promise for advancing reindustrialization and fostering proactive import substitution. Such surveys are instrumental as supplementary tools in devising strategies that leverage the potential of ecosystems to meet the objectives of reindustrialization and proactive import substitution. The findings from this expert survey indicate that ecosystems characterized by openness, networked structures, and inter-sectoral collaboration are particularly conducive to supporting reindustrialization and proactive import substitution initiatives.

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