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Zuiderwijk-van Eijk, Anneke; Janssen, Marijn; van de Kaa, Geerten; Poulis, K.

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The wicked problem of commercial value creation in open data ecosystems: Policy guidelines for governments

Anneke Zuiderwijk*, Marijn Janssen, Geerten van de Kaa and Kostas Poulis
Delft University of Technology Jaffalaan 5, Delft, The Netherlands

Abstract. Creating commercial value through open data use in open data ecosystems is a wicked problem. This problem is characterized by a lack of specific formulation, complex interactions amongst a variety of stakeholders, a lack of criteria determining a satisfactory solution, including what constitutes 'value', and uncertain outcomes. Wicked problems cannot be solved by only considering part of the problem. Yet, open data efforts all too often focus mainly on open data publication and neglect the use of the data; while it is the *use* of data (not just publication) that generates value. This paper addresses the question: *Which policy guidelines can support commercial value creation from open data?* This study first elicits characteristics of wicked problems for studying the wicked problem of commercial open data value creation. Subsequently, we use the wicked problem characteristics to study open data innovation in two countries and consult experts. This work results in eliciting four policy guidelines that can help to derive greater commercial value from open data ecosystems. The four policy guidelines show that governmental open data policies for commercial value should pay attention to: 1) increasing the knowledge of open data ecosystem stakeholders about contextual factors influencing open data use and commercial value creation, 2) ensuring the availability and quality of five types of resources: open data, open Information Technology (IT), internal IT, knowledge and governance, 3) cooperating between businesses and citizens to create alliances, and 4) reducing the negative effects of value creation by companies in the open data ecosystem. These policy guidelines are expected to stimulate commercial value creation with open data use.

Keywords: Open data, commercial, companies, value creation, wicked problem, ecosystem

1. Introduction

The bulk of prior research in the area of open data presumes that open data positively affect the generation of social, environmental and economic value [1]. It is argued that open data can stimulate innovation and deliver new opportunities to companies [2,3]. In open data ecosystems, the provision of open data by governments and the use of open data by companies as intermediaries and end-users are expected to result in commercial value for companies. From an economic perspective, *commercial value* can enhance the price of a product or reduce costs [4]. This type of value can be indirect as open data can complement existing products and in this way result in more sales and profit. Value is often relative in comparison to other alternatives and dependent on the stakeholder's viewpoint. Each stakeholder can have a different perception on the value that is generated by open data. Whereas one stakeholder might

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*Corresponding author: Anneke Zuiderwijk, Delft University of Technology Jaffalaan 5, 2628 BX Delft, The Netherlands. Tel.: +31 15 27 86471; E-mail: a.m.g.zuiderwijk-vaneijk@tudelft.nl.

perceive value, another might not, which contributes to the wickedness. As mentioned by Lindman et al. [5], "value is created through the assemblage of open data complementarities and therefore the value network in which the companies operate is essential" (p. 741). Commercial open data value can particularly be created through the merit or worth of data reuse, innovation and economic growth. For instance, open data enables companies to produce novel services on the data, to interpret the raw data and to use open data applications and interpretations [5,6].

Open data ecosystems can generally be defined as all activities for "releasing and publishing open data on the internet, [. . .] [where open data users can conduct activities such as] searching, finding, evaluating and viewing data and their related licenses, [. . .] cleansing, analyzing, enriching, combining, linking and visualizing data and [. . .] interpreting and discussing data and providing feedback to the data provider and other stakeholders" [7, p. 17]. Open data ecosystems show the users how open data might potentially be used and they provide guidelines concerning data use. Furthermore, they provide a system to manage quality issues of open datasets and they provide different types of metadata that are needed for the interpretation of the data [7]. In this paper we focus on commercial value creation in open data ecosystems. Other types of value creation are outside the scope of this paper. The use of the term 'companies' in this paper refers uniquely to "commercial, for-profit companies" and excludes non-profit companies.

Creating commercial value through open data use in open data ecosystems is a type of problem that Churchman [8] and Rittel and Webber [9] refer to as a wicked problem. Wicked problems are characterized by the following features, among others: a lack of specific formulation, no immediate and ultimate test of a solution and by being unique [9]. In open data ecosystems, value creation is dependent on permanent feedback from the environment and there is no specific formulation of value creation in open data ecosystems. Currently no criteria exist for finding solutions for commercial open data value creation and there is no exhaustive set of solutions for open data value creation. Different types of open datasets can be used for many different purposes by a variety of stakeholders (e.g. researchers, citizens, developers, journalists) and each type of open data use is unique.

An open data ecosystem is characterized by a variety of stakeholders who "find, manage, archive, publish, reuse, integrate, mash-up, and consume open government data in connection with online tools, services and societies" [10, p. 326]. Open data ecosystems typically consist of "multiple interdependent socio-technical levels, dimensions, actors (including data providers, infomediaries and users), elements and components" and "develop through user adaptation, feedback loops and dynamic supplier and user interactions and other interacting factors" [7, p. 23]. In such open data ecosystems, value creation is characterized by a lack of specific formulation, complex interactions among a large variety of actors having different stakes, a lack of criteria that show when a solution has been found, and uncertain outcomes of value creation.

The main question of this paper is: *Which policy guidelines can support commercial value creation from open data?* The following secondary research questions were developed:

1. To which extent is commercial value creation by companies in open data ecosystems a wicked problem?
2. How can an ecosystem handle the wicked problem of commercial open data value creation by companies?
3. Which policy guidelines can support commercial value creation by companies in an open data ecosystem?

This paper is structured as follows. The following section first discusses the wicked problem literature, followed by the research approach. Based on the characteristics of wicked problems, we consult

experts to examine to which extent commercial value creation by companies in open data ecosystems can be considered to be wicked problems and how an ecosystem can be structured to handle the wicked problem of commercial open data value creation by companies. Subsequently, based on the findings from the expert consultation, the next section develops policy guidelines for commercial value creation in open data ecosystems. This paper builds on a paper that we presented at the 16th Annual International Conference on Digital Government Research [11].

2. Wicked problem literature

This section provides an overview of the literature concerning wicked problems. It gives an initial overview of characteristics of wicked problems, that could subsequently be used for analyzing commercial open data value creation in a practical situation.

In general, governmental organizations aim to create public value by meeting the needs and wishes of the public to create particular benefits and by contributing to a better government [12]. In the context of open data, two overarching value generating mechanisms that explain how open data may lead to the creation of value are the information sharing mechanism and the market mechanism [13]. The information sharing mechanism refers to offering new information enhancing transparency and reducing information asymmetry. The market mechanism refers to the creation of value through markets when using open data as a resource for new products and services or to facilitate process improvements.

Creating commercial value for open data use by companies in the open data ecosystem is a wicked problem. Churchman [8] states that wicked problems are a set of ill-formulated social system problems, "where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (p. B-141). Wicked problems are dynamically complex, ill-structured and public problems, that are sometimes referred to as social messes or untamed problems [14]. Distinguishing properties of wicked problems, as mentioned by Rittel and Webber [9], are that solutions to wicked problems have consequences that may outweigh intended benefits, there is no opportunity to learn by trial-and-error as every attempt counts significantly, there is no exhaustive set of solutions that policy makers can draw from to solve the problem, every wicked problem is essentially unique, and every wicked problem can be considered to be a symptom of another problem [9].

According to Rittel and Webber [9, p. 160], "wicked problems include nearly all public policy issues". Wicked problems are related to cognitive, strategic and institutional uncertainty and different stakeholders are dependent on each other [15]. Wicked problems can be related to, for instance, global climate change, healthcare, poverty and crime [14]. For wicked problems, there is no specific formulation, since "the problem includes a permanent feedback with its environment. The process of formulating the problem is interconnected with the process of its solution" [16, p. 278]. Moreover, there are no criteria that tell when *the* or *a* solution has been found [9]. The problem definition of wicked problems changes over time, causes and effects of wicked problems are scientifically uncertain and stakeholders may disagree about them, and different types of societal stakeholders are involved in value conflicts about the wicked problem [14,17,18]. In the context of commercial open data use, the type of companies aiming to create value with open data may change over time, and the type of open data use may change. For instance, at first innovative startup companies may try to create commercial value with open data by developing new services and products. Later on bigger companies may also become interested in commercial value creation by combining open data with existing data owned by the company, by analyzing this data through data analytics, and by making decisions based on the conclusions derived from this. The change

Table 1
Characteristics of wicked problems

Wicked problem characteristic	Reference
No specific formulation	Rittel and Webber [9], Skaburskis [16]
A set of ill-formulated social system problems	Churchman [8]
Dynamically complex, ill-structured and public	Batie [14]
Every wicked problem can be considered to be a symptom of another problem	Rittel and Webber [9]
No opportunity to learn by trial-and-error as every attempt counts significantly	Rittel and Webber [9]
No criteria that tell when the or a solution has been found	Rittel and Webber [9]
The problem definition of wicked problems changes over time	Batie [14], Dentoni and Bitzer [18], Dentoni and Bitzer [17]
Causes and effects of wicked problems are scientifically uncertain and stakeholders may disagree about them	Batie [14], Dentoni and Bitzer [18], Dentoni and Bitzer [17]
Different types of societal stakeholders are involved in value conflicts about the wicked problem	Batie [14], Dentoni and Bitzer [18], Dentoni and Bitzer [17]
Solutions to wicked problems have consequences that may outweigh intended benefits	Rittel and Webber [9]
There is no exhaustive set of solutions that policy makers can draw from to solve the problem	Rittel and Webber [9]

Expert consultation (academic researchers and companies):
To which extent is commercial value creation by companies in open data ecosystems a wicked problem? (RQ1)
How can an ecosystem handle the wicked problem of commercial open data value creation by companies? (RQ2)

Policy guidelines: Which policy guidelines can support commercial value creation by companies in an open data ecosystem? (RQ3)
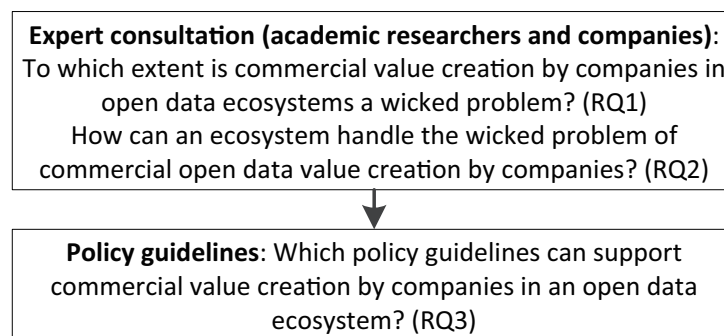
Fig. 1. Research approach.

in commercial value creation with open data can be problematic, since their effects are different and they should be measured and evaluated in different ways. Moreover, policies may need to support these types of open data use in different ways and different types of resources are needed (e.g. Information Technology (IT) resources).

Table 1 provides an overview of the key characteristics of wicked problems that apply specifically to commercial value creation in open data ecosystems. How each of these characteristics applies to the wicked problem of commercial value creation with open data is explained in the remainder of this paper, where the overview of characteristics is used to study open data value creation.

3. Research approach

This section presents the approach used for this study (see Fig. 1). Each of the blocks in Fig. 1 is explained below.

As a first step of our study, experts were consulted through different sources. The combination of sources may help to maximise construct validity and reliability [19]. Multiple sources can be integrated in a triangulating fashion and are expected to provide more comprehensive results than a single

Table 2
Characteristics of consulted experts

Respon-dent #	Type of respondent	Country	Objective of open data use
1	Academic open data researcher	Netherlands	NA
2	Academic open data researcher	Netherlands	NA
3	Academic open data researcher	Greece	NA
4	Academic open data researcher	Greece	NA
5	Data user: company representative	Netherlands	Creation of informative maps
6	Company representative	Netherlands	Data reuse
7	Company representative	Netherlands	Data analysis
8	Company representative	Netherlands	Obtain insights from combining datasets
9	Company representative	Netherlands	Facilitate innovation
10	Company representative	Netherlands	Urban networks analysis
11	Company representative	Netherlands	Better interaction and co-creation with citizens and companies
12	Company representative	Netherlands	Re-use of own open data services
13	Company representative	Netherlands	Building semantic technology
14	Company representative	Netherlands	Get a better overview of what is going on in project areas
15	Company representative	Greece	Insight in technological knowhow
16	Company representative	Greece	Application creation
17	Company representative	Greece	Targeted advertisement
18	Company representative	Greece	Application creation

source [19]. In order to put the findings into context and to support the development of policy guidelines, our study combines the information sources of semi-structured interviews and a survey. Given the wicked nature of the problem that we study, interpretive research was employed. Innovation through commercial open data use was studied in two countries, namely in Greece and in the Netherlands. The study focused on these countries for practical reasons, since the researchers had access to experts in these countries and they spoke the language. Table 2 provides information about the experts consulted in our study.

For the interviews, the consulted experts included four academic researchers. Semi-structured interviews were carried out with two Dutch and two Greek academic researchers. The interviews included both the publication of open data and its (commercial) consumption. Questions concerning the background of the interviewees were asked, as well as questions about the cultural characteristics of companies using open data in the Netherlands and Greece, including uncertainty avoidance, short term or long run orientation. Subsequently, questions were asked about innovation in the open data ecosystem, such as the extent to which the interviewees believed that open data could be used as a source of commercial product and service innovation, economic growth, or to enhance customer satisfaction. Subsequently, key resources for open data use were discussed (e.g. open datasets, computer skills and stakeholder networks), as well as the possibility to create competitive advantage with open data (i.e. a discussion about the characteristics of open data resources). Although a limited number of interviews was carried out with academic researchers, the interviews allowed for obtaining a better view on the importance of the resources for commercial value creation in an open data ecosystem and how these resources were related.

In addition to the academic researchers, representatives of fourteen companies using open data were consulted through a survey. Representatives from ten Dutch and four Greek companies were asked questions that were to a large extent similar to the interview questions asked to the academic researchers, although they were asked in a structured form. The questions included the background of the company, the cultural characteristics of the company, open data innovation, key resources for open data use and

competitive advantage. In addition, we asked the company representatives about the use and the importance of the identified resources for commercial open data use in an open data ecosystem. Additionally, the respondents were asked to which extent each resource was Valuable, Rare, Inimitable, and Non-substitutable (i.e. the VRIN characteristics), since the Resource Based View advocates that resources must have these VRIN characteristics in order to create competitive advantage and obtain value [20]. The complete overview of questions that were asked is provided in the study of [21]. Since the survey sample was small, the survey results were only analyzed in a qualitative fashion and not quantitatively.

Company representatives were reached through social media (Twitter, Facebook and LinkedIn), e-mail lists, and through e-mails sent to personal contacts in the field of open data. The respondents were selected based on 1) their concern with open data publication and use in the Netherlands and Greece, 2) their expertise and experience in the area of commercial open data publication or use, 3) their availability and accessibility. As shown in Table 2, the fourteen companies in our sample consumed open data for various reasons, such as generating informative maps, developing applications and semantic technology, and carrying out targeted advertising. The sample was not limited to respondents with a certain function or from a certain industry, since we attempted to understand how open data can be used in a broad variety of industries. Specific questions were asked regarding value creation in an open data ecosystem that could only be answered by open data experts within a company. The consultation of companies offered insight in the key resources that need to be available for commercial value creation with open data, and to which extent they can be used to obtain competitive advantage for companies in an open data ecosystem.

The results of the expert consultation were used to determine which characteristics of wicked problems are applicable to commercial value creation using open data. From the results, we elicited elements of the wicked problem of commercial open data value creation, that were subsequently used to create policy guidelines for generating commercial value in open data ecosystems. Thus, as a second step in our research, policy guidelines for governments were developed. In the context of this study, *policy guidelines* are directions that support policy makers in developing policies to enhance value creation with open data. Since there is no specific formulation of the wicked problem of open data value creation, and since this problem is complex and ill-structured, it is important to produce policy guidelines that can assist policy makers to handle this problem. Based on the findings from the expert consultation, we elicited elements of the wicked problem of commercial open data value creation. To develop policy guidelines, we focused on those elements that need to be and can be addressed in governmental policies. For instance, the expert consultation resulted in information about the types of resources that companies need to create value with open data. This resulted in the policy guidelines that policy makers should ensure the availability and quality of these particular types of resources, so that open data value creation can be stimulated. Focusing specifically on the publication of data that could be used by companies and the subsequent commercial use of these data by companies, the policy guidelines should help policy makers to create a level playing field for commercial open data use. The policy guidelines set the conditions and stimulate value creation in open data ecosystems, and they provide help for dealing with the wicked problem of open data value creation.

4. Wicked problems in the open data ecosystem – expert consultation

In this section we use the wicked problem characteristics as described in the literature to analyze wicked problems in the open data ecosystem. We answer the first and second research question, namely: *To which extent is commercial value creation by companies in open data ecosystems a wicked problem?*

And how can an ecosystem handle the wicked problem of commercial open data value creation by companies? We focus on the wicked problems of value creation by companies. A description of the country backgrounds is provided, followed by the findings from the expert consultation.

4.1. Country backgrounds

The expert consultation focuses on open data use in the Netherlands and Greece. According to existing benchmarks, The Netherlands is ranked 6th in the Open Data Barometer [22] and 8th in the Open Data Index [23]. Greece is ranked 31st [22] and 42nd respectively [23]. This means that both countries are not considered to be among the top five frontrunners in the open data field, yet they are also not considered to be lagging behind considerably compared to other countries in the benchmarks. Various problems related to commercial open data value creation are present in the two countries (e.g. unclear what the quality of the data is and when and where data will be provided or updated), which was an important reason for studying them. Both in Greece and in The Netherlands policies are under development that should stimulate open data use. Since both countries are not considered to be frontrunners but do pay attention to further developing the open data field, there is still much space for improvements, and therefore these two countries can profit from the creation of policy guidelines for governments.

There are cultural differences between the two studied countries. While Greece belongs to Eastern Europe, the Netherlands belongs to Western Europe. Eastern and Western Europe have shown cultural and behavioural differences in various aspects. Hofstede et al. [24] identified six cultural dimensions that can be observed, namely power distance, individualism, masculinity, uncertainty avoidance, long term orientation and indulgence. With regard to the cultural aspects of uncertainty avoidance and power distance, Hofstede et al. [24] state that the Netherlands has low to medium uncertainty avoidance and low to medium power distance, while Greece has high uncertainty avoidance and medium to high power distance. One could argue that managers in Dutch companies may be more tolerant in accepting ideas for value creation in the open data ecosystem from different levels of the company employees, and that Dutch companies may take more risk in creating value with open data than Greek companies. Greek companies rely on a more hierarchical structure [24], which could mean that decisions related to commercial open data value creation usually come from the top management of the company. Furthermore, the Netherlands has a relatively high score on individualism, whereas the score for Greece is much lower. Dutch companies may be more concerned with their own interests or interests of people and companies directly involved in them. Greek companies function in a more collectivist society where people belong to groups that take care of them. A high score on individualism may hinder collaboration with other companies, governments and citizens. Moreover, Greek companies operate in a society that has a high score on masculinity, indicating that competition, achievement and success are important. This could lead to innovative use of open data, focusing on the creation of competitive advantage. Dutch companies function in a society with a low score on masculinity, indicating that quality of life and caring for others is found to be more important than competition, achievement and success.

The foregoing shows that the two countries under study involve a diversity of cultural characteristics concerning power distance, individualism, masculinity and uncertainty avoidance. As far as long term orientation and indulgence are concerned, the Netherlands has a slightly higher score on these dimensions, yet the cultural differences on these dimensions for Greece and the Netherlands are small. These cultural characteristics need to be taken into account in interpreting the findings below.

4.2. Findings from the expert consultation

In this section we analyze the findings from our expert consultation and interpret them in the context of our research. Findings from the expert consultation are described for all of the wicked problem characteristics that were mentioned in section two, although some of them were clustered since they relate to each other.

4.2.1. No specific formulation of how open data value creation can take place

The literature showed that wicked problems have no specific formulation [9,16] and that every wicked problem can be considered to be a symptom of another problem [9]. Furthermore, different types of societal stakeholders are involved in value conflicts about the wicked problem [14,17,18]. Applied to open data ecosystems, value creation in open data ecosystems cannot be understood without knowing the context of the value creation. Defining and understanding open data value creation requires knowledge of the context and potential solutions for creating this value. In our study, we found that value creation for companies both in The Netherlands and in Greece considerably depends on the context of how the company aims to create value. The fourteen Dutch and Greek company representatives that we consulted indicated that their companies use open data for various reasons, such as the creation of informative maps, the development of applications and semantic technology, and targeted advertising. It was found that a company attempting to generate value by developing applications focuses on other solutions (e.g. data processing and representation tools) compared to a company attempting to generate value by using open data for targeted advertising (e.g. data analytics, social media).

Moreover, the expert consultation showed that understanding how value creation in open data ecosystems takes place also requires insight in cultural aspects, such as uncertainty avoidance and power distance. The importance of cultural aspects was emphasized by all four academic researchers. For example, a Greek interviewee indicated: "*my feeling is that cultures play a very essential role in open data use*" and another Greek interviewee stated that "*culture really influences if a company will accept the "open" concept*". A Dutch interviewee believed that culture within a company was important, but was not sure whether the culture of a country also influenced open data use by companies. Our study suggests that cultural aspects might influence the type of value that can be created. If a company tries to avoid uncertainty as much as possible, it may not want to innovate by using risky solutions or by using open data with uncertain quality levels, while companies with less uncertainty avoidance may be willing to do this. This was illustrated by several quotes of both Dutch and Greek interviewees: "*In my opinion the companies who base their business models on open data have greater tolerance towards unpredictability. This is due to the fact that open data are by nature uncertain and you cannot predict or guarantee that you could use certain open data for too long.*" It was also mentioned that "*[. . .] at early stages in the open data publication process, there is no guarantee of sustainability. So only companies that recognize and accept this risk would try to build a kind of new service, based on an unsustainable process.*" This finding may indicate that creating value by companies in open data ecosystems in the Netherlands could be easier than creating this value in Greece. This finding is important for the development of international open data policies.

Furthermore, the way that open data are provided influences to which extent value can be created. Companies using open data to create value in the open data ecosystem depend on other actors (e.g. governmental organizations publishing the data and different types of resources), which was confirmed both by Dutch and Greek respondents. For instance, one interviewee gave an example of the German open data portal, which had very tight and restricted licenses for the use of the provided data. The data

were therefore not considered to be open, and this was a barrier for value creation. This barrier may not be present in other countries, so that it may not influence open data value creation in other contexts. Another example concerned the quality of the data, as mentioned by a Greek interviewee, ("*I believe that open data should become as reliable as research data to increase the level of innovation*") and the type of data that was available ("*it is important to observe what kind of data is in demand by companies to understand which of the data has value. Examples are geographical data, weather, financial information, statistics, etcetera."*), which also influenced the extent of value creation. The involved actors have different interests which could lead to value conflicts (e.g. restricted licenses of datasets versus free and open use of the data). In sum, problems related to open publication but also problems related to the availability of resources (e.g. availability of the desired data, tools to use open data and resources such as human skills) were considered to be symptoms of problems related to commercial open data use, which is on its turn a symptom of not realizing open data policy objectives, such as stimulating innovation, economic growth, transparency and accountability.

4.2.2. *How companies can create value in open data ecosystems is ill-formulated, complex and ill-structured*

According to the literature, wicked problems are ill-formulated social system problems [8], that are dynamically complex, ill-structured and public [14]. Causes and effects of wicked problems are scientifically uncertain and stakeholders may disagree about them [14,17,18]. Our study showed that the problem of how to create value for companies in open data ecosystems is also ill-formulated, complex and ill-structured. In one of the interviews it was mentioned that "*the use of open data is complex, and for all the challenges that arise you have to come up with a business idea, try to convert it into a kind of service, and then disseminate it to possible users. So knowledge is critical and skills are very important.*" This means that companies require different types of skills and resources to be able to create value with open data. This was confirmed by the company representatives. In our study, human and knowledge resources were seen as important for handling the ill-formulation and complexities of open data: "*You need proper human resources in order to analyze the data. To illustrate this is when you have high quality of open data and good open data tools but in the end you cannot find the right solutions because of the incapability of the data scientists and other experts.*" Besides human resources, other important resources concerned open data resources, open (external) IT resources, internal IT resources and governance resources.

The company representatives were asked whether certain VRIN characteristics of resources are present, i.e. whether the resources are Valuable, Rare, Inimitable and Non-substitutable. The presence of the VRIN characteristics may indicate whether companies can create competitive advantage in the open data ecosystem. All company representatives stated that open data resources are to a certain extent valuable, and most respondents stated that they are rare. This means that two of the VRIN characteristics can be found in the open data ecosystem, which could help companies to generate value in the form of competitive advantage. At the same time, almost all company respondents disagreed that open data resources are inimitable (the third VRIN attribute), since open data can be obtained by anyone and are freely available. With regard to the fourth VRIN attribute, the non-substitutability of open data resources, opinions of the company respondents were divided. Thus, open data resources appeared not to match all of the VRIN attributes to create competitive advantage. For example, an academic researcher pointed out: "*Open data is valuable in the sense of open data use, but I do not believe that open data resources by themselves can lead to competitive advantage*". Nevertheless, the company responses show that other resources could be used to obtain competitive advantage and these resources may match the VRIN attributes. In-house resources may be used to gain competitive advantage with open data. For example,

out of the fourteen companies, nine stated that human and knowledge resources are inimitable, and thirteen out of the fourteen respondents believed that human and knowledge resources are non-substitutable. These findings suggest that open data value creation by companies should put the resources that can be used for obtaining competitive advantage, central to open data use.

4.2.3. Dependence on other actors and risk avoidance in open data value creation

As mentioned in the literature, for wicked problems there is no opportunity to learn by trial-and-error as every attempt counts significantly [9]. This also applies to the open data ecosystem. The extent to which companies can create commercial value in the open data ecosystem is influenced by the decision of a governmental organization to not publish a certain dataset (anymore), to not update the data, to change the format in which the data is published or to reduce the quality of the data or the way it can be used. Moreover, when public agencies publish wrongful or sensitive data on the internet, this is irreversible, and this could not only harm the government but also companies that use these data. This was also mentioned by one of the academic researchers: "*If a company uses some open data [. . .] [of which the] integrity and quality are not guaranteed, then the company could experience major damage because if the data are not reliable then your service or product will not be reliable as well. And that influences the reliability of the company itself.*" Citizens and other end-users of applications and services based on open data also depend on these companies, which function as intermediaries. The dependence of different actors on each other in the open data ecosystem is therefore of considerable importance for commercial value creation in the open data ecosystem. Moreover, uncertainty avoidance may to a certain extent be necessary in the open data ecosystem, since it could help with reducing the negative effects of publishing data.

4.2.4. No criteria for finding solutions and no exhaustive set of solutions for open data value creation

Solving problems is important to stimulate commercial value creation in open data ecosystems. However, wicked problems are characterized by a lack of criteria that show when a solution has been found [9]. Additionally, there is no immediate and ultimate test of a solution to a wicked problem and solutions to wicked problems have consequences that may outweigh intended benefits [9]. There is also no exhaustive set of solutions that policy makers can draw from to solve the wicked problem [9] and the problem definition of wicked problems changes over time [14,17,18]. The wicked problem of commercial open data value creation does not have an infinitive set of solutions, nor is there a well-described set of permissible operations that may be incorporated to solve related problems. Additionally, in the context of open data, there are no criteria that indicate if a solution for a problem related to open data value creation has been found. There are no objective criteria for determining the correctness of solutions to open data value-related problems. In addition, our study indicated that what might be a solution to commercial open data value creation by one company, might not be the solution to commercial open data value creation by another company. For instance, publishing data on a low granulation level instead of on a high aggregation level might be a solution that could support value creation by one company, while another company needs solutions in the form of high quality data, data publication in another format, or skills and tools to be able to analyze the data. Still, there are no criteria that indicate whether data are published on a sufficiently low level of granularity, whether sufficient metadata are published or whether the data are of sufficient quality, since this is determined by the purpose of open data use and the fitness of the data for this use. This differs per data use case and may also change over time, since the open data ecosystem is continuously evolving. In addition, the benefit of a certain solution, such as publishing data on a low level of granularity, may be outweighed by the risk on revealing people's identity when such data are available.

Policy Guidelines (PGs)
PG1: Governments should develop policies to increase the knowledge of open data ecosystem stakeholders about which contextual factors influence commercial open data use and stimulate commercial value creation.
PG2: Governments should develop open data policies which focus on ensuring the availability and quality of five types of resources: open data, open IT, internal IT, knowledge and governance.
PG3: Governments should cooperate with businesses and citizens to create alliances between governmental data providers on the one hand and companies on the other hand, which is expected to result in more open data use and commercial value creation by companies.
PG4: Governments should develop open data policies which pay attention to reducing the negative effects of commercial value creation by companies in the open data ecosystem.

Fig. 2. Policy guidelines for creating commercial value for companies in open data ecosystems.

5. Policy guidelines for generating commercial value in open data ecosystems

The previous section provided the findings from our expert consultation and showed which problems need to be taken into account when governments aim to develop open data policies stimulating commercial value creation in an open data ecosystem. Drawing from these findings, this section answers the third research question, namely: *Which policy guidelines can support commercial value creation by companies in an open data ecosystem?* The following four policy guidelines have been elicited (see Fig. 2).

Governments should develop policies to increase the knowledge of open data ecosystem stakeholders about which contextual factors influence commercial open data use and stimulate commercial value creation. Recent research has started to investigate and analyze such factors [25,26]. Our expert consultation indicated that policy makers need to be made aware of the context-specific factors (e.g. culture-specific, type of company-specific or general trade-offs) that influence commercial value creation in the open data ecosystem, for example through training. For international policies, this includes the creation of awareness of cultural differences that may influence open data value creation by companies. Knowledge about contextual factors is essential in an open data ecosystem, as governments (as data providers) and companies (as data users) depend on each other, and commercial value can only be created when both governments and companies collaborate (for instance when governments provide the data that a company needs, and when a company creates value by combining this data with its own IT resources and human resources). If the level of collaboration between governments and companies is low in a certain culture or country, it is important to be aware that such contextual factors could lead to less commercial value creation in open data ecosystems.

Governments should develop open data policies which focus on ensuring the availability and quality of five types of resources: open data, open IT, internal IT, knowledge and governance. These resources are essential to support commercial open data value creation for companies. As mentioned by the academic researchers and company representatives that we consulted in our study, the availability and quality of these five types of resources is essential to support commercial open data value creation for companies. Combining different types of resources could help companies in creating competitive advantage, which

could lead to value creation in the ecosystem. In such an open data ecosystem, companies can select the (combination of) resources that they need. The needs for certain resources can differ per company. Whereas some companies may have sufficient internal IT resources and may need only limited open IT resources, for other companies this might be different. The need for resources depends on the company and its objectives for using these resources.

Governments should cooperate with businesses and citizens to create alliances between governmental data providers on the one hand and companies on the other hand, which is expected to result in more open data use and commercial value creation by companies. Our expert consultation showed that there are many dependencies between the stakeholders participating in the open data ecosystem (see Section 4.2.4). It suggested that open data policies should focus on managing these dependencies. Companies that lack resources to use open data (e.g. human skills, open datasets) can more easily collect these resources from other actors involved in open data when they create alliances. In an open data ecosystem, stakeholders can offer resources that can also be offered by other stakeholders. Governmental open data policies should ensure that all the required resources are available.

Governments should develop open data policies which pay attention to reducing the negative effects of commercial value creation by companies in the open data ecosystem. The expert consultation showed that the Netherlands and Greece experience different levels of uncertainty avoidance. Negative effects of commercial value creation by companies in the open data ecosystem can be reduced by a certain level of uncertainty avoidance. For each open dataset, a trade-off needs to be made of advantages and disadvantages of open data publication and use. This can be complicated, as in the open data ecosystem an advantage for one stakeholder could be a disadvantage for another stakeholder. For instance, companies could profit from analyzing sensitive data to create insight in their competitive advantage, yet governments may not want to provide this data since it might result in the violation of data protection legislation. More culture-specific insight in these trade-offs and the negative effects resulting from them could help in the development of international open data policies, since the trade-offs and negative effects may differ among countries.

6. Conclusions

The creation of commercial value in the open data ecosystem is a wicked problem. The main question of this paper is: *Which policy guidelines can support commercial value creation from open data?* Drawing from the literature on wicked problem characteristics, we studied open data innovation in the Netherlands and Greece and consulted experts in both countries (i.e. four academic researchers and fourteen representatives of companies using open data). Interviews and a survey were used for the expert consultation. The research findings show that commercial value creation by companies in the open data ecosystem is influenced by 1) a lack of specific formulation of how commercial open data value creation can take place, 2) ill-formulated, complex and ill-structured information about how companies can create commercial value in open data ecosystems, 3) interdependencies between stakeholders and potential risks of uncertainty in commercial open data value creation, and 5) a lack of criteria for finding solutions and a non-exhaustive set of solutions for commercial open data value creation. Based on the expert consultation, we developed the following four policy guidelines that aim at stimulating the creation of commercial value in open data ecosystems:

1. Governments should develop policies for increasing the knowledge of open data ecosystem stakeholders about which contextual factors influence commercial open data use and stimulate commercial value creation.

2. Governments should develop open data policies which focus on ensuring the availability and quality of five types of resources: open data, open IT, internal IT, knowledge and governance. These resources are essential to support open data value creation for companies.

3. Governments should cooperate with businesses and citizens to create alliances between governmental data providers on the one hand and companies on the other hand, which is expected to result in more open data use and value creation by companies.

4. Governments should develop open data policies which pay attention to reducing the negative effects of commercial value creation by companies in the open data ecosystem.

Analyzing the open data ecosystem as a wicked problem demonstrates that not only a narrowly focused set of open data barriers needs to be considered, such as barriers only related to open data use or to open data publication, but to consider all barriers found in the open data ecosystem as a whole. This paper contributes to the literature by offering policy guidelines for finding solutions to the wicked problem of value creation in open data ecosystems, and including various contextual aspects and different stakeholder perspectives (e.g. open data providers and companies as users). While many open data policies are under development and aim at stimulating innovation and economic growth, there is still limited insight in which factors influence commercial value generation for companies in open data ecosystems. The expert consultation and the policy guidelines contribute to practice by providing insight in the conditions under which open data use by companies may help to create commercial value in the open data ecosystem. They offer guidance for further development of governmental open data policies and contribute to successful open data adoption by companies. This could help in achieving open data policy objectives, including innovation, economic growth and participation.

To analyze the wicked problem of commercial value creation in open data ecosystems we involved open data experts and companies from two countries, namely The Netherlands and Greece. An important question is whether the results are equally applicable in other contexts (e.g. other countries, other types of companies using open data). Although Greece and the Netherlands are different, the policy guidelines derived were similar, suggesting that these can be used in a variety of countries. We recommend future research to also examine commercial open data value creation in other contexts and countries, using a variety of research methods. Furthermore, we recommend future research to investigate whether policies that focus on commercial open data value might conflict with other open data values. For example, it is important to investigate whether stimulating commercial value creation might conflict with creating societal value from open data. This type of research is expected to result in additional guidance for policy makers who aim to develop policies creating value in open data ecosystems.

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