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Transformation of Industry Ecosystems in Cities and Regions: A Generic Pathway for Smart and Green Transition

Nicos Komninos

URENIO Research, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece; komninos@urenio.org

Abstract: This research paper focuses on pathways towards a digital and green transition. We assess a generic pathway for the transformation of industry ecosystems in cities and regions based on processes of prioritisation, ecosystem identification, and platform-based digital and green transition. We start with problem definition and hypotheses; review related works on transition pathways, such as digital transition, green transition, system innovation, industry ecosystems, and multi-level perspective of transformation; assess the generic pathway with case studies; and conclude with a discussion of findings, outline of conclusions, and policy implications. Overall, the paper investigates pathways, priorities, and methods allowing public authorities and business organisations to master the current industrial transformation of cities and regions introduced by the twin digital and green transitions as an opportunity for radical change of city ecosystems, innovation leapfrogging, and system innovation.

Keywords: industrial transformation; city ecosystem; activity ecosystem; smart ecosystem; pathway; system innovation; digital transition; green transition; smart specialisation

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1. Introduction and Problem Definition

This paper focuses on the ***transformation of industry ecosystems in cities and regions under the influence of digital and green transition***. Industry ecosystems or "activity-based ecosystems" are the most common type of ecosystems in cities, created by companies and organisations that share space, infrastructures, labour market, and other urban externalities. These ecosystems are formed around sectors of economic activity and different vertical markets of manufacturing and services.

There are ecosystems that cities do not choose to develop but grow inherently together with the entire urban system. For instance, cities do not choose to have or not to have housing, transport, energy, and water networks, even though they can choose the type of such ecosystems at the next stage. However, there are ecosystems open to choices, such as the activity ecosystems that flourish in a city. Out of hundreds of different economic activities and industry branches, each city chooses and specialises in a few of them. This choice is evolutionary, based on converging or competing decisions of private and public actors. Nevertheless, the activity specialisation of cities is an outcome of choice.

Our interest in the transformation of activity-based ecosystems by the twin transition, digital and green, is both theoretical and methodological. At the level of theory, we attempt to connect several discrete theory strands dealing with industrial change, innovation, smart systems, and climate-neutral technologies, which are driving this transformation. At the level of methodology, the ambition is to identify pathways to manage the evolving industrial transformation sustained by digital and green transitions. Smart systems and technologies are redefining the industrial landscape. A profound transition of energy systems is underway based on smart energy optimisation and distributed renewable energy production, while climate change adaptation is pushing forward industrial innovation.

This research on pathways of industrial transformation also takes into account the new European policies that appeared after 2020, such as the Green Deal, the new industrial strategy, the policies on digital and green transitions, the research and innovation strategies for smart specialisation, and the good governance of these strategies [1,2]. Overall, this paper investigates pathways, priorities, and methods allowing us to master current industrial transformation as an opportunity for systemic change of cities and regions, innovation leapfrogging, and system innovation introduced by the digital and green transitions.

1.1. Problem Definition

The problem we want to explore concerns the ***pathways of industrial transformation linked to digital and green transitions***. These pathways can (a) connect digital and green technologies enabling a twin transition, (b) produce system innovation leading to a radical change of routines, and (c) transform economic activities and industry ecosystems. Such pathways are of high interest to all countries, regions, and cities. They affect how innovation and transition strategies are implemented and allow for the current transformation of industrial activities and ecosystems to be mastered.

As Figure 1 shows, pathways of change operate in two directions: on the one hand, innovation strategies transform economic activities and their ecosystems through state-led policies, and on the other hand, the twin digital and green transitions transform the same activities through state-led and market-led processes. Therefore, this research can contribute both to research and innovation strategies for smart specialisation (RIS3–RIS4) and the related entrepreneurial discovery processes and to the management of the digital and green transition policies.

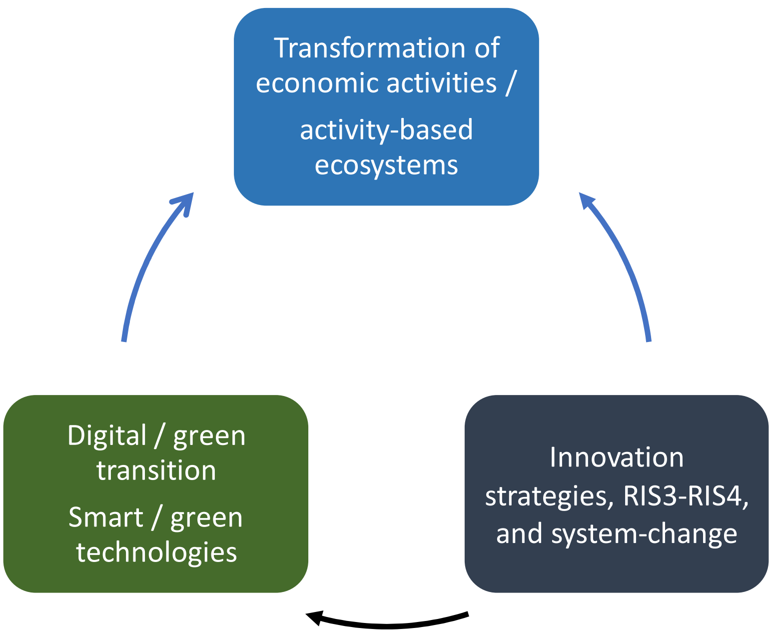

Figure 1. Pathways for innovation, twin transition, and industrial transformation.

The current industrial transformation encompasses all manufacturing, energy, utilities, and services sectors. However, the conditions, technologies, science, and business models of transformation are specific to each sector and change from one sector to the other. The landscape of the current industrial transformation is multifaceted, characterised by different maturity levels [3], different skills [4], and variability of innovation across industries and sectors of economic activity [5].

There is also high variability in pathways of digital and green transitions across economic activities, which are classified by NACE into 88 industry divisions, 272 industry groups, and 615 industry classes [6]. The question is, what economic activities and industries should be placed at the centre of policies for industrial transformation? What ecosystems should a city or region specialise in? How should public funds be invested?

Should all industry divisions, groups, and classes be given equal attention? Are some industry groups more receptive to industrial transformation and effective in high performance, and therefore, should they be placed at the focus of attention?

The sectoral variability of industrial transformation and its pathways is a source of complexity both at management and policy levels. Public authorities and policymakers must elaborate generic pathways for industrial change that can be applied across sectors of economic activity and the numerous vertical markets of industries. We want to find solutions to the "one size does not fit all" problem [7,8].

The search for generic and groundbreaking pathways for industrial transformation is important for many different reasons. It is a global challenge; all counties try to elaborate and promote innovations by smart and green technologies and systems. It is a European challenge, clearly reflected in the new growth policy of the Green Deal, the new industrial strategy of the EU, the research and innovation strategies for smart specialisation, and the strategies for digital transition and ecological transition. Above all, is a challenge for the future of the industry, the future of work, and the well-being of 21st-century societies, cities, and regions.

We want to identify generic trajectories of industrial change with strong potential for a smart transition, high impact on growth and innovation, and minimal environmental footprint or high environmental transition gain. We expect that effectiveness and receptivity to industrial transformation differ with spatial level. Therefore, it is important to combine local, regional, and national perspectives and elaborate pathways of a multilevel government.

1.2. A Generic Pathway towards Smart and Green Transition

The pathway towards a smart and green transition and industrial transformation we want to explore is based on interconnected processes of change that start with smart and green technologies, involve system innovation, and end with the transformation of industrial ecosystems. It is a ***generic transition pathway*** defined by three instances: "prioritisation", "ecosystem perspective", and "platform-based smart and green solutions".

Prioritisation. By focusing on a relatively limited number of important economic activities, even at a high level of granularity, we can capture most economic activities of a city or region. Given that cities and regions tend to specialise in a few industries, prioritising results in dealing with most of the existing industrial activities. Defining pathways of change at the priority level allows for a lowering of complexity in terms of the industrial activities considered for the twin smart and green transitions. It is neither effective nor feasible to go into the details and assess the potential transition pathways of all economic activities in the 272 industry groups or the 615 industry classes of the NACE classification. It is necessary to apply some prioritisation.

The hypothesis here (H1) is that the most important economic activities (by size, specialisation, investment) are expected to include a high share of all economic activities in a territory, and a relatively small number of principal economic activities contain the bulk of all economic activities of a city or region. In other words, there is a high level of polarisation of economic activities in a region.

Ecosystem perspective. In cities and regions, economic activities tend to interconnect, forming activity-based ecosystems. An ecosystem is made by a group of organisations interacting with each other and the environment to achieve common objectives, create value, or other advantages [9,10]. Interconnections with other economic activities occur along supply chains, across vertical markets, over the common infrastructure of cities, as well as in the local labour market and commercial markets. Due to interconnections, activity-based ecosystems are organised and grow.

The hypothesis here (H2) is that we expect to identify ecosystems around the most important economic activities when these are defined by size and specialisation. The size and specialisation increase the probability of interactions and communalities among activities. We expect that activity-based ecosystems occur around economic activities that are large in size and have high specialisation.

Platform-based smart and green transition enables collaborative innovation in products, services, and processes that transform entire ecosystems. On the other hand, ecosystems facilitate the adoption of platforms. Platforms have an impact on many businesses and organisations of an ecosystem and pave the way towards system innovation and the radical transformation of ecosystems. They bring transformations in connections and the organisation overall of the ecosystem, not only its parts, enabling the emergence of routines that change the entire system.

As highlighted in the literature, "industry platforms are technological building blocks (that can be technologies, products, or services) that act as a foundation on top of which an array of firms, organized in a set of interdependent firms (sometimes called an industry "ecosystem"), develop a set of inter-related products, technologies and services" ([11], p. 287). Equally, platforms are described as collaborative business models that sustain ecosystem development: a platform is "a plug-and-play business model that allows multiple participants (producers and consumers) to connect to it, interact with each other and create and exchange value" [12]. Platforms offer the foundation for products and services developed by third parties, a relationship that Gawer and Cusumano [13] name "platform leadership", enabling some companies to exert influence over the direction of innovation in an industry, by engaging other companies to develop complementary products. Platforms are foundations for setting up ecosystems by organisations that share resources, knowledge, or access to markets [14].

The hypothesis here (H3) is that within the economic activities of prioritisation and the ecosystems created around them, we can identify platforms for smart and green transition meaningful for many companies and organisations of the industry or ecosystem. This will enable us to share objectives for collective action, common infrastructure, and pathways for system change for the entire ecosystem to be developed.

The above three instances combine conditions of industry volume and specialisation (prioritisation), systemic organisation (ecosystems), and innovation niches (smart/green solutions). The pathway they define is generic because these instances can be applied in the industry groups of any territory. Hypotheses H1, H2, and H3 measure how representative these instances are within the overall landscape of urban activities and can be assessed with data from case studies.

To do this, the rest of the paper is organised into four sections. In Section 2, we refer to the literature on transition pathways and processes, such as digital transition, green transition, system innovation, industry ecosystems, and multilevel perspective of transformation. In Section 3, we describe a generic pathway that can guide the twin smart and green transitions and assess with case studies how this pathway can be implemented, as well as the outcome of the implementation. In Section 4, we discuss the pathway proposed and the hypotheses described, assessing the feasibility and scenarios of implementation. The last section highlights the conclusions and policy implications.

2. Pathways for Industrial Transformation: Related Works

Previous research on industrial transformation identified multiple drivers, such as digitalisation and smart transition, green transition, system innovation, and ecosystem development [2,15–19]. The arrow of change originates from the twin transitions and moves towards system innovation, ending with the transformation of industry ecosystems. This interconnection is clearly articulated in the new industrial strategy of the European Union, organised around three drivers: a globally competitive and world-leading industry; an industry that paves the way to climate neutrality, the supply of clean and affordable energy and raw materials; and an industry shaping Europe's digital future with investments in artificial intelligence, 5G, and data and metadata analytics [20]. Place-based innovation is also encouraged, allowing regions to develop new solutions with companies and consumers valorising local characteristics, strengths, and specialisations in the framework of smart specialisation strategies [21].

The ***digital (or smart) transition*** is the dominant driver of industrial transformation and refers to the adoption of technologies, such as smart systems, automation and robotisation, sensor networks, Internet of Things, cloud, software, platform and infrastructure as a service (SaaS, PaaS, IaaS, XaaS), analytics, big data, artificial intelligence, and distributed ledger technologies, which transform business environments, operations, and strategies [22–24].

Various terms have been used to describe the current transformation of the industry, such as industrial transition, industry 4.0, smart industry, and the fourth industrial revolution. The digital transition also refers to industries that adopt digital technologies and knowledge-intensive processes. All these terms point towards industrial transformation based on knowledge, information technology, data-based innovation, and a transition from machine-dominant processes to digital.

Industrial transition by digital technologies and smart systems extends to all industry sectors, from agriculture to manufacturing, transport, energy, health, and financial services. Changes to skills and human capital are also associated with the digital transition [25], as well as new business models that connect digitalisation to servitisation and push product companies towards services [26,27]. Industrial transition and industry 4.0 are also characterised by novel processes at the production and enterprise levels, such as smart manufacturing, deployment of embedded actuators and sensors, digital enhancement and reengineering of products, customisation of differentiated products, and coordination of products and services along the supply chain [28]. All these changes require continuous learning and innovation. Overall, the enterprise and industry levels have indeed gathered more attention in terms of research and technology compared with the production level [29].

Assessing the transition to industry 4.0 in the US manufacturing sector, Rojko et al. [30] found that the manufacturing output employment and labour productivity have barely grown. However, the projections for the next decade show brighter developments. They argue that the future will be in cooperation between robots and humans, a partnership that can bring wealth and increase labour productivity, while among the main challenges are the interactions between AI and employees. In this step towards industry 5.0, distributed computers, the Internet of Everything, multiagent systems and technologies, complex adaptive systems, and widespread intelligence are considered the main components of the transition [31]. This new stage in industry development (Industry 5.0) should "focus primarily on human and robot engagement and the integration of human knowledge, creativity, intuition, skills, experience, etc. within robotized production" ([31], p. 303).

The green transition is another major driver of industrial transformation. Guided by the objectives of sustainability and adaptation to climate change, it offers broad opportunities for change due to transversality across industry sectors and territorial scales [22]. Like the digital transition, the green transition has an important systemic impact, as it applies to the entire life cycle of products and engages all segments of a value chain. Systemic for instance is the transition from the "linear economy" of extract, consume, and dispose processes to the "circular economy" that aims to reduce, reuse, and recycle.

Geels [15] investigated the fundamental changes in energy, transport, housing, and agrofood systems related to sustainability. He identified different types of innovations in energy and transport systems, including radical technical innovation (battery electric vehicles, decarbonisation), grassroots and social innovation (car sharing, bike clubs), and business model innovation (mobility services and infrastructural innovation (intermodal transport, compact cities)). Zhai and An [32] analysed the factors influencing the green transformation in China's manufacturing industry with a survey of 500 Chinese enterprises and identified human capital, financing strength, technology innovation, and government policy as having a significant positive impact on the green transformation performance. Governmental behaviour had the greatest impact coefficient, followed by human capital, technology innovation, and financing ability. On the contrary, environmental regulation decreased the positive impact and acted as a reversal mechanism affecting financing capacity, technology innovation, and governmental behaviour.

The European Green Deal is also expected to make an important contribution to the green transition. It is the new growth strategy for the European Union and an integral part of implementing the United Nations 2030 Agenda and the Sustainable Development Goals. The EU Green Deal is holistic and covers all areas of activity, climate, energy, transport, industry, construction, and nature. In response to these challenges, it outlines a development strategy to transform the EU into a just and prosperous society, with a modern, resource-efficient, and competitive economy, without greenhouse gas emissions in 2050 and economic growth decoupled from resource use [1,33–35].

It is important to underline that the green transition together with efforts for renewable energy and CO_2 reduction promotes processes of reuse, zero waste, and modular production that allows repair and replenishment rather than total rejection of products. Through reuse, the green transition converges with the digital transition in the continuous reuse of knowledge products. Knowledge, as shown by the new growth theory, is not only not consumed during use but is improved by repetition and reuse [36,37]. Both the digital transition and the green transition are based on a wide range of technologies, systems, and solutions.

System innovation or transformative innovation is a direct outcome of radical changes introduced by the digital and green transitions. Already, the term "transition" brings in the idea of movement or change from one state of a system to another. This type of innovation goes beyond products and technologies and involves changes in the broader sociotechnical system. System innovation is characterised by large-scale transformations having wide societal value, such as energy, housing, mobility, and food; transformations through coevolution between different elements and actors; and transformations that occur at multiple levels, such as the niche level, the regime level, and the landscape or wider political and economic level [38]. This is a new framing of innovation that emphasises system-level changes in the structure or architecture of the system of reference [39–43].

This type of innovation encompasses both production and consumption activities and the complex relationships of actors ranging from firms and knowledge producers to households and consumers. Government has a more important role through policies enabling system-level innovations. As Pontilakis et al. [2] point out, system-level innovations do not have a single designer and are codeveloped through countless contributions within industry ecosystems. Therefore, distributed agency and being loosely connected by fleetingly aligned interests are key features, as well as the identification of interconnections between disparate parts of a system and potential domains for policy intervention, in particular, interventions for radical change through smart specialisation strategies.

In less developed regions, system innovation may have an important leapfrogging effect. For instance, environmental leapfrogging can enable developing countries and regions to skip some of the "dirty" stages of development followed in the industrialised world and contribute to environmental goals and climate mitigation solutions [44–46]. The same holds true for industry 4.0, where leapfrogging innovation can offer momentum in the dynamics of industrial growth with the early adoption of advanced digital systems [47–49].

The turn towards industry ecosystems is another important new dimension of the current industrial transformation driven by the twin digital and green transitions. It highlights a change of focus from individual companies to groups of organisations connected at multiple spatial scales [50,51]. An industry ecosystem is an organic network of collaboration among two or more business entities that create and share assets and value. It must be distinguished from an innovation ecosystem, which refers to organisations (R&D, producers, financiers, market makers) that collaborate in new product development and innovation. Industry ecosystems appear as global manufacturing networks [52], cross-industry ecosystems [17], platform ecosystems [53–55], and local entrepreneurial ecosystems [56].

In a review of the ecosystem concept in the field of management, Tsujimoto et al. [10] provide an overview of 90 studies that use the concept and identify four types: *industrial* *ecosystems* based on the industrial ecology perspective, material and energy flows, and interaction with the environment; *business ecosystems* based on the theory of organisational boundaries, comprising digital ecosystems, cross-industry ecosystems, supplier ecosystems, and business group ecosystems; *platform ecosystems* organised in two-sided markets; and *multiactor network ecosystems* based on social network theory.

The shift to ecosystems is clearly articulated in the updated EU industrial strategy that identifies 14 industry ecosystems as being important for the EU, including aerospace and defence; agrifood; construction; cultural and creative industries; digital; electronics; energy-intensive industries; energy renewables; health; mobility, transport, automotive; proximity, social economy, civil security; retail; textiles; and tourism [57].

The multi-level perspective (MLP) offers a theoretical framework that allows integrating the above-mentioned elements of industrial transformation, twin transitions, system innovation, and industry ecosystems. The MLP was developed by Rip and Kemp [58] and was further elaborated and refined by Geels [59] and Geels and Schot [60]. It is an attempt to bring together different strands of innovation theory, such as evolutionary economics, the sociology of innovation, neoinstitutional theory, and science and technology studies, and combines overlapping but disconnected themes of technological change and innovation [61].

The MLP focuses on radical innovations or system-change innovations. These are enacted by the tandem action of multiple social groups, enterprises, consumers, social movements, policymakers, researchers, media, and investors. In this sense, the MLP comes closer to quadruple helix innovation perspectives. Geels [15] points out that the MLP as a process theory "has both a 'global model' component (consisting of three analytical levels and several temporal phases), which describes the overall course of socio-technical transitions, and a 'local model' component, which addresses-specific activities and causal mechanisms in multi-level interactions". Transformations are nested at three levels within the system, the landscape (macrolevel), the regime (mesolevel), and the niche (microlevel). The theory gives more emphasis on the role of agency and transition pathways to new states of a system [62].

A system-level transition starts when the prevailing sociotechnical regime shows significant problems, key innovations appear that drive new designs, and early adoptions of the transition technologies take place. Geels and Schot [60,63] have identified five transition pathways: (a) the transformation of sociotechnical regimes without recourse to one dominant technology, (b) technological substitution when a radical technology replaces an existing technology, (c) dealignment and realignment of existing regimes when competing for new technologies solving existing problems, (d) opening up a new sociotechnical system that offers new social functions, and (e) reconfiguration and system change when many technologies and organisations change.

More recent works have connected MLP with smart specialisation strategies and technological changes in local industrial systems, considering MLP as a place-based driver for the technological transition of regional economies [64,65]. De Propris and Bailey [16] suggest that the transformation of a local system rests on three types of capabilities: innovation capabilities, docking capabilities to attract delocated niches, and translational capabilities to absorb radically new technologies. They identify four transformative pathways—(a) endogenous, (b) hypertransformative, (c) importation, and (d) regional obsolescence—and argue in favour of a transformative place-based policy enabling the joining up of technologies, sectors, and places, through a transformative entrepreneurial discovery process.

3. Towards a Generic Pathway of Transition: Evidence from the Case Studies

3.1. Generic Pathway Instances and Hypotheses from a Multilevel Perspective

In the MLP approach, two branches of research on transitions can be identified, referring to systems in transition and management of the transition. This distinction indicates an analytical versus an interventionist approach that focuses on how to actively steer technological change and how purposive, science, and technology-led transitions can be organised [61,66,67].

The generic pathway we described in Section 1.2, its three instances, and related hypotheses (prioritisation, ecosystem perspective, platform-based smart and green transition) stem from the above understanding of transition as system changes in cyber-physical systems of innovation. Due to digital transition, the continuous widening of digital networking, rich and real-time data availability, e-infrastructures, and e-services, all innovation systems are currently becoming cyber-physical. Their physical and institutional dimensions are interwoven with a strong digital dimension (Figure 2).

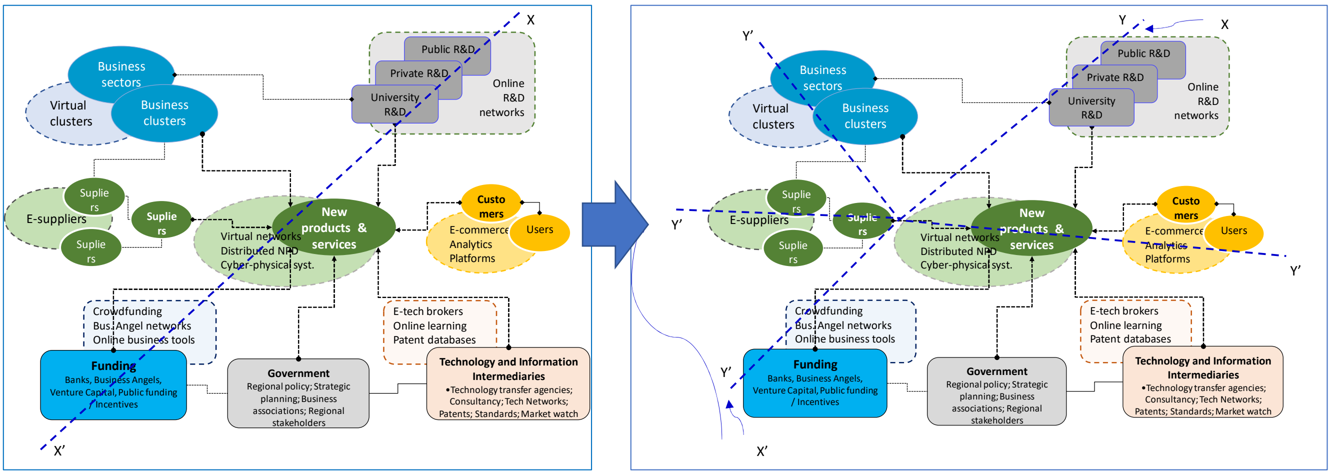

Figure 2. System innovation in cyber-physical innovation systems.

The "prioritisation" is mainly justified by the absence of theoretical prediction on how industries are affected by the twin digital and green transitions. It is highly probable to find innovative solutions in less expected economic activities. Therefore, all 272 NACE industry groups should be reviewed as potential fields of promising transition, which demands an enormous effort from policy-making authorities. Prioritisation is also a cornerstone of smart specialisation strategies and the entrepreneurial discovery process (EDP). As has been noted, "Smart Specialisation should address the difficult problem of prioritisation and resource allocation based on the involvement of all stakeholders in a process of entrepreneurial discovery, which should secure a regionally and business-driven, inclusive and open prioritisation process" [68]. Thus, prioritisation allows for transformations at the landscape macrolevel to be managed, giving priority to certain industry groups. It is meaningful if hypothesis H1 is valid, and an important share of economic activities is included in the selected priority activities.

The "ecosystem perspective" is also strongly related to the twin transition, as digital and green transitions initiate system innovations that change the entire networking architecture of ecosystems, not just products and services [69]. However, there is something more. The current dominant pathway for product and service innovation is based on close associations between "research breakthroughs", "venture capital funding", and "startup creation" along connectivity illustrated as X-X′ axis in the cyber-physical system (Figure 2). In system innovation, this pathway and the networking architecture change, and the focus moves from startups to supply chains along with wider networking, illustrated as Y-Y′. The twin transition moves the entire system from state A to a new state B. For instance, the green transition combined with digital collaboration in the energy ecosystem introduces renewable energy, energy optimisation, and nature-based solutions, and changes the entire energy ecosystem, not only the innovative products of startups. The ecosystem perspective allows transformation to be organised at the regime mesolevel, connecting actors of the industry, science, technology, consumers, and policymakers into a new regime. It is meaningful if H2 is valid, and within the selected priority economic activities, we find a strong presence of ecosystems.

The "platform-based smart and green transition" allows transition to be organised at the niche microlevel, enabling an important number of actors of an ecosystem to adopt innovative solutions in tandem. As mentioned, ecosystems make easier the adoption of platforms. Over platforms, niche actors, entrepreneurs, startups, and spinoffs can experiment with radical innovations that deviate from existing regimes and propel the entire system towards a new state.

3.2. Evidence from the Case Studies

We assessed this generic pathway of industry transformation in research we conducted for the European Commission, DG Regional and Urban Policy, titled "Ecosystems and functioning EDP for S3 2021–2027" [70–72]. We investigated pathways of industry change in Greece and Cyprus relevant for research and innovation strategies for smart specialisation. The research was placed in the framework of good governance of national and regional smart specialisation strategies 2021–2027, which is assessed by seven fulfilment criteria, among which is the "functioning of stakeholder cooperation in the entrepreneurial discovery process".

The main rationale of EDP within RIS3 is that European regions should explore and exploit key capabilities for global niche markets and create long-term competitive advantages [21,73–75]. EDP is expected to reveal innovative, but place-specific and evidence-based, opportunities that take advantage of available resources and competencies. During the EDP, different entrepreneurial actors are brought together in a government-led participatory process generating a collective debate, integrating the divided and dispersed knowledge belonging to different actors, and setting common priorities for intervention.

Thus, the objective of the EDP is to identify pathways for industrial diversification and transformation towards higher added value activities [68]. Diversification may be *intraindustry*, when research and innovation change and improve the products and processes of an industry, or *interindustry*, when innovation leads to a branching of an industry towards other sectors. Interindustry diversification may be "*related*" or "*unrelated*" to existing skills and know-how. Empirical evidence suggests that knowledge spillovers within a region occur primarily among "related" economic activities and only to a limited extent among "unrelated" ones [76]. It is the "related variety" in a region that feeds branching out to new activities from technologically related activities, not regional diversity or regional specialisation *per se* ([77], p. 67). Unfortunately, we do not have any theoretical guidance about the diversification of industries in the other trajectories, in the case of either an intraindustry unrelated change or an interindustry unrelated change.

This theory gap is accompanied by a methodology gap regarding the granularity of the EDP. The granularity allows the level of detail to be defined when modelling industries or decision-making processes. The greater the granulation, the deeper the level of detail and the better the understanding of future trends. However, we do not proffer any methodological guidance about the best industry granularity level to perform the EDP. For instance, is it better to perform the EDP at the level of industry sections, industry divisions, industry groups, or industry classes?

Given these gaps, we addressed the functioning EDP as a transformation pathway defined by "prioritisation", "ecosystem identification", and "platform-based innovation", first, by identifying the most important economic activities per region; second, by identifying ecosystems, intra- or inter-regional, that have the potential for future growth and inclusive growth for most of their members; and third, by evaluating the potential for innovation, especially platform-based innovation and smart/green transition. Consequently, this research was conducted in three consecutive stages.

Stage 1: Identification and prioritisation of economic activities. As mentioned, NACE Rev. 2 classifies economic activities in industry sections, divisions, groups, and classes. Regional data are available for sections, divisions, and groups, and in some cases, for industry classes. Usually, the industry group level is at the level of higher granularity and detail when it comes to regional data. If the EDP is manageable at this level of detail, then the industry group level is preferable to any other level of granularity.

Data on the regional distribution of industry groups in Greece is provided by ELSTAT. We used the dataset of 2017. In this dataset, three variables are given per region and industry group: (1) number of legal entities (companies), (2) turnover, and (3) number of employees. Based on this dataset, we calculated two more indicators: (4) the location quotient based on the number of companies and (5) the location quotient based on the number of employees. The location quotient allows for the strength and size of a particular industry in a region to be evaluated. It quantifies how concentrated an industry is within an area compared with the country as a whole. It is the most preferred index of specialisation, calculated as a proportion of an industry in a region compared with the proportion of the same industry in the country. Having those five variables, we created our basic data matrix, which comprised 7 columns and 3536 lines (272 industry groups $\times$ 13 regions).

For each one of the above five variables, we ordered the industry groups per region and selected the top 10 by size and specialisation. We produced four ordered lists, by the number of companies, the number of employees, the location quotient on companies, and the location quotient on employment (top 40 industry groups). Then, we cleaned these ordered lists by removing industry groups with limited entrepreneurial activity, such as public companies, utilities provided by public authorities, public services for administration, defence, libraries and museums, and service sectors in which self-employment dominates, legal, accounting, veterinary, and so on.

Per region, the ordering and cleaning of industry groups by size (number of companies and employment) and specialisation (location quotient on the number of companies and employment) produced a list of the ***top 40 groups***, in total, 520 industry groups in the 13 regions of Greece. However, this was not a combined ordering. To arrive at a combined ordering of industry groups per region, we selected one after the other, industry groups at the top 10 positions in all four lists, industry groups at the top 10 positions in three out of four lists, industry groups at the top 10 positions in one list related to size and one list related to specialisation, and industry groups in two lists of specialisation. Table 1 shows the logic for selecting the top 10 industry groups per region. We start with the selection of groups that figure in all lists of size and specialisation and move down to industry groups of high specialisation.

Table 1. Selection of top 10 industry groups per region.

Top10 per Number of Companies		**Top10 per Employment**		**Top10 per Specialisation on Companies**		**Top10 per Specialisation on Employment**	
NACE	**Index**	**NACE**	**Index**	**NACE**	**Index**	**NACE**	**Index**
55.1	1077	55.1	20,284	10.4	8.12	10.4	6.39
10.7	591	10.7	3241	30.3	4.55	55.1	2.97
72.1	499	79.1	2570	23.4	3.55	50.1	2.80
10.4	466	50.1	1707	32.2	3.18	23.4	2.30
79.1	378	72.1	1323	55.1	2.51	79.1	2.04
62.0	351	10.4	1237	79.1	2.14	72.1	1.69
90.0	269	10.1	791	72.1	1.98	32.2	1.65
31.0	235	31.0	699	25.2	1.88	13.9	1.51
16.2	208	62.0	663	10.5	1.87	10.1	1.14
10.5	95	61.2	624	16.2	1.79	28.3	1.13

NACE	**Top10 per Number of Companies**	**Top10 per Employment**	**Top10 per LQ on Companies**	**Top10 per LQ on Employment**
55.1	1077	20,284	2.51	2.97
10.4	466	1237	8.12	6.39
72.1	499	1323	1.98	1.69
79.1	378	2570	2.14	2.04
16.2	208		1.79	
50.1		1707		2.80
10.1		791		1.14
10.5	95		1.87	
23.4			3.55	2.30
32.2			3.18	1.65

We consider these industry groups as the most important industry groups per region because they exhibit both large size and high specialisation. Looking at all 13 regions together, we find that the top 10 industry groups belong to 51 categories only, of which 26 categories appear in more than one region and 25 in one region only (Table 2). The 26 interregional industrial groups hold 105 of the 130 (81%) positions in the top 10 industries in all regions of Greece. From a prioritisation perspective, this finding shows that in 51 industrial groups, we can explore the most important economic activities in Greece, while 26 industrial groups capture 81% of the most important economic activities in the country.

Table 2. Most important (top 10) industry groups in regions of Greece.

NACE	Name	Number of Regions	NACE	Name	Number of Regions
55.1	Hotels and similar accommodation	8	63.9	Other information service activities	1
11.0	Manufacture of beverages	8	61.3	Satellite telecommunications activities	1
10.5	Manufacture of dairy products	7	61.1	Wired telecommunications activities	1
03.1	Fishing	7	50.2	Sea and coastal freight water transport	1
16.2	Manufacture of products of wood, cork, straw, and plaiting materials	6	32.2	Manufacture of musical instruments	1
31.0	Manufacture of furniture	5	32.1	Manufacture of jewellery, bijouterie, and related articles	1
03.2	Aquaculture	5	30.3	Manufacture of air and spacecraft and related machinery	1
25.1	Manufacture of structural metal products	4	29.1	Manufacture of motor vehicles	1
23.4	Manufacture of other porcelain and ceramic products	4	28.9	Manufacture of other special-purpose machinery	1
10.9	Manufacture of prepared animal feeds	4	26.7	Manufacture of optical instruments and photographic equipment	1
10.7	Manufacture of bakery and farinaceous products	4	26.2	Manufacture of computers and peripheral equipment	1
10.6	Manufacture of grain mill products, starches, and starch products	4	26.1	Manufacture of electronic components and boards	1
10.3	Processing and preserving of fruit and vegetables	4	24.3	Manufacture of other products of first processing of steel	1
90.0	Creative, arts, and entertainment activities	3	24.2	Manufacture of tubes, pipes, hollow profiles, and related fittings of steel	1
79.1	Travel agency and tour operator activities	3	23.6	Manufacture of articles of concrete, cement, and plaster	1
72.1	Research and experimental development on natural sciences and engineering	3	23.3	Manufacture of clay building materials	1
50.1	Sea and coastal passenger water transport	3	22.2	Manufacture of plastic products	1
23.7	Cutting, shaping, and finishing of stone	3	21.1	Manufacture of basic pharmaceutical products	1
16.1	Sawmilling and planning of wood	3	20.5	Manufacture of other chemical products	1
10.4	Manufacture of vegetable and animal oils and fats	3	18.2	Reproduction of recorded media	1
10.2	Processing and preserving of fish, crustaceans, and molluscs	3	15.1	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, and harness; etc.	1
10.1	Processing and preserving of meat and production of meat products	3	14.2	Manufacture of articles of fur	1
62.0	Computer programming, consultancy, and related activities	2	14.1	Manufacture of wearing apparel, except fur apparel	1

Table 2. *Cont.*

NACE	Name	Number of Regions	NACE	Name	Number of Regions
28.3	Manufacture of agricultural and forestry machinery	2	13.3	Finishing of textiles	1
22.1	Manufacture of rubber products	2	10.1	Processing and preserving of meat and production of meat products	1
10.8	Manufacture of other food products	2			

White for the primary sector, green for manufacturing, and brown for services.

Stage 2: Identification of business ecosystems. It is an important finding that 51 industry groups, which gather activities at a high granularity level, capture the most important economic activities of a country. Now, at stage 2 of research, we moved further and searched for ecosystems within those 51 industry groups.

This survey was carried out in 2020 and covered all 13 NUTS 2 regions of Greece. It was based on field research and interviews with companies and experts from relevant stakeholders and agencies to trace value chains, common strategies, common infrastructures, or operating platforms among the companies in the top 10 industry groups of each region. We prepared 13 questionnaires allowing us to identify the three most important business ecosystems per region. An example can be found at https://www.surveymonkey.com/r/7FKJVHF (accessed on 26 June 2022).

The survey showed that among the 51 identified industry groups, 25 have ecosystem features. They share a common infrastructure, natural or energy resources, or technology; they work with common platforms or are part of the same value chain. Moreover, these industry groups have typical characteristics of business complexes, such as geographical boundaries in one area, productive specialisation, and location quotients higher than 2 in all cases and higher than 10 in some cases. Those 25 industry groups/ecosystems are listed in Table 3. Most ecosystems are interregional, indicating the need for multilevel government across cities and regions.

Table 3. Key features of identified ecosystems/industry groups.

REGION	Industry Group/Ecosystem	Size of Ecosystem	Mature/ Emerging	R&D and Innovation Demand	Innovation Platform	Regional/Interregional
East Macedonia and Thrace	22.2 Manufacture of plastics	Small	Mature	Medium	New product and materials	Regional
	23.7 Cutting, shaping of stone	Large	Mature	Medium	Brand and by-products	Interregional
	26.2 Manufacture of computers	Small	Emerging	High	No	Regional
Central Macedonia	10.3 Processing fruit and vegetables	Large	Mature	High	Brand and packaging	Interregional
	14.1 Manufacture of wearing apparel	Large	Mature	Medium	Brand and design	Regional
	25.1 Manufacture of structural metal products	Large	Mature	Medium	Materials	Regional

Table 3. *Cont.*

REGION	Industry Group/Ecosystem	Size of Ecosystem	Mature/ Emerging	R&D and Innovation Demand	Innovation Platform	Regional/Interregional
West Macedonia	16.2 Manufacture of products of wood	Large	Mature	Low	Brand and eco-quality	Interregional
	14.2 Manufacture of fur	Large	Mature	Low	Export	Regional
Epirus	10.1 Processing of meat	Medium	Mature	Medium	Brand and packaging	Interregional
	10.5 Manufacture of dairy products	Large	Mature	High	Brand and packaging	Interregional
Thessaly	22.1 Manufacture of rubber products	Small	Emerging	Low	No	Regional
	31.0 Manufacture of furniture	Large	Mature	Low	Commercial infra	Interregional
Sterea Ellada	24.2 Manufacture of tubes of steel	Small	Mature	Low	New product	Regional
Ionian Islands	79.1 Travel and tour operator activities	Large	Mature	High	New product	Interregional
Attica	90.0 Creative, art activities	Large	Mature	High	Digital infrastructure	Interregional
	62.0 Computer programming	Large	Emerging	High	Market and infrastructure	Regional
	21.1 Manufacture of pharmaceutical products	Small	Emerging	High	New product	Regional
Western Greece	03.2 Aquaculture	Medium	Mature	Medium	Brand and new product	Interregional
	10.9 Manufacture of prepared animal feeds	Medium	Mature	Medium	Production and supply chain	Interregional
Peloponnese	11.0 Manufacture of beverages	Large	Mature	High	Production and by-products	Interregional
North Aegean	10.4 Manufacture of vegetable oils and fats	Large	Mature	High	Brand and quality	Interregional
	03.1 Fishing	Large	Mature	Low	Brand and Infrastructure	Interregional

Table 3. *Cont.*

REGION	Industry Group/Ecosystem	Size of Ecosystem	Mature/ Emerging	R&D and Innovation Demand	Innovation Platform	Regional/Interregional
South Aegean	50.1 Sea passenger water transport	Large	Mature	Low	Infrastructure	Interregional
Crete	55.1 Hotels and similar accommodation	Large	Mature	High	Market access	Interregional
	72.1 Research in natural sciences and engineering	Large	Emerging	Medium	Infrastructure	Interregional

Stage 3: Opportunities for platform-based digital and green transition. At this third stage of research, we further studied the 25 ecosystems identified, sketching their profile, assessing bottlenecks for innovation, needs and demand for innovation, and potential platforms that can lead to their smart and green transformation. Areas of ecosystem diversification were explored to better understand emerging trends and future growth areas.

The survey was based on secondary data from various sources, such as sectoral studies published by the Foundation for Economic and Industrial Research (IOBE) or other industry organisations; data from business directories on financial performance per industry and other secondary data sources, such as company websites, news, and reports from industry associations; and data from research proposals submitted in response to two national calls for research and innovation support. A report was prepared for each of the 25 ecosystems providing information on the ecosystem profile, relationship to regional research and innovation policy priorities, business and growth challenges, research and innovation demand, common challenges, and potential areas for platform-based ecosystems.

Based on this information, we produced a typology of the 25 ecosystems combining size, business challenges, and innovation demand, which reveals four different types of ecosystems, clustered around challenges of product design and development, production and supply chain optimisation, branding and promotion, and market innovation and export market access (Figure 3).

New product design and development is the dominant innovation challenge in ecosystems, such as 21.1–manufacture of basic pharmaceutical products (new medicines and molecules, pharmaceutical discovery, relocation and drug retargeting), 22.2–manufacture of plastic products (new degradable plastics, transition to a circular model), 55.1–hotels and similar accommodation (services to specific population targets, digital applications to provide advanced services or optimise existing services), 62.0–computer programming and consultancy (smart applications and new e-services), 79.1–travel agency and tour operator activities (replacement of services previously offered, design of new services). This challenge is pertinent for large and small ecosystems; emerging ecosystems, such as pharmaceuticals; or mature ecosystems, such as hotels and accommodation.

Production modernisation, supply chain optimisation, and environmental sustainability is the dominant innovation challenge in ecosystems, such as 03.2–aquaculture (improving the productivity, diagnosis and control of diseases, expansion of activities), 10.1–processing and preserving of meat and production of meat products (verticalisation, standardisation and processing, storage and distribution), 10.9–manufacture of prepared animal feeds (increased specialisation, supply of raw material, lowering production costs), 11.0–manufacture of beverages (protocols for the clonal selection of grapevine, vertical coordination, high labour costs), and 23.7–cutting, shaping, and finishing of stone (automation, exploitation of mining and marble by-products, environmental remediation, quarry rehabilitation). These innovation challenges are pertinent for large and medium-size ecosystems, characterised by midlevel demand for research and innovation and needs for technology transfer rather than radical process innovations.

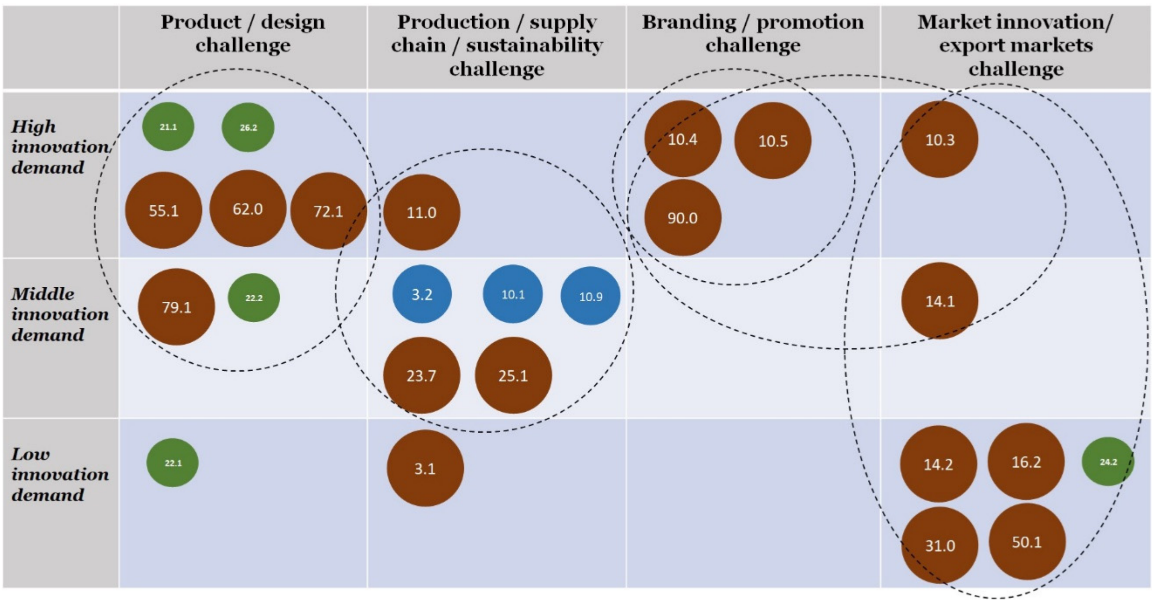

Figure 3. Areas for platform-based innovation in the 25 identified business ecosystems (brown, ecosystems with more than 200 companies; blue, ecosystems having between 50 and 200 companies; green, ecosystems with less than 50 companies).

Branding and promotion are the dominant innovation challenges in ecosystems, such as 10.4–manufacture of vegetable and animal oils and fats (high quality of products but low branding, standardisation of quality, trade-in bulk form), 10.5–manufacture of dairy products (local brands, better packaging, international sales networks), 90.0–creative, arts, and entertainment activities (access to media, innovative platforms for promotion, dissemination of intangible cultural heritage).

Market innovation and access to global markets is the dominant innovation challenge in ecosystems, such as 4.2–manufacture of articles of fur (sharp drop in demand from abroad, lost market shares due to traditional promotion models). In the internal market, the collapse of demand due to the construction sector crisis exerts pressure in industries, such as 16.2–manufacture of products of wood, cork, straw, and plaiting materials; 24.2–manufacture of tubes, pipes, hollow profiles, and related fittings; 31.0–manufacture of furniture, making urgent the turn towards new markets. The 50.1–sea and coastal passenger water transport was also affected by the crisis. All these ecosystems are mature, characterised by low-level innovation capabilities and demand. This is an additional barrier to industrial transformation.

The profiles of industry groups/ecosystems also reveal the potential for platform-based development to address common challenges of companies belonging to an ecosystem. We identified product, production, trade, technology, and environmental challenges, and consequently, platforms were identified in 23 cases to lead the twin digital and green transitions. Platforms may be physical, institutional, infrastructural, or digital. They can be *market-driven*, providing access to markets, branding, and promotion; *product-driven* for new product design and development, smart products, product quality, and certification; *technology-driven* to facilitate research, processing technologies, and supply chain integration/optimisation; *infrastructure-driven* to provide physical, institutional, and digital infrastructure; and *materials-driven* to better manage new materials, raw materials, waste, and recycling. Such platforms strengthen the ecosystems identified, acting as anchors for orchestrating complementors.

Technologies to be used in platform development are listed in Table 4. These are smart and green technologies to be applied at the company and ecosystem levels, enabling the orchestrated innovation and growth of the respective ecosystem.

Table 4. Technologies for digital and green transition.

	Smart Technologies	Green Technologies	Smart–Green Technologies
Company level	• ERP, CRM • e-Commerce • Digital marketing • Automation • IoT, smart meters • AI • Data and analytics	• Circular design • Waste treatment • Recycling • Renewable energy (RE) • Energy storage • Energy saving • Building retrofitting	• Energy optimisation • Energy saving • Materials optimisation • Telework • Digital twins
Ecosystem level	• Branding • Two-sided platforms • Marketplace e-commerce • Crowdsourcing • Supply chain optimisation • Cloud, smart infrastructure • Data and analytics	• The above plus • Large-scale RE • Ecosystem-based RE storage • Energy communities • Footprint benchmarking • Nature-based solutions	• Energy sharing platforms • Smart grid • Smart grid energy storage • Data dashboards • Pollution alert • Digital twins • Blockchain self-organisation

A good working example of platform-based innovation is Mediterra S.A, the research and innovation centre of the mastiha producers of Chios Island. It was founded by the Chios Mastiha Growers Association for product development and marketing of mastiha and the promotion and sales of mastiha products worldwide. To date, the company has developed a retail outlet network under the brand "mastihashop" that comprises stores in Greece and abroad, has established a food production facility in Chios where over 100 different products are produced, and has developed a wide distribution network for brands, such as natural mastiha, mastiha chewing gum, cosmetic products, parapharmaceutical products (selling line: mastiha therapy), and Greek food products (selling line: cultura mediterra). The centre performs R&D on the antibacterial activity of mastiha, nonoxidative action, mastiha in oral hygiene, dermatological and healing properties of mastiha, and new product development using mastiha as a natural supplement to functional foods. Own facilities cover an area of approximately 10,000 m^2 and house the total range of activities, including two production units for mastiha processing and packaging, testing new products, and distillation of mastiha oil.

Another example is a smart–green platform for the industry ecosystem, 10.3–processing and preserving of fruit and vegetables, which brings together companies from Central Macedonia (177), Western Greece (64), Thessaly (74), and Peloponnese (78) with 9601 employees and EUR 1.382 billion turnover (2017). This platform promotes green production and nonplastic packaging, which is a common challenge among companies in this industry. The aim is to create a high-quality brand that provides also quality certification, branding products for green production and alternatives to plastic packaging. Demand for sustainable production and packaging is likely to increase during the next years, and their early adoption can provide a competitive advantage for fruit producers. Using digital tools, the platform offers to all participating companies' full information and traceability of products throughout the supply chain. At the same time, the platform can work as a competence centre promoting learning and the adoption of green production technologies and related smart systems in the processing of agricultural products. This may further enhance the competitiveness of this transregional ecosystem of processing and preserving fruits and vegetables.

4. Discussion

The literature on the current industrial transformation in cities and regions reveals the central role of smart and green technologies in enabling system innovation or transformative innovation through the processes of digitalisation, optimisation, dematerialisation, CO_2 reduction, and circularity. The multilevel perspective offers a good theoretical framework that allows industrial transformation, twin transitions, system innovation, and industry ecosystems to be connected and integrated. The interest in industry ecosystems and platforms, enabling the formation of ecosystems, is a direct outcome of system-level changes that transform the organisation of industries, not only their products and services.

The contribution of the present paper to this debate is through the assessment of a generic pathway for managing the transformation of activity ecosystems in cities and regions, which stands on instances of "prioritisation", "ecosystem identification", and "platform-based smart and green transition". The case studies we summarily presented provide good feedback on the feasibility of this generic pathway and how its three instances work together and complement each other.

We have seen that prioritisation with respect to size and specialisation allows the complexity of industrial transformation to be lowered. At a level of high industry granularity, instead of considering the transformation of 272 industry groups, we can focus on 51 groups only. In Greece, these top 10 industry groups per region capture an important share of industrial activity, including 34.04% of companies, 38.57% of employment, and 42.20% of turnover. In the Cyprus case study, also working with top 10 industry groups by the number of companies, size of employment, production value, fixed capital investments, and emerging industries, the same prioritisation method allowed us identify 16 industry groups that account for the lion's share of the overall industrial activity, including 43.33% of companies, 57.37% of employment, 64.34% of production value, and 72.73% of fixed capital investment.

Prioritisation and a focus on a smaller collection of industry groups pave the way for surveys on ecosystem identification. Within the 51 top 10 industry groups across the 13 regions, we identified 25 ecosystems (see Tables 2 and 3). Most ecosystems are large (17), having more than 200 companies; fewer are small (5); and even fewer are midsized ecosystems (3). Additionally, the majority are established mature ecosystems, justifying a deviation from the startup innovation model towards a model engaging existing supply chains and wider networking, as illustrated in Figure 2.

The third stage of the case studies focused on identifying technologies and platforms that offer opportunities for digital and green transition. Platforms, on the one hand, upgrade products, services, and processes at the ecosystem level and, on the other, affect a large number of businesses and organisations that are active in the ecosystem. Working with industry-wide platforms involves a two-part structure: on the one side is the platform with its infrastructure, hardware, software, and data, and on the other side are the organisational or technological solutions hosted on the platform. A typology proposed by Srnicek [78] classified platforms according to their purpose: *advertising platforms* that offer advertisement space, *cloud platforms* that offer hardware and software as a service, *industrial platforms* that offer infrastructures for the transformation of manufacturing, *product platforms* that generate revenue by offering goods as a service, and *lean business model platforms*. In platform-based ecosystems, the orchestration of producers and consumers is achieved by the platform, its services and infrastructures, and the business model for viability. Platforms offer services or infrastructure and have income from these services that ensure their sustainability.

All three hypotheses related to the instances of the generic pathway for industry transformation have been verified by the case studies: H1, that most important economic activities (by size, specialisation, investment) have a high share of all economic activities and a relatively small number of principal economic activities account for the mass of all economic activities of a city or region; H2, that we can identify ecosystems around the most important economic activities when these are defined by size and specialisation; and H3, that within the economic activities of prioritisation and the ecosystems created around them, we can identity platforms for smart and green transition relevant for many companies and organisations of the industry or ecosystem.

Working along with these three instances that define a generic pathway for industry transformation, the critical path is related to the third instance of platform-based transition. Platforms providing services for market making (access, branding, promotion), product development (innovation, quality, certification, standardisation), and technology development (materials, processing, supply chain optimisation, circularity) are mostly needed to collectively address the innovation and transformation challenges faced by activity ecosystems. They give birth to or strengthen ecosystems created around common challenges. Platforms and ecosystems also guarantee the public character of the innovation policy as they serve the common needs of industry groups rather than the interests of individual companies in the group. The collective character of innovation and transformation trajectories is introduced by user and stakeholder engagement in decisions about platform selection, deployment, and operation procedures. This is a standard procedure within smart environments [79,80].

5. Conclusions

In this paper, we described and assessed a generic pathway for managing the transformation of activity ecosystems in cities and regions defined by the processes of "prioritisation", "ecosystem identification", and "platform-based digital and green transition". These three processes drive a system change of ecosystems, as outlined by the multi-level perspective in the socioeconomic landscape (wider trends of globalisation, population, financial conditions, lifestyles), sociotechnical regime (conventional routines and rules), and niches (new technologies and practices) [81].

The three instances of this generic pathway work in tandem. "Prioritisation" lowers complexity and allows the potential for system change in the most important industries to be assessed, while maintaining a high level of granularity and detail. "Ecosystem identification" delineates the change at the level of industry groups rather than individual companies, maximising the impact and ensuring the public character of innovation policy. "Platform-based smart and green transition" strengthens the ecosystem perspective with technologies and solutions over which many organisations can build complementary products and services.

Assessing the pathway in Greece and Cyprus, we showed its feasibility and functionality. Prioritisation worked as foreseen, enabling a focus on the most important industry groups; ecosystems and platforms for transition were identified within the priority industry groups. The ecosystem perspective is justified as the core component of the pathway, linking prioritisation and platform-based innovation and capitalising on the capacity of the digital transition to mobilise connected intelligence and capacity building in human–computer–community networks [82].

Industries and activity ecosystems in cities and regions are undergoing restructuring due to the widespread use of digital and green technologies, related products and processes, that can address contemporary challenges of growth, sustainability, and climate change. The pathway we described allows public authorities to assess the potential for smart and green transition at the level of each industry group without excluding any important group in advance. Two reasons justify the orientation of this approach: first, the widely accepted principle of smart specialisation for a place-specific innovation strategy or "one-size-does-not-fit-all", which suggests that theoretical predictions about future growth should be assessed and validated with place-specific data; second, the probability of finding innovative smart/green solutions in less expected activities, a trend outlined in many aspects of the innovation theory, such as the probabilistic and nondeterministic character of innovation, serendipity in innovation, and innovation outcomes by chaotic systemic combinations.

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