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Digital Entrepreneurship Services Evolution: Analysis of Quadruple and Quintuple Helix Innovation Models for Open Data Ecosystems

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Abstract: Open data hackathons are events where the actors from an ecosystem collaborate to build platforms that will benefit the public, creating a win–win scenario for all of them. Sadly, many digital services produced in hackathons are discarded only by providing access to open data that cannot boost economic benefits. Therefore, it is necessary to create a model that fosters value and entrepreneurship for the open data ecosystem, aiming to develop an economically self-sustained ecosystem. The purpose of this paper is to identify the challenges participants of open data hackathons can face to present a model that will support the improvement of these contests. This paper uses the quadruple/quintuple helix innovation model to drive innovation and entrepreneurship in Thessaloniki's open data ecosystem to develop applications using open data. The results indicate that, although actors are aware of open data use, a new type of open data ecosystem that creates a win–win scenario between the entities in the open data ecosystem is required. The proposed model implies a full effect that promotes cooperation and networking among the entities in the city's ecosystem towards achieving the aim of increasing citizens' quality of life.

Keywords: entrepreneurial ecosystem; innovation; open data; hackathons; triple helix; quadruple helix; quintuple helix

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1. Introduction

Open data is a vital field both for scholars and researchers. Open data should be published without costs, available for everyone, and reused without restrictions. The most significant motivations, according to the usage of open data, are economic and social motivations. Open data provided by government or businesses have economic benefits for developers, citizens, and businesses in the private sector. Public sector organizations and businesses publish data to nascent entrepreneurs to create platforms and develop digital services to enhance the quality of citizens' lives. Regarding the social motivation, the government publishes data to decrease bureaucracy and increase accountability, transparency, and participation in government [1–15]. Furthermore, [16] highlighted some advantages for citizens. These advantages include an increase in accountability, transparency, and civil participation. Other benefits of open data for citizens are increased accountability, trust, citizens' satisfaction, and efficiency of the decision making process [17].

The value of the published data is not only for public organizations, but this value is distributed between the actors of an open data ecosystem. These actors may be public sector organizations, data providers, service and infrastructure providers, businesses, developers, research centers, and academic institutions, or nascent entrepreneurs [18–21]. In the current literature, the advantages for entrepreneurs that create new business models or services based on open data have been identified. Open data helps them develop new business

models and boost innovation, firm performance, and competitive advantage. Another benefit is the development of new digital services based on the use of open data that increase innovation. Many digital tools are available for nascent entrepreneurs to optimize data to improve digital services for society [22–27].

Although the advantages for citizens, startups, and public sector organizations are significant, there are some obstacles, such as limited knowledge about the benefits of open data and limited new business and operation models. Other obstacles concern the availability and access of data, the usability of developed digital services, the quality of published data, and the compatibility of data to develop platforms [2,28]. Significant barriers concern the quality of information, the legislation, and citizens' participation [21,29,30].

Despite the advantages of open data for developers of digital platforms, the lack of an ecosystem that creates value has been cited as an essential concern for the development of services and platforms using open data [18,19]. This fact could be explained because developers cannot use data to establish new startups, or they do not have the appropriate technical skills to use data. Furthermore, the published data format is complex, and developers cannot combine data to develop digital services [31]. Additionally, the difficulty of generating data to develop applications or platforms, the insufficient access to national or regional data repositories, and legal and technical restrictions on accessing data are substantial barriers to using data for the development of digital services and applications [32–34].

Open data hackathons, or digital innovation competitions, are events where people from various sectors collaborate to build platforms that have benefits to the public, creating a win–win scenario between the actors involved. In the hope of promoting the creation of digital services that can be the fundamental element of the development of new start-ups, government agencies coordinate such events. This is a remarkable way of growing entrepreneurship [35]. In this way, developers could extend their applications to a new start-up as they can efficiently collaborate with the help of organizers because they have access to the required infrastructure in terms of increasing entrepreneurship, and hackathons can be an excellent experience as nascent entrepreneurs cooperate with external partners to promote new ideas [36]. Unfortunately, many applications produced in hackathons are discarded only by providing access to open data that is not enough to boost economic benefits [37–39].

According to previous researchers, academics and practitioners highlighted a research gap in understanding the development of applications using open data. It would be interesting to explore the actors that participate in an open data ecosystem, their relationships, and how value can be created to develop innovative services. Therefore, it is necessary to create a model that fosters value and entrepreneurship for the open data ecosystem, aiming to develop an economically self-sustained ecosystem. In this view, there is a need to understand the challenges and benefits of various actors in the open data network and the obstacles in data sets to develop improved services for citizens, consumers, firms, and organizations in the public sector [40–42].

The purpose of this paper is to identify the challenges that participants of open data hackathons can face to present a model that will support the improvement of these contests. This paper uses the quadruple/quintuple helix innovation model to drive innovation and entrepreneurship in Thessaloniki's open data ecosystem to develop digital services using open data. The helix innovation model was created many years ago and expanded to the quadruple helix innovation model and then to the quintuple helix model to boost innovation and entrepreneurship in several research areas. The outcomes of this article present the role of each actor involved in Thessaloniki's open data ecosystem, the relationships among them, and their motivations to enhance entrepreneurial activities. The results indicate that although actors are aware of open data use, a new type of open data ecosystem that creates a win–win scenario possible between the entities in the open data ecosystem is required. The proposed model implies a total effect that promotes cooperation and networking among the city's ecosystem entities towards increasing citizens' quality of life. As more

open data hackathons are organized in many cities and considered enablers of innovation, organizers must cooperate with academic institutions, governments, end-users, and other entities of a city's ecosystem. Therefore, the quality of these events will be increased, as well as the quality of applications and citizens' life.

The following is the structure of the article. The Section 1 presents a brief introduction to the area and demonstrates the significance of this study and the research gap. The Section 2 presents the theoretical analysis of the paper. The methodology is described in Section 3, and Section 4 represents the outcomes. Section 5 represents limitations and suggestions for further research.

2. Materials and Methods

2.1. Open Data Ecosystem

An open data ecosystem includes the actors who cooperate to create applications and increase value and innovation. Data and infrastructure providers, application developers, and end-users are involved in these actors. Data providers are usually governments or other public organizations that offer data to other entities in the ecosystem without costs or legal licenses. The purpose of data providers' activities is to provide data to develop services for companies or citizens and improve the economy. Licensors can achieve access and copyright authorizations to provide data to organizations for free using many public licenses [18,19,43–47].

Service providers provide services that have been created using open data. Service providers aim to increase their profit from the distribution of these services. They can distribute complete services or just a part of a service chain. Service providers can buy the processed data from data providers because they cannot implement the data processing themselves. Therefore, service providers need to define consumers' requirements, generate relevant data from input data for a particular context or domain, and display it in a usable format to deliver services [18,19,43–47].

The essential tools for the rest of the actors involved in the ecosystem are offered by infrastructure and tool providers. They support the actors of the ecosystem and increase their profit from the usage of applications and platforms. Additionally, marketplace providers provide a marketplace where digital services and applications are available for sale. Tools for developers are available from tool providers to help them develop platforms regarding various end-users' needs and create and test the platform. Cloud service providers provide the physical resources to the ecosystem's actors and increase their profit from the facilities' "rent" [18,19,43–47].

All the actors of the ecosystem collaborate with application developers to develop innovative platforms using open data. Application developers can gain feedback from users who have ideas for new platforms and services. This feedback affects the continuous and iterative development of platforms. In contrast, users of these platforms consume data by using services and platforms that have been created using open data. Users could be customers, citizens, or companies [18,19,43–47].

The cooperation among these entities is substantial, and each one of these actors has a different role. These roles are the following: the raw data provider, the linked data provider, the linked data application provider, and the end-user. The first one offers raw data to the linked data producer. The second one converts data into a suitable format for delivery to the application provider. Then application providers use linked data to create platforms for users [42,48]. Therefore, transforming raw data into a suitable format and creating platforms using linked data are significant revenue sources of open data [49]. The entities of the open data ecosystem and their roles are described in Table 1.

Table 1. Actors of the open data ecosystem.

Actors of the Open Data Ecosystem	Definition
Data providers	Data providers are usually governments or other public organizations that distribute data without costs or legal licenses to other entities in the ecosystem. The purpose of data providers' activities is to provide data to develop services for companies or citizens and improve the economy [18,19,43–47]
Service providers	Service providers provide services that have been created based on open data. Service providers aim to increase their profit by distributing these services [18,19,43–47]
Infrastructure and tool providers	The required resources for the entities of the ecosystem are provided by infrastructure and tool providers. They benefit ecosystem actors by increasing their profit from applications and platforms [18,19,43–47]
Application developers	Application developers can gain feedback from users who have ideas for new platforms and services. This feedback affects the continuous and iterative development of platforms [18,19,43–47]
Application users	Users of platforms consume data by using services and platforms that have been created using open data. Users could be customers, citizens, or companies [18,19,43–47]
Raw data providers	The raw data provider provides raw data to the linked data producer [42,48,49]
Linked data providers	The linked data converts data into a suitable format for delivery to the application provider [42,48,49]
End-users	They use the platforms that have been created by developers [42,48,49]
Applications developers	They develop open data-driven platforms [49]

The authors of [50] examined the perspectives of various groups of stakeholders. These stakeholders could be primary actors (e.g., actors of the political system, organizations in the public sector, and international organizations), secondary actors (e.g., civil society activists, funding donors, technology providers, and scholars), companies, or end-users in Chile. The authors suggest that further research is necessary for this field, considering data publication as an emerging phenomenon.

The authors of [51] examined different actors in the open data ecosystem. The researchers highlight that the open data ecosystem consists of citizens, public sector organizations, companies, and innovators (third-party developers). Each role of these actors is essential for the open data ecosystem because the distribution of open data value in the public sector can be created if these actors collaborate and promote applications. According to the researchers, government information is a valuable source of innovation for organizations in the public and private sectors. The transparency of government, as well as its cost-efficiency, are what make the encouragement of these applications so appealing, and their stakeholder is essential actors in the open government data. Considering that the open data ecosystem is an emerging topic for e-government studies [51], the analysis of actors' viewpoints is required in related research, presenting cases and examples of such perspectives.

To investigate different stakeholder perspectives of the open data ecosystem, [52–54] conducted stakeholder analysis of citizens, practitioners, politicians, businesses, publishers, open data users, data intermediaries or wranglers, public agencies, developers, and users in different countries (Sweden, The Netherlands, North Europe, and Ireland). Furthermore, many e-government researchers focused on examining specific groups of open data actors because they are usually denominated as intermediaries who participate in the distribution of open data. Open data is a topic that promotes collaboration, mainly when it refers to the analysis of the perspectives of different civic actors, business players, scientific communities, developers, and public agencies [16,27,29,55–57].

2.2. Quadruple/Quintuple Helix Innovation Models

There was a requirement for more efficient collaboration procedures in new product development due to technology development and the impact of globalization. The significant assumption of the concept for collaboration among academic institutions, governments, and industry was the triple helix model [58] (Figure 1). The triple helix model of knowledge production was created by [59]. The authors of [59] developed three "helices" that interweave and form an innovative system including academic institutions, industry, and government. They focused on "university–industry–government relations" and networks, and they paid specific attention to "tri-lateral networks and hybrid organizations" where the helices intersect. The triple helix may be described as a "core model" for innovation, arising from interchanges in knowledge production involving academic institutions (higher education), industries (economy), and governments (multilevel). The triple helix was examined by the broader innovation model of the quadruple helix (government, academic institution, industry, and citizens), which added attributes of the public, such as society, media, and culture [60]. Furthermore, the parts of the triple helix system form the institutional circles of academic institutions, industry, and government that contain the stakeholders [61].

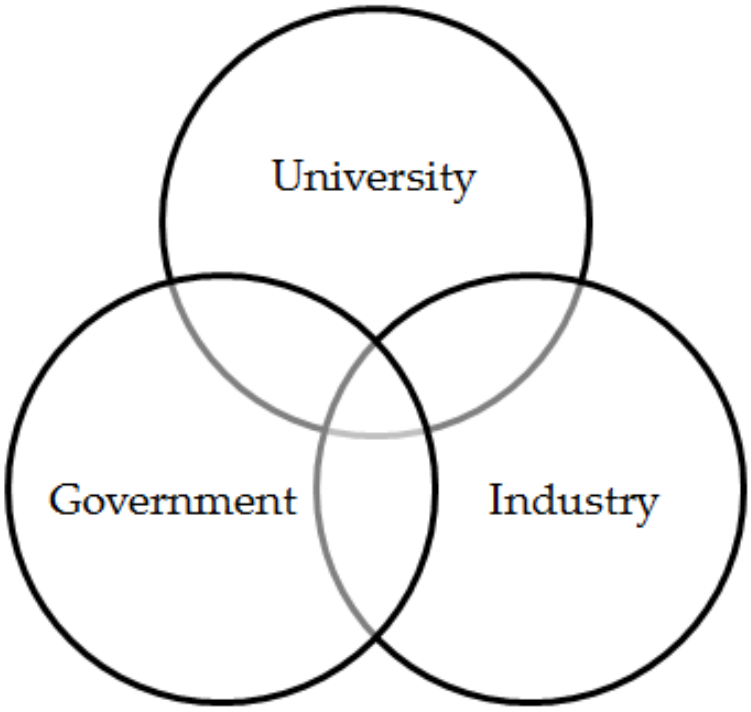

Figure 1. Triple helix model (Modified from [62]).

The authors of [63] presented an extension of the triple helix model, named the quadruple helix innovation system framework (Figure 2). This framework highlights that a more comprehensive understanding of how knowledge and innovation are created is necessary as the public consolidate more into advanced innovation systems [60]. The quadruple helix innovation system framework emphasizes collaboration, co-creation, and co-specialization of the innovation process within and across regional and sectoral ecosystems [63–65]. Innovation could be viewed as an enabler for various smart specialization strategies (and marks the start of a shift systemic and user-centered innovation structures). The quadruple helix innovation system framework highlights that users are a core element of innovation and supports creating innovations relevant to users (civil society). Within this frame of reference, users are involved in the development of new innovative products and services. Users act as co-developers, lead users, and co-creators during the innovation process [62].

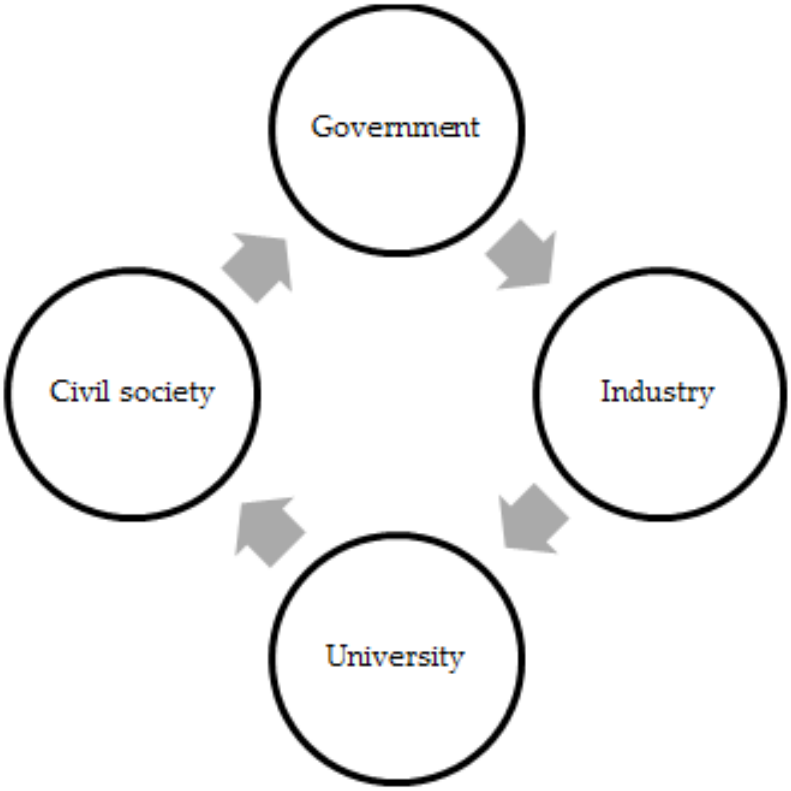

Figure 2. Quadruple helix innovation system framework (modified from [62]).

Moreover, the triple helix model mentions the concepts of "Mode 1" and "Mode 2" knowledge production [66]. The first concept focuses on basic academic research (basic research produced by universities), which is being classified in a disciplinary manner to be aligned with the linear model of innovation. The second model is related to knowledge execution and knowledge-based problem-solving and includes the following attributes: execution knowledge, transdisciplinarity, diversification and business homogeneity, social responsibility and reflexivity, and quality evaluation [65]. "Mode 3", which is aligned with the broader view of the quadruple helix innovation system framework, focuses on innovation ecosystems that support the co-creation of several knowledge and innovation modes. Furthermore, when it comes to multi-level innovation systems, it balances non-linear processes of innovation [63].

The evolution of the knowledge-based society, information society, and knowledge-based economy support the transformation and development of innovation processes, as well as the persuasion of new stakeholders to participate in the process. The participation of new stakeholders supports the exchange of information. Governments, entrepreneurs, and municipalities have to communicate with them, which generates the opportunity to add a more significant entity to the model, the media. The media is a substantial element in any innovation process and acts as a communication channel between the general public and potential auditors and implementers. It is a successful factor in any practical implementation [67–69].

The quintuple helix innovation model (Figure 3) is fascinating and helpful in analyzing ecosystems and describing the knowledge sharing process, which occurs in such collaborative ecosystems. Each stakeholder in this ecosystem contributes to the overall success of the ecosystem. These attributes can be used both for the diffusion of research and development and for knowledge sharing between focus groups to use the outcomes of action and, as a result, educate civil society about the benefits of those projects [58].

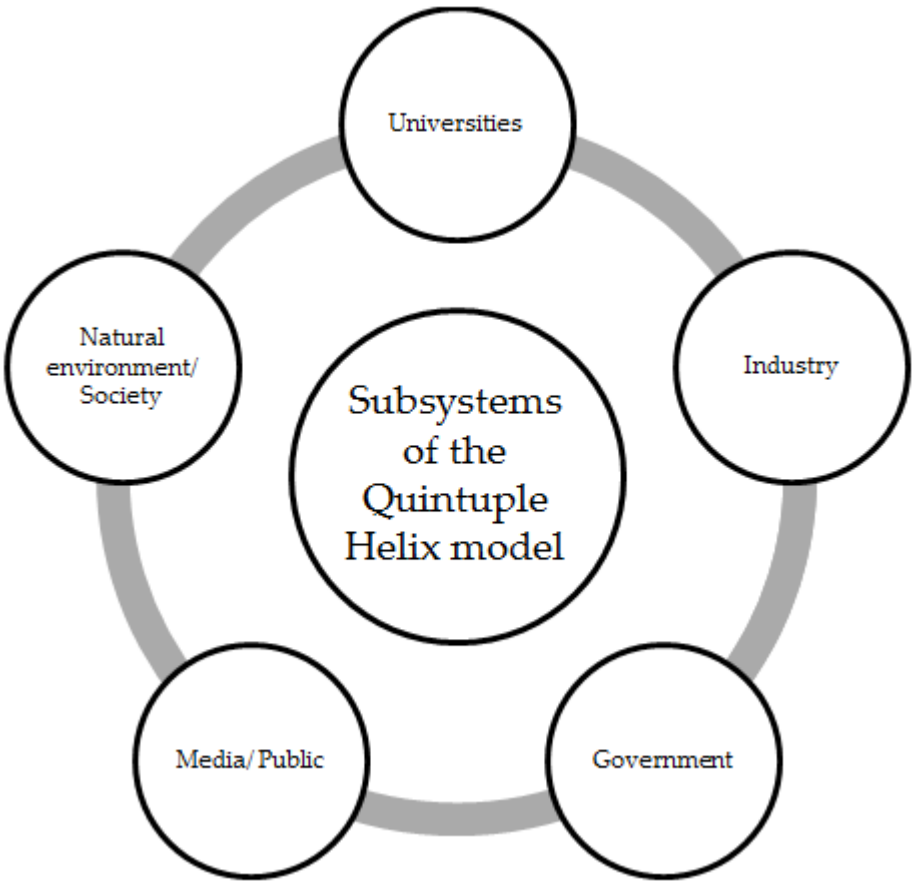

Figure 3. Subsystems of the quintuple helix model (modified from [62]).

2.3. Description of Interviews

Existing researchers presented the motivations, benefits, and obstacles according to open data that face data providers, service providers, tool providers, developers, and end-users [18,19]. The authors of [70] explored the gaps among data providers and users who use data. The challenges are related to data format, a lack of knowledge about existing data sets, the ability to acquire and use data, and the ability to assess the effect of open data. The authors of [71] presented some metrics that can develop and sustain value in a network. These metrics are related to data selection, the type of licenses and privacy, the assessment of data quality, data accessibility and traceability, the level of support provided by organizations that are involved in the publication of data, the user's participation in open data, the exploitation for profit, and the assessment of the effect of open data. The authors of [20] described the benefits and value of open data for firms and for the ecosystem in order to be sustainable. They implemented interviews with businesses that were chosen during their participation in a contest in Finland.

In this respect, the survey is based on the findings of 13 semi-structured interviews with actors of open data value ecosystem. These interviews were implemented with the actors of Thessaloniki's open data ecosystem in Greece. The choice of participants is based on guidelines of previous similar studies [20,70,71]. Each interview lasted an average of 60 min, with a range of 55–70 min. The participants were chosen because they are well-versed in the open data ecosystem in which they act. Actors that joined hackathons were chosen because digital contests are events where people create teams to cooperate and develop digital services and platforms for the public [37]. Therefore, these actors can provide information concerning the collaboration among them, the obstacles of open data, the value of digital services, and how they could develop platforms and digital services using open data [18,19,43–45]. Two service providers, two data providers, three application

developers, two infrastructure and tool providers, and four application users participated in the interviews. Participants discussed the following topics: What are the relationships among the entities of the open data ecosystem? What are their activities? What are the most critical challenges for them? [43–45].

The analysis of interviews focuses on the following concepts: the main activities of each actor, the relationships among actors, challenges and barriers that face each actor to create value based on open data, and suggestions for improving Thessaloniki's open data ecosystem based on actors' perspectives.

3. Results

Findings show that Thessaloniki's open data ecosystem is not mature, and it has not been developed yet. The value for the actors of the ecosystem is not significant because actors are not aware of it yet. As a result, the opportunities for application developers are not important. Developers cannot develop entrepreneurial activities because they do not have the appropriate tools. Many hackathons have been implemented in the city but there is a lack of entrepreneurial opportunities. The developers who have been involved in hackathons developed business models for their services or platforms but are not commercial. All the entities of Thessaloniki's open data ecosystem highlighted the need to boost entrepreneurship by organizing hackathons, but the efforts that have been implemented so far are insufficient. A negative factor is that actors cannot understand the benefits of open data value in the city's economic growth.

New entities can be involved in Thessaloniki's open data ecosystem such as infrastructure providers, startups, and mentors for developers. These new actors can increase the entrepreneurial activities of the ecosystem. Companies and intermediaries could be engaged in the ecosystem because they can support new platforms or digital services to be launched to the market and thus developers can create new startups. Although the participation of more entities in the open data ecosystem is significant, there are barriers to their participation such as limited awareness regarding the advantages of open data.

The distribution of data is based on both the Hellenic and European legal framework, and actors have to follow these instructions. In Greece, there are some restrictions for the availability of open data regarding the legal framework. Actors are required to comply with the guidelines of this framework while organizations make efforts to open data in appropriate formats to enhance transparency and entrepreneurship. Actors in the public sector organizations do not use contracts because they do not intend to receive economic profit. The contracts are helpful for individuals in private sector.

The portal of municipality is used by data providers as a communication channel to make data available. Despite the fact that this is a common method, it should be enhanced because the portal does not make it apparent where the data is published from. In addition, the service provider uses the Open Knowledge Foundation (OKFN) portal to publish data. Developers launch their applications to the market using the Google store or the App Store or many European platforms. All actors in the open data ecosystem highlight that the development of new websites is required to offer datasets and tools that will be useful for developers.

Data are published in the following formats; .doc, .xls, .pdf, and .jpeg. The aim of data providers is to increase data quality and update them. However, the format of published data is static. Tools are developed by service providers to share data between the actors of the ecosystem. The technical characteristics of data are not a barrier in order to increase entrepreneurial activities in the ecosystem. The most significant obstacle is the lack of education of users about the use of data. Application developers highlight that they use open data to develop platforms, but they do not have significant value because the data are not updated. In addition, all entities indicated that they should have access to additional data, and the format may be enhanced.

Providers use resources that concern the collection, publication, and preservation of data. However, they need support to educate the users about open data. Users must be

knowledgeable about the value and significance of open data and how they can use it. Individual and businesses have already considered the value of data, but more training about open data usage is still necessary. Providers mentioned that they are willing to create new tools to be used for the statistical analysis of open data. Developers require more resources when they join digital contests to develop their platforms and enhance their entrepreneurial opportunities. During digital contests, they face many challenges developing new platforms because data providers do not offer data in an appropriate format. Moreover, there is a lack of technical resources. Furthermore, businesses and mentors do not attend hackathons to support developers in expanding and launching their platforms.

The data provider of the ecosystem highlighted that collaboration among municipality, research institutes, academic institutions, laboratories, and the private sector is necessary to offer more data to application developers and enhance the entrepreneurial opportunities for their platforms. Data providers collaborate with academic institutions, research centers, and organizations in the public sector to open data and distribute it to application developers to create their platforms. Data providers make efforts to encourage organizations in the public and private sector to publish their data when a hackathon is organized in the city. Application developers indicated that service providers have a supportive as well as a technical role because they can support developers to launch their platforms and provide technical infrastructure to create their platforms. However, even though the city hosts several innovation competitions, companies do not engage in supporting developers to establish new startups and do not publish their data. Businesses should collaborate with organizations in the public sector to provide data that will be helpful for developers who develop digital platforms.

Companies have realized the motivations and advantages of their participation in the city's open data ecosystem. This engagement can help them generate new ideas, visualize data, and develop new services. The value of products based on open data is increased, and the ecosystem supports the development of these products or services that do not compete with the firm's products. Thus, open data are considered as an effective way to increase competitive advantage. Open data increases the rate of use of data and makes it accessible to developers who create platforms for specific target groups with certain needs.

The government is a significant source of data that is provided among the actors of the ecosystem. The government makes decision about the collection and publication of data as well as the amount, format, and quality accessible data. Technical formats and quality standards throughout the government can help ensure that datasets are meaningful and usable.

Another significant actor in the open data ecosystem is the non-government sector. This sector provides consultative and administrative services to citizens, developers, government agencies, and other non-governmental organizations and offers many funding options for the development of platforms or digital services based on open data for the local and national economy. The social value of open data aims to help developers to create startups and enhance collaboration and engagement of society in associated decision-making activities. Universities and research centers are significant drivers of the awareness of collaborating, publishing, and using open data. Such institutions of education are the centers where open data and open source software movements are becoming fundamental. Figure 4 presents the actors who join Thessaloniki's open data ecosystem and their roles.

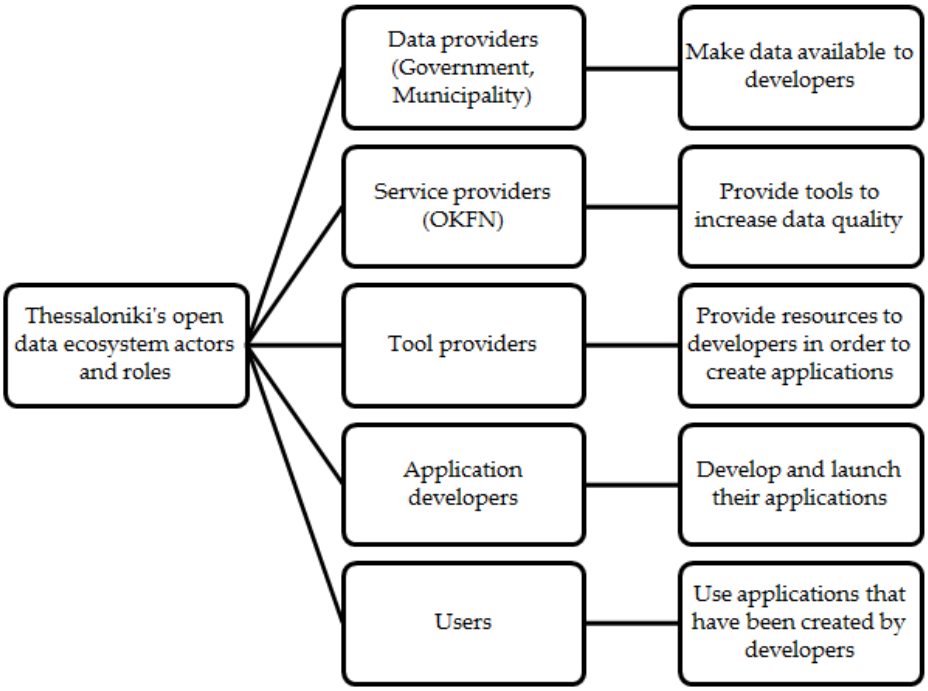

Figure 4. Thessaloniki's open data ecosystem actors and roles.

4. Discussion

The creation of application using open data requires skillful developers who should have the willingness to participate in the ecosystem and contribute their knowledge, time, and expertise in order to collaborate with other actors of the ecosystem and develop platforms or services without cost, because government and non-government organizations do not usually offer funding for the development of platforms or services. Many events have been implemented in the city to enhance innovation, such as hackathons, contests, and competitions. During these events, developers have the chance to win prizes to create new platforms. However, these events are only helpful in awarding the best applications and providing initial support to nascent entrepreneurs. Organizers of hackathons do not provide a sustainable way for developers to expand their concepts and launch their platforms into the market on a long-term basis.

A possible solution would be to create business models that will financially support developers for the development of platforms using such mechanisms as grants, similar to adopting a successful method that is implemented today in academic institutions to enhance innovation in the public sector and share new knowledge when practitioners must compete for restricted resources, which are often offered by national or local governments and are less frequently provided by development funds, organizations in the private sector, non-governmental organizations, and charities.

As mentioned before, one significant obstacle is that the original form of data is not available, data are not updated, and the format is not usable. Therefore, developers cannot evaluate data quality and utilize it. Despite the technical restrictions, a significant obstacle is that many organizations are inclined to publish data. Thus, developers participating in hackathons cannot develop platforms. Collaboration among academic institutions, research institutes, and organizations in the public sector is required to open data. In addition, companies and mentors should participate in hackathons to help developers expand their concepts and create platforms or services that meet citizens' requirements and earn money from their launch into the market.

It is required for businesses, policymakers, citizens, practitioners, and developers to create strong collaboration to publish and reuse data sets because they aim to gain applications, platforms, and knowledge from such new startups. Therefore, the involve-

ment of developers in the open data ecosystem is crucial. They have enthusiasm, and non-government sectors or businesses often support them to develop digital platforms and services based on open data. For companies, this participation provides a significant chance to increase collaboration among public sector organizations, businesses, and local governments to gain benefits from e-commerce projects and associated applications. For organizations in the non-government sector, their collaboration in open data platforms and services may encourage transparent and collaborative government. Furthermore, these organizations may aim to create new communication channels between citizens and the government, and they have the opportunity to use data sets and perform more research. Thus, the creation of open data platforms and services can be considered an efficient tool to increase collaboration between public and private sector organizations.

Our outcomes suggest organizers fully realize the knowledge and insight production potential of hackathon execution, create precise knowledge management mechanisms, and develop their ability to utilize this potential within the several phases of hackathons entirely. Organizers should realize the full potential of digital technologies in fulfilling actors' requirements and feedback. As a result, it has become crucial for organizers to create a transparent open data-driven culture, promote open data-driven values, and develop an extensive, broad open data-driven strategic direction.

Table 2 presents the subsystems of the quintuple helix model and how they are modeled in the case of Thessaloniki's open data ecosystem. Furthermore, it represents the entities that should join the open data ecosystem to increase innovation and entrepreneurship and improve the value of digital services for citizens.

Table 2. Actors of the Thessaloniki's open data ecosystem.

Subsystems of the Quintuple Helix	Thessaloniki's Open Data Ecosystem
Universities	Collaboration among academic institutions, research institutes, and organizations in the public sector is required to open data.
Industry	Companies and mentors could attend hackathons to support developers to expand their concepts and create platforms or services that meet citizens' requirements and earn money from their launch into the market.
Government	Local governments and policymakers are responsible for the availability of open data regarding the legal framework.
Media/public	Social media promote the organization of hackathons in the city and inform developers about these events.
Natural environment/society	Citizens who use applications that have been developed in hackathons and have been released to the market require an improvement in their quality of life. Thus, developers create applications and digital services. However, they should respect natural resources.

The results of this paper are similar with the outcomes of existing studies. Apart from the value that open data provide to public administration, open data increase the value among all the entities of an open data network. The primary commodities are public administration, commercial open data publishers, data analyzers, communities that extract and transform open data, user experience providers, consumers, and organizations [18–20]. Recent studies highlight the benefits for entrepreneurs that use open data. Startups use open data in order to create new business models, increase profitability and competitiveness. Moreover, open data contribute to developing new products and services, which increase innovation and firm profitability. Nascent entrepreneurs can use tools to visualize data that help them make more efficient decisions about the development of new services for citizens [22–27].

Although the developers of applications could greatly benefit from the business opportunities of open data, the lack of value networks and business models has been highlighted as the significant challenge to data utilization in services and applications [18,19]. It is because of the weakness of developers to use data to develop new businesses as well as

of the lack of technical readiness in terms of using data sources related to complex data formats or interfaces that the mentioned challenges and problems usually stem from [31]. Along with these issues, the difficulty of generating relevant data for application purposes, the insufficient access to regional data sources to create applications or local services, the unclear licensing of open data, legal issues, technical limitations regarding data publishing platforms, the guarantee of data quality and reliability, and finally the lack of availability and usefulness of local data could be attributed [32,34].

Juell-Skielse et al. [24] surveyed participants of an open data hackathon. They concluded that despite the fact that more than 80% of the teams planned to expand their service further, only one-third had achieved the development after the contest. This could be explained due to the limited support to developers by organizers after the contest. Kitsios et al. [1] claimed that when organizers in open data hackathons are knowledgeable about developers' motivations, they could involve entrepreneurs and venture capitalists on the panels of judges. Moreover, they could organize competitions and closing ceremonies that involved potential funders. Thus, developers will have many opportunities to expand their applications because they can discuss their applications, present them in real time, and obtain funding.

5. Conclusions

This paper uses the quadruple/quintuple helix innovation model to drive innovation and entrepreneurship in Thessaloniki's open data ecosystem to develop applications using open data. This paper makes significant contributions in many directions. Firstly, cooperation has to be achieved by aligning the requirements and practices of different actors (institutions, developers, businesses, consumers, government, organizations in the public sector, etc.). Collaboration with academic and research institutions and other government agencies is vital for the publication of accessible data. In addition, companies and consultants should participate in innovation competitions to inspire participants to develop their concepts and create applications that fulfill citizens' requirements and raise funds from them.

Second, companies should be aware of data privacy and security concerns that significantly impact the willingness of customers and other stakeholders to participate in innovation processes. Businesses should develop, adopt, and promote open data communication and management policies to create open data-based product architectures that are characterized by increased levels of modularity, flexibility, scalability, and integrability, and, as a result, are suitable to increase the volume of open data generated from the product and service consumption spaces.

Third, the outcomes of this article help practitioners who intend to re-invest business models to develop services that will enhance firms' competitiveness. These firms aim to be leaders by creating new IT-based service models, such as developing software as a service for their consumers. Open data are fundamental to increase service value through these new business models, which have significant implications for the business structure and culture, and companies' operations. Practitioners will be aware of how to develop and launch services into the market based on open data.

This paper provides many directions for future researchers. Firstly, the analysis has to be evaluated using further cases in order to assess its soundness and adequacy in different open data ecosystems. Additional case studies may highlight different factors within components that are globally significant for practitioners to take into account. Second, a limitation of this study concerns the interviews that were implemented in one open data ecosystem that is not mature. However, these are useful to understand the roles of the entities that participate in Thessaloniki's open data ecosystem. However, several challenges and obstacles should be considered to further develop the open data ecosystem and enhance entrepreneurial activities. The findings of the interviews indicated that the need for actors to develop an open data ecosystem that will provide value for all of them has increased. Therefore, the ecosystem can offer chances for the actors and the platforms

developed based on open data. Thus, future research is necessary to examine the obstacles and to boost profitable new business for nascent entrepreneurs.

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