Developing citizen science ecosystem: critical factors for quadruple helix stakeholders engagement

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Abstract

Purpose – The purpose of this paper is to provide answers regarding the factors that motivate or discourage the quadruple helix (QH) stakeholders and the wider public in citizen science (CS) activities. The research reveals a current overview of the perceptions, attitudes, concerns and motivation with regard to development of CS ecosystem in four countries: Greece, Lithuania, the Netherlands and Spain.

Design/methodology/approach – The researchers deploy a mixed methodology, entailing an in-depth literature review and a large-scale quantitative survey (approximately 2,000 citizens) targeting QH stakeholders and general public from the local national ecosystems. The results contain both descriptive statistics and statistical analysis per country. After the comprehensive overview of drivers and barriers regarding the participation in CS activities in general, the focus is narrowed down on the engagement motivation of different QH stakeholders and the differences in enabling/hindering factors at the local ecosystems.

Findings – Depending on the country and the pre-existing level of CS maturity, the results provide a complicated network of factors that unlock or block participation in CS activities. These factors include, to name a few, political maturity, civic engagement, technological infrastructures, economic growth, culture of stakeholder collaboration, psychological stimulus and surplus of resources. The implications of the findings necessitate the alignment of the envisioned CS ecosystem with the local dynamics in each country.

Research limitations/implications – The quantitative nature of the survey method, limited sample size and only four countries context are noted as limitations of the study and offer future research potential for longitudinal settings and mixed-methods studies.

Originality/value – The results contribute to the wider literature on CS that focuses on perspectives, possibilities and differences in local contexts with respect to the public engagement by developing CS ecosystem.

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At the same time, its added value lies in the overall practical proposition, and how the latter can effectively and efficiently attract and retain different stakeholder groups and citizens, under a collaborative approach.

Keywords Citizen science hub, Quadruple helix stakeholders, Engagement, Co-creation

Paper type Research paper

Introduction

Scientific knowledge is crucial for improving decision-making, providing communities with greater capacity and safety to tackle existing societal problems. The opening of research data has been indicated in many scientific sources and policy documents as a tool to increase the speed, quantity and quality of scientific research results. However, the "debate on open science has gained prominence, mainly in two of its axes: open research data and citizen science" (Albagli and Iwama, 2022). Participatory- and community-based approaches and methodologies have shown promising results for influencing the resilience of communities (Ensor *et al.*, 2016; Kondo *et al.*, 2019) and making room for citizen innovations (Sauermann *et al.*, 2020). Scientists usually create citizen science (CS) programs to capture crowdsourced data that would be hard to obtain otherwise due to time, geographic or resource constraints, or to make use of the collective intelligence of humans that outperform automatic procedures in identifying and classifying information in data collected via various ways. Participation and motivation of the most affected and vulnerable social groups, policymakers and private actors play in these actions important role to address complex problems. Bringing their own unique perspective to scientific problems and thinking "outside the box" may result in new scientific discoveries (Dickinson, 2011). In addition, being part of CS community appears to be an important factor for creativity to take place and provides motivation for solving project problems (Jennett *et al.*, 2016). CS consist mainly of voluntary non-scientist collaboration in collecting and interpreting data useful for research, such as images, sounds and other types of records, improving research results and lowering costs. CS projects may cover various scientific fields, such as biology, astronomy, medicine, computer science, statistics, psychology and engineering. They may also range from large international projects, which involve professional scientists and research institutions, to small projects by groups with a common interest. It can span from being better informed about science to contributing to the scientific process itself by developing the research question, designing the method, gathering and analysing data and communicating the results (European Commission, 2020; European Citizen Science Association, 2022).

Today, the number and scope of CS projects have expanded due to the development of smartphones that have built-in GPS receivers and other sensors. Besides, worldwide participation in CS is growing because the percentage of highly educated, well informed and active citizens interested in science is also increasing; and due to growing concerns about various issues, such as environmental sustainability (Grey *et al.*, 2016). In this frame, the politicians throughout Europe progressively see CS as an opportunity for greater public engagement and science democratisation. European Commission (EC) supports CS in its research funding programs (e.g. Citizens' Observatories, Responsible Research and Innovation). Besides, the funding agencies promote CS with tailored programs, such as the European Horizon 2020 "Science with and for Society" program (European Commission, 2021). CS ecosystems thrive because of complex interdependencies and dynamic relationships between and among its participants. Understanding the diversity and complexity of factors that either enable or hinder the participation of general public and stakeholder groups is of critical importance for any successful CS initiative. While citizens and universities have often been highlighted as the key players in the CS projects, the role of other stakeholders, despite its strategically influential position in stimulating innovation and entrepreneurship, has not received sufficient attention in scholarship (Pittz and Hertz, 2017; Carayannis and Campbell, 2012). The authors attempt to address this gap in scientific literature by exploring the role and motivation factors of different quadruple helix (QH) stakeholders in the larger CS ecosystem. These factors have been extracted from the relevant literature and identified through case studies that cover different countries and contexts during this research project; thus, the results aspire to provide a holistic picture that is able to accommodate – at a conceptual level – as many dimensions as possible. Thus, the research questions to be answered through this study, while examining the CS ecosystem in the local contexts, are as follows:

RQ1. What are current trends in citizen science?

RQ2. What are the main driving and hindering factors for QH stakeholders that usually affect citizen science participation?

RQ3. What are the current patterns and similarities/differences in citizen science in the four participating countries?

The remainder of the study is structured as follows: after a general introduction, the next section provides a review of the literature underlying the concept and most recent trends of CS. The third section outlines the research methodology, followed by the results of the research in the fourth section, which are discussed in more detail in the final section. The research activities were commenced using an exploratory research approach, whose objective was to identify a range of cross-national driving factors and barriers with regard to CS participation from the citizens on the one hand, while on the other hand presenting the current landscape of CS maturity level in the four participating countries: Greece, Lithuania, the Netherlands and Spain.

Literature review

Citizen science, also known as "Community science", "Amateur science", "Crowdsourced science" and "Volunteer monitoring" (Scistarter, 2021), is defined as the participation of non-scientific stakeholders in the scientific process. CS can be interpreted as a part of "the wider open science movement, along with open access publishing, open data standards and alternative metrics for impact assessment" (Grey *et al.*, 2016). It can promote the efficient and transparent use of science and research funding, lead to better engagement in research, governance and accountability and contribute to economic growth and social change through open innovation. In recent years, a small number of world-leading Research Performing and Funding Organisations (RPFOs) have established transdisciplinary hubs for stimulating and supporting excellent CS. Essentially, the hubs aim to bring different stakeholders together and bridge society with science in an institutionalized way by developing CS ecosystems. A defining aspect of most ecosystems is interaction between multiple stakeholders (Velt *et al.*, 2017). CS ecosystem entails a collaboration between all QH stakeholders: the public and researchers/institutes, also governments and funding agencies (Haklay *et al.*, 2021). The development of crowdsourcing platforms and networks that enable volunteers to contribute to different research projects, the use of machine learning technologies and artificial intelligence may extend CS ecosystem capabilities, especially those depending on human intelligence. As a result, citizens' roles in CS projects may expand further and become more demanding (Grey *et al.*, 2016).

Since CS is *de facto* based on creating and sustaining a critical mass of participation, it is vital to identify what are the conditions that may foster or discourage the level of citizen involvement (Larson *et al.*, 2020). It is worth noting that citizen scientists come from all walks of life, including retirees, online gamers, educators and students (Scistarter, 2021). In principle, drivers can be distinguished between those stemming from subjective perceptions, desires, motivations and personal goals, and to drivers that refer to objective circumstances of the macro environment, such as the overall environmental conditions (e.g. weather), cultural, social and economic conditions.

Citizen scientists, as the main stakeholders' group in CS, can gain personal enjoyment, social benefits and satisfaction by contributing to scientific evidence and influencing the policy (Rotman *et al.*, 2014a; Butteriss, 2019; Geoghegan *et al.*, 2016; Jennett *et al.*, 2016; Larson *et al.*, 2020; Kragh, 2016). Psychosocial parameters such as the ability of citizen scientists to express their personal value and creativity (Scotland Counts, 2016), as well as fulfilment of curiosity and personal desires for discovery (Larson *et al.*, 2020; Kragh, 2016) are also important. Self-prestige and personal growth matter too: fostering personal reputation among community members, increasing scientific literacy and acquiring new skills and information are typical examples of internal motivations (Butteriss, 2019; Larson *et al.*, 2020; Asingizwe *et al.*, 2020). Accomplishment of such goals pertain to learning benefits through participation in CS (Rotman *et al.*, 2014b; Martin *et al.*, 2016); fostering personal CV and career track, especially for young persons (Gordienko, 2013; Geoghegan *et al.*, 2016) as well as creating new professional contact points (Scotland Counts, 2016); monetary incentives as compensation for the efforts and time devoted (Gordienko, 2013); incentives for recreation and nature-based activities (Geoghegan *et al.*, 2016; Kragh, 2016).

There are however, objective barriers that can seriously inflict the individual's decision to enter a CS initiative. Age is an objective factor: the desire to voluntarily participate in CS increases until the 20s and then again between 40 and 45; consequently, demographic dynamics is an important factor (Wilson Center: Commons Lab, 2014; Geoghegan *et al.*, 2016). Low scientific literary and poor skills from participants can indeed occur (Pocock *et al.*, 2018), low levels of self-confidence regard also the false inability to collect adequate data volume (Mitchell *et al.*, 2017), which can cause various observer and sampling biases (Burgess *et al.*, 2017). Language barriers (Pocock *et al.*, 2018) and high level of difficulty in the assigned tasks (Kleinke *et al.*, 2018) can function as burden for participants and discourage them. Still, one of the gravest obstacles can be time. When there are time constraints from the side of citizen scientists, and when CS activities require excessive time, then, this time-consuming process may simply exhaust participants and lead to drop out, eventually blocking the scientific venture (Collins *et al.*, 2015; Kleinke *et al.*, 2018; Butteriss, 2019; Rotman *et al.*, 2014b; Martin *et al.*, 2016; Asingizwe *et al.*, 2020). Finally, a very common barrier is inertia and lack of general interest from participants (Pocock *et al.*, 2018).

Individual motivational factors are important, but the significance of collective motivational factors cannot be neglected. Collective motivational factors that are perceived to be critical are the existence of previous good practices and "success stories" of CS that will inspire other *QH stakeholders* (Wilson Center: Commons Lab, 2014), the professional recognition of citizen scientists' efforts and encouragement for further work (Garcia-Soto *et al.*, 2017; Science Communication Unit, University of the West of England, Bristol, 2013; Butteriss, 2019), and the public acknowledgement of impact and contribution of citizen scientists by the scientific community (Geoghegan *et al.*, 2016; Jennett *et al.*, 2016). The existence of scientists with previous engagement in CS activities, who are more "outward-facing" and show higher level of trust in the regional ecosystem is another factor (Burgess *et al.*, 2017) that may facilitate the creation of team bonds and sense of sharing common goals (Jennett *et al.*, 2016). Values related to altruism and collectivism may turn out particularly powerful collective drivers for NGOs and governmental institutions. A sense of socio-ecological responsibility and commitment to a common cause can push different QH stakeholders towards actions (Rotman *et al.*, 2014a; Rotman *et al.*, 2014b; Butteriss, 2019; Geoghegan *et al.*, 2016; Larson *et al.*, 2020; Kragh, 2016; Asingizwe *et al.*, 2020).

To a large extent, the barriers and factors that hinder the participation of citizens and stakeholders in CS activities and projects can be understood as the reversal of the facilitating factors outlined above (Martin *et al.*, 2016). Misperceptions at a collective level and from other stakeholder groups can often prevail and burden CS's success. The false perception from citizens of being unable – as inadequately educated and thus amateur – to deliver high-quality, reliable and rigorous scientific pushes *traditional scientist* to believe that the results and data will be of poor quality (Garcia-Soto *et al.*, 2017; Wilson Center: Commons Lab, 2014; Mitchell *et al.*, 2017; Pocock *et al.*, 2018; Science Communication Unit, University of the West of England, Bristol, 2013). Some scientists believe that ethics mismanagement and misuse of public data is hard to avoid in CS (Parthenos project, 2019; Hecker *et al.*, 2018). At the same time, citizen scientists may also be uncertain regarding the honesty of the exploitation of the data they have collected from scientists, potentially leading to harmful effects. This is linked to the fear of potentially inappropriate policy decisions, such as block to public access to natural sites (Martin *et al.*, 2016). Policymakers can share analogous, yet often unfounded, fears about the quality of CS efforts and outcomes. Fears of privacy violation and issues related to ownership of results and intellectual property rights are often recorded (Wilson Center: Commons Lab, 2014; Hecker *et al.*, 2018; Gordienko, 2013). Often, there is limited awareness from all groups of QH stakeholders on the benefits and potentials of CS, whereas bias and scepticism pervade the scientific community members regarding the acceptance of data sources from CS. The latter is justified on lack of rigorous research design, data collection inconsistencies and a general tendency to opt for data traditionally collected from peer scientists (Burgess *et al.*, 2017). Unsurprisingly, this cultivates mistrust between the scientific community, policymakers and citizen scientists, leading to low levels of created social capital (Parthenos project, 2019; Hecker *et al.*, 2018; Pocock *et al.*, 2018). It can be concluded, that the role and motivational drivers of different QH stakeholders in the larger CS ecosystem are subjects that have been largely unaddressed by current scholarship.

A last dimension to consider is those enabling factors that transcend the individual and collective motivational level and stem directly from the *wider macro-context*. The dynamics within the regional ecosystem define to a large extend the level and quality of citizens' involvement. The growing research field neglects the issue of Open Science applicability in the countries where the collaboration between science and society has limited traditions and civic participation in public activities is not mature. Disparities in research and innovation performance among member states are a well-recognized issue, and the European Union (EU) aims to address it through increased investments. Robust funding is necessary for a CS activity to flourish, so when there is lack of funding channels or opportunities, and when budgetary constraints arise due to absence of national funding schemes, CS becomes a luxury (Wilson Center: Commons Lab, 2014; Parthenos project, 2019; Collins *et al.*, 2015; Pocock *et al.*, 2018). Partnerships with universities, other federal agencies, contractors, museums, philanthropists and schools (Wilson Center: Commons Lab, 2014), technological resources that support social networking and development are essential. Another aspect deserving attention that applies to all the aforementioned factors is that they can change over time and at different stages of stakeholders' participation (Land-Zandstra *et al.*, 2016; Vohland *et al.*, 2021). Adequate communication mechanisms between scientists and citizens as well as constant and good communication on project's concept, objectives and progress through channels such as website, social media, mails and newsletters is a precondition to create a critical mass for participation (Rotman *et al.*, 2014a; Butteriss, 2019).

The literature review, as a form of secondary data analysis offered a series of advantages from a research point of view: it offered high-quality data as a starting point for theoretical reasoning and questionnaire structure; and it opened new possibilities for re-interpretation of collected primary data (Bryman, 2012). Generalizing theoretical framework, the drivers and obstacles have been categorised into those that relate to individual motivations (subjective perceptions, desires and personal goals), those who impact QH stakeholders and those that derive from objective circumstances of the macro-environment (cultural, social and economic conditions). On this basis, complementary information will be retrieved from empirical research by narrowing focus on the engagement motivation of different QH stakeholders and on the differences in enabling/hindering factors at the local ecosystems.

Methodology: quantitative survey in four countries (Greece, Lithuania, the Netherlands and Spain)

The aim of the large-scale survey was to quantitatively capture the factors shaping the willingness of the QH stakeholders and of the general public at large, to actively develop CS ecosystem.

Sample size

The survey uses a quota sample of 1,936 responses in total, from the general public in four countries across Europe: Greece, Lithuania, the Netherlands and finally Spain. The research was initiated as part of the implementation of the *H2020* project INCENTIVE ("Establishing Citizen Science Hubs in European Research Performing and Funding Organisations to drive institutional change and ground Responsible Research and Innovation in society"). Data collection took place from April 2021 to June 2021. The four countries represent the four pilot RPFOs of the INCENTIVE project. The project's RPFOs have a nationwide scope in terms of students, visiting personnel and networking channels and therefore having evidence from the overall national population will help them co-create CS hubs that reflect national patterns. However, the selected sample size is random sample and not representative for population. Random sampling ensures that results obtained from sample should approximate what would have been obtained if the entire population had been measured (Shadish *et al.*, 2002). The simplest random sample allows all the units in the population to have an equal chance of being selected. Initially, a quota sample of 500 responses was set as target for each country (resulting to 2,000 responses roughly). However, the demographic dynamics and uneven sizes of the selected countries necessitated a different internal division of the sample, so as to achieve representation in terms of actual population sizes. Therefore, following an open deliberation between the pilot partners, it was decided that 350 responses should be collected approximately for the cases of Greece and Lithuania, while 600 responses should be collected approximately for the cases of the Netherlands and Spain. In the case of Spain, due to the overall larger national population, an external platform "Clickworker" was used to collect the number of responses needed through crowdsourcing. In the case of the Netherlands, the external agency "Markeffect" was commissioned to disseminate the survey and collect the answers. The selection was justified on the basis of the considerable population size of the country, similar to the case of Spain.

For the creation of the survey, the EC survey platform was used, the survey was translated into the national languages and then distributed through a survey link. As such, pilot countries took over responsibility for collecting the required number of responses and meet the internal quotas. The dissemination channels included:

- the internal community of the pilot universities (e.g. staff, researchers and students);
- the networks of various stakeholders and organizations;
- local associations and networks where representatives from the pilot universities' team are active members; and
- stakeholders from the local media who shared the survey in their social media accounts.

Questionnaire structure

The survey questionnaire was structured to get additional insights and quantitatively confirm the findings from the thematic analysis and literature review. The survey questions were clustered in 6 main sections, each of which corresponds to a research question:

(1) *Introduction to the topic*: level of familiarity with concepts such as CS and responsible research and innovation, previous experience with CS, if any;

(2) *Perceptions towards* CS: opinion about what are the most significant benefits of CS, what should be the role of citizens in CS activities and how the envisioned CS ecosystem should respond to current needs;

(3) *Barriers:* barriers to participation in CS activities, potential drawbacks of and obstacles to CS;

(4) *Drivers*: most important driving motivation factors and enablers of CS activities;

(5) *Willingness to join*: the preferred scientific topics and stages of CS activities were captured, with the aim to understand what fields attract most people and in which phases they would like to be involved; and

(6) *General information*: basic demographic information such as sex, age, country, educational background, occupational status and others.

Another critical element was the classification of responses according to the QH groups: private sector/industry (e.g. SMEs owners, entrepreneurs and CEOs), public administration (e.g. policymakers, civil servants and elected officials), academia (e.g. professors and researchers) and civil society (e.g. CSOs representatives and NGOs representatives). For participants that were reluctant to choose one of the previous categories, the category of "general public", could be selected.

All demographic information was collected in compliance with the General Data Protection Regulation of the EU and used solely for research and statistical reasons. In addition, to participate in the survey, all research subjects had to fill in a consent form that was included in the introductory session of the questionnaire.

Stakeholder distribution is of equal importance to understand better the national samples. For the case of Lithuania, the distribution of stakeholders is interestingly even, with almost all categories having a share of roughly 20%, except from participants from the general public and civil society (43.28%). On the other hand, both in the cases of the Netherlands and Spain, the majority of respondents come from the general public/civil society (60.00% and 43.05%, respectively). However, the two countries differ regarding the distribution among the other stakeholder groups. In Spain, academic stakeholders come second (25.80%), while in the Netherlands the second highest stakeholder group is industry (21.04%). Finally, in Greece, stakeholders from academia form the majority of participants, with a noticeable share of 63.04%.

Results

Familiarity and previous experience with citizen science. To ensure that all participants approach the concept in an identical way, a description of the term was provided in the survey questionnaire as follows:

> Citizen Science refers to the active engagement of the general public in scientific research tasks of several disciplines (from natural sciences to social sciences and humanities) and the collaborative production of new knowledge.

This definition was selected as the most inclusive one, so people from different countries and therefore socio-economic and cultural settings could easily understand the term and provide valid answers.

Interestingly enough, results reveal that the lowest levels of familiarity are detected in the Netherlands (57.60%) and Lithuania (57.60%) (Figure 1). Spain presents a more balanced distribution of scales of familiarity, even though people who declare that they are "somewhat familiar" form the majority (26.97%). Nevertheless, more than one out of four participants in Spain state that they are completely unfamiliar with the term. Greece shows some common patterns with Spain. On the one hand, the largest proportion of participants (30.12%) fall under the category "not at all familiar". On the other hand, people who state that they are "somewhat familiar" form the second highest category, with 23.60%. At the same time, across all countries, Spain and Greece have the highest shares of people who say that they are extremely familiar with the term (7.54% and 8.07%, respectively). As general conclusion, it can be inferred that the maturity level of CS varies across countries, and even if two countries show commonalities, there are still differences with respect to the actual type of experience of the general public with CS activities. This necessitates different governance structures and possibly dissemination and engagement channels for the development of proper CS hubs that respond to local social realities.

Nevertheless, it must be stressed that the national variations on the awareness of CS can be partly explained by the age groups and educational level of participants. For instance, the higher levels of awareness in Spain and Greece are influenced by the fact that CS is a quite new concept and in those countries the percentage of 20–29 years old is higher with respect to the Netherlands and Lithuania. Moreover, in Greece, half of participants hold either a master's degree or PhD, and there may be a positive correlation between educational level and level of CS awareness. At the same time, more than 4 out of 10 participants in the Netherlands hold only a high school diploma – a fact that may affect how knowledgeable are about CS. Background variables must be taken into account when unpacking the reasons of awareness levels.

Table 1 deals with the previous experience, if any, with CS from participants from all pilot countries. In this case, all national countries show exactly the same trends: more than 8 out of 10 respondents have not any previous experience whatsoever with the CS activities. On the other hand, it should be mentioned that Greece and Lithuania present the highest shares of people who have some previous experience (18.32% and 18.42%, respectively).

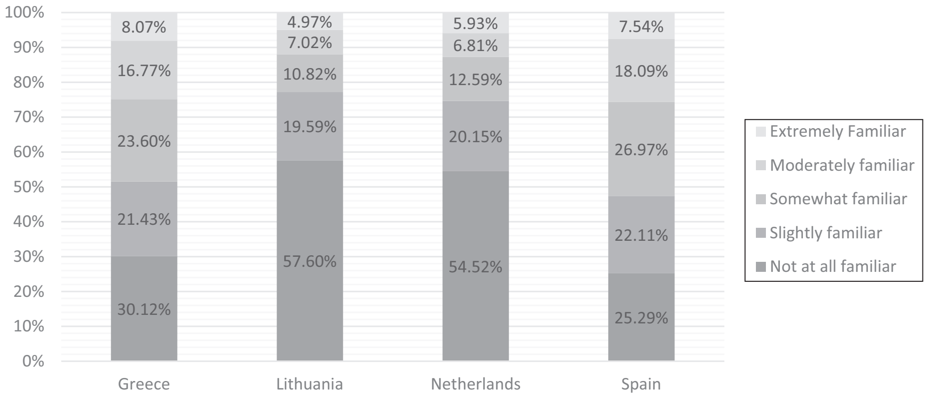

Figure 1.
Level of familiarity with citizen science

The participants who answered "Yes" in the survey questionnaire were re-directed to another question that captures the precise type of previous experience with CS. Strong differences can be observed between pilot countries. In Lithuania (63.39%) and Spain (38.27%), most people responded that their type of experience is "I have heard the term Citizen Science". However, in the Netherlands, more than half of the sample (52.17%) stated that they initiative and/or designed themselves a CS project – this finding strongly contrasts the findings from the other countries. Finally, in Greece, almost half of participants (45.76%) selected the category "I have participated myself in a Citizen Science project".

Barriers and drivers, willingness to join. Significant benefits, drivers and barriers for CS projects were analysed related to the different type of stakeholders to get some specific insights about each type separately. All the identified factors that encourage or hinder participation with respect to CS activities, were statistically analysed and then selected as most important. This is valid for the hindering/enabling factors that were examined both for each stakeholder group and for the local ecosystems. The factors that were found to be statistically significant (i.e. they have an important impact on the perception or involvement of participants) are marked with a tick sign in all respective tables.

Starting from the *academics and the researchers* that participated in the survey, they have highlighted all identified benefits – apart from considering CS as a hobby – as significant for their perceptions and involvement in CS projects (Appendix 1). In terms of drivers, their involvement seems to be motivated by continuous feedback, acknowledgements, inspiring coordination teams and clear guidelines and instructions. Barriers related to their perceptions include concerns whether they belong to a socio-demographic group that is underrepresented in the scientific community, lack of receiving the necessary guidelines and feedback, scepticism about cooperating with other stakeholder groups and fear that the project will not be properly organized and managed.

When taking a closer look at the responses received from *policymakers* (Appendix 2), it is obvious that fewer factors can be captured referring to these aspects. More specifically, benefits related to society and/or natural environment are the only significant factor in the first group, alongside with continuous feedback, inspiring coordinators and clear guidance that can work as significant drivers for policymakers and stakeholders coming from the public sector. Moreover, barriers related to their involvement in CS projects include lack of receiving the necessary guidelines and feedback.

Almost all factors included in the benefits' list can significantly improve perceptions and involvement of the participants from the *business and the private sector* (Appendix 3) in CS projects. Drivers in this case include – once more – continuous feedback and updates about the progress of the project, together with good organization and management. At the same time, barriers referring to perceptions highlight the importance of the lack of the technological equipment that might be required, receiving the necessary guidelines and feedback, the feeling of belonging to a socio-demographic group that is underrepresented in the scientific community, as well as concerns about the ability to effectively cooperate with other stakeholder groups. When it comes to actual involvement in CS project, the identified

Previous experience	Greece (%)	Lithuania (%)	Netherlands (%)	Spain (%)
No	81.68	81.58	85.63	86.10
Yes	18.32	18.42	14.37	13.90
Total	*100.00*	*100.00*	*100.00*	*100.00*

Table 1.
Previous experience with citizen science

barriers include low participation rates and lack of time to participate in such activities from persons in the private sector.

The final stakeholder group under investigation refers to *citizens and the civil society*. All identified benefits seem to motivate general public towards participating and having an increased perception of CS initiatives. In terms of drivers, even though being acknowledged for your contribution and provided with specific guidelines and instructions for the tasks can boost positive perceptions, only receiving continuous feedback and updates about the progress of the project seems to effectively improve participation in CS projects by general public. At the same time, it is interesting to notice that there are more barriers that affect both perceptions and involvement when compared to the other stakeholder groups. Common barriers between these two attitudes include: lack of the technological equipment, fear that the contribution will be exploited by scientists/policymakers, fear of leading to wrong or harmful scientific or policy decisions and scepticism about cooperating with other stakeholder groups. Barriers that are solely related to overall perception about CS refer to the lack of the necessary skills and knowledge to be involved in such activities, the feeling of belong to a socio-demographic group that is underrepresented in the scientific community, the lack of receiving the necessary guidelines and feedback and fear that the project will not be properly organized and managed. Finally, additional barriers that significantly affect citizens' involvement in these initiatives include low participation rates, lack of time and fear of not finding an interesting research topic.

The next section presents a more thorough descriptive analysis on the trends and patterns in each of the four pilot countries, with the aim to provide a more detailed picture of attitudes, perceptions and propensities at national level.

Results from Greece. To begin with, it is interesting to notice that even though the overall perception of CS is positive among citizens in Greece (77% replied either "Agree or Strongly Agree"), one out of five respondents state their uncertainty about the positive dimensions of the CS concept. This scepticism is complemented by the fact that to the statement "In my opinion, citizens should have an active role in the design and execution of scientific projects", 34% of the respondents – which equals one out of three – adopted a neutral position ("neither agree, nor disagree"), while 13% said that they disagree. This is important, because the neutral 34% is exactly the same as the positive 34% of respondents who selected "I agree".

With respect to the citizens' abilities to participate in CS activities, the vast majority agreed (33%) or strongly agreed (47%) with the necessity to first provide adequate training to citizens, with only 4% disagreeing. However, opinions are divided regarding whether citizens have the required skills and knowledge for actual participation. Even though most participants agreed that citizens lack the necessary skills and know-how, 20% disagreed with the statement and 6% strongly disagreed. This dichotomy becomes more complex by adding a 33% of neither agreeing nor disagreeing. The patterns in willingness to join CS activities, are even between the different stakeholder groups. In all stakeholder groups, almost half, or more than half of participants agreed that they would join a CS activity, even though it is interesting to highlight that among the groups, the lowest percentage comes from academia (47.78%) and the largest from public administration (57.14%). However, regarding the trends on the participants who strongly agreed about participating in CS, the highest percentage comes from of scientific stakeholders (27.09%), and the lowest (19.76%) from the general public and civil society.

Figure 2 shows the main topics of interest per stakeholder group for the Greek case. As we can see, there are some common topics between the different types of stakeholders, such as energy and sustainability, educational and environmental sciences. However, we can see

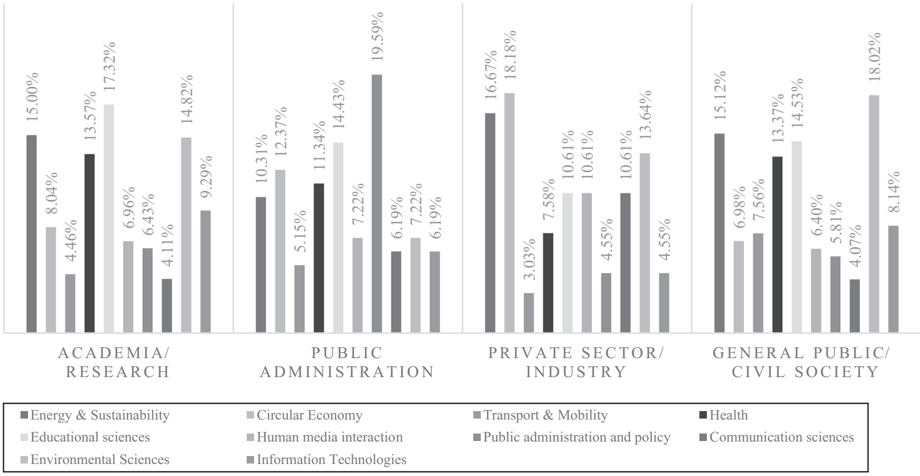

Figure 2.
Topics of interest in Greece (per stakeholder group)

that there are some specific topics that are of interest only in some of the QH groups. More specifically, we can see that topics related to public administration and policy are of high interest in the case of stakeholders coming from the public sector (as expected), *circular economy, human media interaction and communication science* are in the centre of attention when it comes to stakeholders from the business sector, whilst *health and educational services* lie in the heart of interest when it comes to citizens and academics.

Figure 3 presents the various stages in which the different stakeholder groups are interested in participating.

The findings show that participants from academia are mostly interested in designing studies and analysing data, policymakers want to be involved in the interpretation of results, persons from the business sector like identifying research questions and exploiting results, whilst citizens focus on data collection.

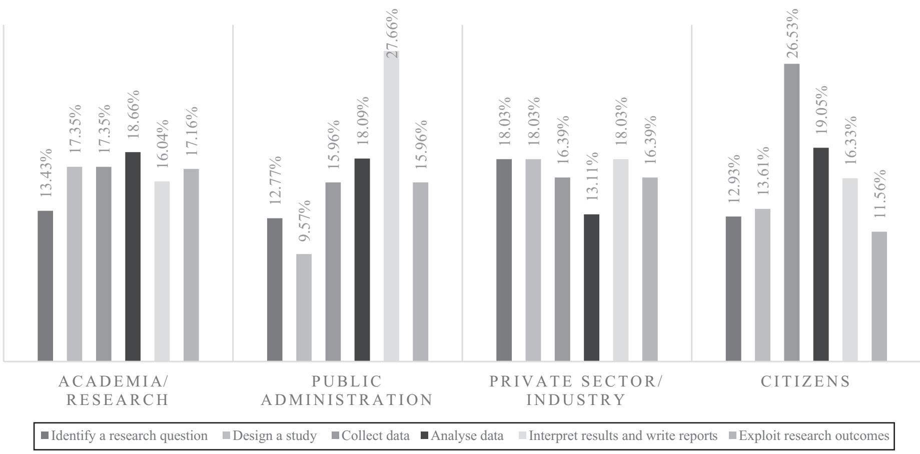

Figure 3.
Stage of the research process that you like to be involved (per stakeholder group)

Results from Lithuania. Compared to the results from Greece, the findings from Lithuania indicate even sharper divisions regarding both the value of CS. Starting with the statement "My overall perception of Citizen Science is positive", even though 4 out of 10 participants (41%) either agree or strongly agree, it is noticeable that almost 30% of respondents selected to either disagree (16%) or strongly disagree (13%). Another 30% had a neutral position, complementing the complicated landscape about the society's perspective on CS.

The overall perception is more positive when it comes to the role and capacities of citizens in CS activities. 45% of participants either agreed (32%) or strongly agreed (13%) that citizens should have an active role in designing and implementing scientific projects. On the other hand, almost one out of three respondents neither agreed nor disagreed, and 18% opposed the idea. Regarding on whether citizens lack the necessary skills and on the subsequent necessity to train citizens in order to be involved in scientific activities, the public opinion is relatively more ambivalent. In both questionnaire items, the level of agreement and the level of neither agreement nor disagreement is almost the same, with those agreeing slightly being the majority. This shows a general consistency between results, since it follows naturally that respondents who advocate that those citizens who lack the scientific expertise must first be adequately trained. The latter point is explicitly supported by the fact that 22% strongly agreed that citizens need to be trained.

In Figure 4, the willingness to join CS activities in Lithuania is presented and broken down per QH stakeholder group. In general, in most stakeholder groups, the majority of participants agree, thus showing willingness to participate. The highest levels of agreement come from academic stakeholders, with 43.84% agreeing and one out of four respondents (24.66%) strongly agreeing, contrary to previous findings that highlight the biases from academic community towards CS. Public administration is also positively positioned, with more than half of participants (60.61%) agreeing to be willing to join CS activities. General public/civil society participants are also eager to support the participation in CS activities, since more than 41% agreed and a further 10.81% strongly agreed. On the other hand, interestingly enough, the highest levels of rejection come from both the private sectors and the general public. In the case of the private sector, the majority of participants either disagreed (21.82%) or strongly disagreed (16.36%). Once these two figures are aggregated, they result to 38.18%, surpassing the 34.55% of neither agreeing nor disagreeing. Finally, regarding the general public/civil society, when combining "disagree" and "strongly

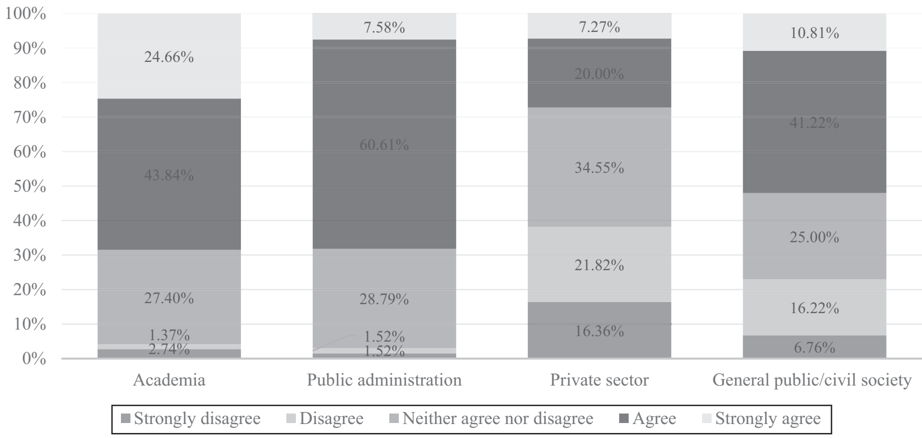

Figure 4.
Willingness to join citizen science activities in Lithuania (per stakeholder group)

disagree", the result is 22.98%, which however does not surpass the sum of "agree" and "strongly agree" (52.03% in total). 25% neither agreed nor disagreed.

In the case of Lithuania, the benefits related to knowledge and skills, alongside aspects related to society and environment can boost perceptions around CS, whereas benefits related to new career opportunities can effectively promote involvement in these projects. Good organization and management, together with clear guidelines and instructions on the tasks are key elements for positive perceptions, whilst continuous feedback and updates about the progress of the projects can act a significant driver for involvement. Barriers for increased perceptions refer to the lack of the technological equipment that might be required (e.g. personal computer, smartphone and internet access), low participation rates and lack of time to participate in such activities. Lack of the technological equipment and time are also significant barriers for being involved in these activities, complemented by individual concerns of leading to wrong or harmful scientific or policy decisions and not being able to find an interesting research topic, as well as lack of financial incentives and scepticism about cooperating with other stakeholder groups.

The main topics of interest per stakeholder group for Lithuania are different form Greece. Topics related to educational and communication sciences, as well as information technologies are essential for stakeholders being part of the academia. Moreover, participants coming from public administration are interested to a large extent in public administration and policy issues, alongside human media interactions and communication sciences. Private sector stakeholders mostly focus on circular economy and information technologies, whereas citizens are interested in health, human media interactions and environmental sciences.

Results from the Netherlands. The third country of the statistical analysis is the Netherlands, a where in which, as already discussed, the overall maturity levels of CS are higher compared to Greece and Lithuania. Figure 5 indicates that energy and sustainability, health and environmental sciences are the three most interesting topics for academics and researchers in the case of the Netherlands. As we can see, the first two are common topics between all different types of stakeholders. Policymakers are also interested in transport and mobility issues and public administration and policy topics. Participants from industry seem to be also interested in circular economy, transport and mobility issues, whereas

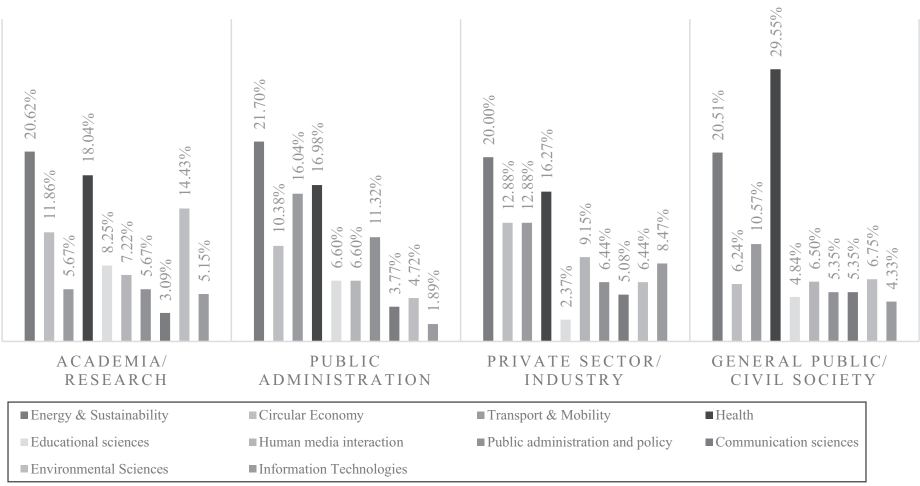

Figure 5. Topics of interest in the Netherlands (per stakeholder group)

citizens do not have any other particular interest apart from the areas of energy, sustainability and health.

When it comes to specific stages throughout the research process, Figure 6 shows an increased interest of academics and researchers in the early stages of these processes, including identifying research questions, designing studies and collecting data.

Data collection is a high priority for policymakers, businesses and citizens, together with data analysis and exploitation. A common pattern exists between these three stakeholder groups.

Results from Spain. Similar to the case of the Netherlands, results at first glance reveal an overall positive mind-set from the Spanish society towards CS. In total, 39% agreed that their perception is positive, and 36% strongly agreed, whereas only 4% disagreed, and 20% neither agreed nor disagreed. Moving on to whether citizens should have an active role in the design and execution of scientific projects, the share of those who do not agree or disagree is higher (31%). Nevertheless, supporters of the statement form the majority, with more than half of the sample (57%) either agreeing or strongly agreeing. The distribution changes and becomes more conflicting when it comes to the skills and know-how of citizens. With the statement "In my opinion, citizens lack the knowledge and skills to be part of the scientific process", 31% agree that citizens do not possess the know-how, but 32% remain indecisive and 20% disagree or strongly disagree. There is consensus, however, regarding the need to train citizens and prepare them for CS activities: 38% agreed that citizens need to be trained in order to participate in science, and 36% strongly agreed.

In Figure 7, the levels of willingness to join CS activities are presented for each of QH. In general, the willingness levels are quite high across all stakeholder groups, and naturally, those who show disagreement form the minority in all cases. However, regarding the level of disagreement, it should be stressed that the biggest shares are recorded from stakeholders from public administration (8.16%) and private sector (6.57%). On the other hand, academic stakeholders have a very high share of people who agree to join CS (40.26%), but also of people who are strongly willing to participate (31.17%). Despite this last figure, it is the private sector in which the highest percentage of people who strongly agree is recorded (32.12%), indicating that private sector stakeholders are to certain extent divided regarding their willingness to join. Finally, stakeholders from civil society and the general public have the highest level of agreement (46.60%), while more than one out of four (25.27%) strongly agree.

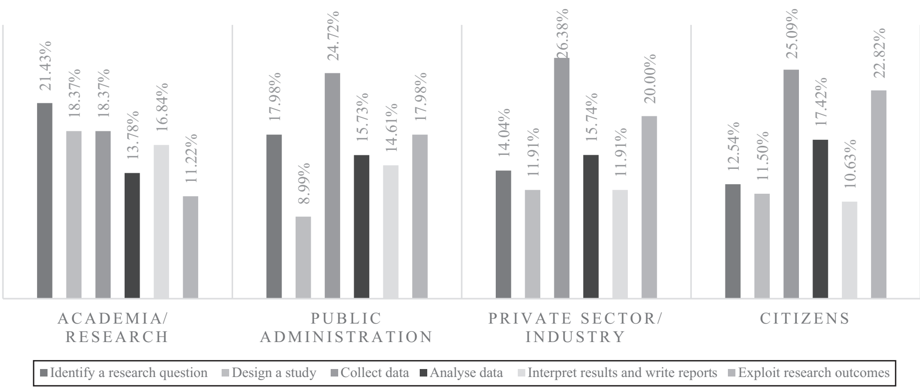

Figure 6.
Stage of the research process that you like to be involved (per stakeholder group)

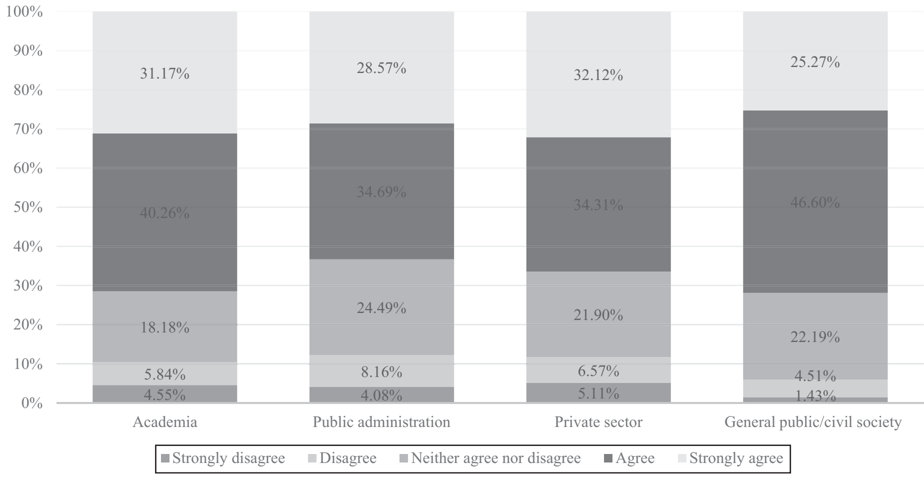

Figure 7. Willingness to join citizen science activities in Spain (per stakeholder group)

There are some common topics of interest between three out of four types of stakeholders (academia, business and citizens), such as energy and sustainability, health and environmental sciences in Spanish case. However, the policymakers indicate a diversified pattern regarding the topics they seem to be interested in, as they mostly highlight the areas of circular economy, public administration and policy and educational sciences. It is interesting to notice that communication sciences have received less attention in almost all cases. At the same time, the findings show that survey participants from all stakeholder groups are mostly interested in participating in data collection and analysis processes. Survey design and interpretation of results are of increased interest in the case of academia and policymakers, whereas exploitation of research outcomes is an interesting stage mostly for stakeholders coming from the private sector.

Limitations and future lines of research

The quantitative nature of the survey method, limited sample size and only four countries context are noted as limitations of the study and offer future research potential for longitudinal settings and for mixed method studies. As new societal challenges continue to emerge, and new democratic models of scientific progress become ever more a necessity, this document at the end aspires to contribute to the wider literature of CS, and how the latter evolve into the new scientific norm, by overcoming current barriers and strengthening its enablers. Given the complexity of the landscape, understanding the specificities of each country and the priorities of QH stakeholder groups is of outmost importance to effectively fulfil local needs and urgent problems.

Discussion

This paper has presented the findings of five-month research on CS ecosystems the in four EU countries – Greece, Lithuania, the Netherlands and Spain. The results reveal a wide range of current trends in CS, both for at the EU (aggregated) level and for each national setting of pilot (individual level). The researcher realized that citizens and communities remain cautious and hesitant regarding new initiatives. All national countries show exactly the same tendencies: more than 8 out of 10 respondents have not any previous experience whatsoever with the CS activities. However, it can be inferred that the maturity level of CS varies across countries, and even if the countries show commonalities, there are still differences with respect to the actual type of experience with CS activities (in the Netherlands, more than half of experience is stated as initiating or designing a CS project, in contrast with experience type in Greece and Lithuania – participating in events or project related to CS). This necessitates different governance structures and possibly dissemination and engagement channels for the development of proper CS hubs that respond to local social realities.

Overall, the research conducted confirmed the relevance of some in literature review mentioned factors. Communication and overall planning are aspects that can function as either determinants or barriers, depending on how they are treated. Other aspects that influence individual motivations refer to the provision of incentives that can stimulate participation (e.g. monetary rewards) and the organisation of the project, in terms of transparency and structure, which lead to reciprocal trust. If we look at such evidence considering the specific national contexts, drives that appear relate to the structure of the project (its organisation and management) and the provision of incentives, although with different degrees of intensity. Focusing on the hindering factors, the scenario is slightly more dispersed in that there are no specific barriers that are perceived as such in all four contexts, which has been justified in light of the different socio-economic, cultural and political frameworks.

Conclusions and recommendations

One of the main purposes of this paper was to identify the main driving and hindering factors for QH stakeholders that usually affect CS participation. To reach this task, the collected data from four pilot countries based on the type of stakeholder categorization were analysed and therefore, it was possible to get some specific insights about each type separately. The major concerns from the research/science stakeholder group are about how the scientific and technological considerations can be introduced as part of the exchanges between academia and society through a participatory process that facilitates this interaction and strengthens the role of citizens as the key actors in the research “process”. In terms of drivers, their involvement seems to be motivated by continuous feedback, acknowledgements, inspiring coordination teams and clear guidelines and instructions. Barriers related to their perceptions include scepticism about cooperating with other stakeholder groups and fear that the project will not be properly organized and managed. From public authorities’ perspective, CS can effectively serve policymaking initiatives and processes by providing evidence and useful insights to support regulatory compliance with a transparent and participatory way. Indeed, considering citizens as “data collectors” and simple sources for the policymaking perspective, eliminates the potential for the citizens to provide valuable evidence to support policies, and this is directly linked to the fact that the policymakers often have different interest, motivations, expectations and understanding towards the achievements and outcomes of the citizens’ science activities and efforts. Lack of cooperation has been spotted as a barrier by public sector participants with low levels of positive attitude towards CSs, whereas lack of guidance and lack of trust are two aspects that policymakers with positive attitudes think should be improved. More specifically, benefits related to society and/or natural environment are the only significant factor, alongside with continuous feedback, inspiring coordinators and clear guidance that can work as motivational drivers for policymakers and stakeholders coming from the public sector. Participants from the industry sector feel cautious due to potential lack of the technological equipment that might be required (e.g. personal computer, smartphone and internet access) and guidance that might be missing from these initiatives, alongside lack of time and cooperation. When it comes to citizens, evidence suggest that almost all factors included in our model are statistically significant for their perceptions and willingness to join CS projects. Lack of skills, inclusion, trust, technological equipment and low participation rates mostly affect persons with positive perceptions on CS, whilst lack of technological equipment, guidance, recognition, cooperation, organization and time are the factors affecting mostly persons with low levels of CS acceptance. The results show that receiving continuous feedback and updates about the progress of the projects is essential for improving overall perceptions about CS across all types of stakeholders. At the same time, having clear guidelines and instructions on the tasks is a significant driver for participants coming from academia, public sector and general public. Business-oriented participants also seem to be motivated from CS initiatives that are well-organized and properly managed.

On top of these, a further important implication is the acknowledgment that financial and organisational aspects are expected to influence the establishment and operation of CS projects. As shown from the literature, the thematic analysis and the statistical results, funding and financial support in general is a critical ingredient. The low level of CS penetration is exemplified several times throughout the paper. For instance, the literature review highlights the insufficient scientific models and the statistical analysis proves that a non-negligible percentage of academic stakeholders remain at least indecisive about their willingness to join CS activities.

Another research task, which was challenged by this research, was to understand the current patterns and similarities/differences in CS in the four participating countries. The most important conclusion that can be drawn from the findings is that despite their commonalities in many patterns, the four countries differ considerably in many aspects. As shown through the exploratory literature review, civic engagement and active retainment in CS activities are impacted by a plethora of factors, in which institutional structures, historical pathways, political maturity and economic development play profound role. Because the four countries are located in different angles of Europe, they have unique characteristics and historical backgrounds, which in turn affect how CS is understood and experienced. Technological and scientific maturity vary across the four countries, as do the level of civic participation, the economic resources, the political environment and the social norms. In sum, CS could not be possibly practiced and endorsed in the same way in so different national contexts. It has been shown that not all factors have the same effect in all countries and that the level of perception and readiness fluctuates in many sensitive issues, such as the involvement of vulnerable groups, the support to citizens to initiate their own scientific project and the topics of scientific interest. Depending on the country and the pre-existing level of CS maturity, the results provide a complicated network of factors that unlock or block participation in CS activities. These factors include, to name a few, political maturity, civic engagement, technological infrastructures, economic growth, culture of stakeholder collaboration, psychological stimulus and surplus of resources.

The implications of the findings necessitate the alignment of the envisioned CS ecosystem with the local dynamics in each country. Transparent communication activities performed by the different partners and effective management are quite important to ensure effective science–policy–society–industry interaction under win-win conditions for all QH stakeholders. Engaging public society is a great challenge, considering that the motivation is not necessarily shared among the participants. Even more, there is a significant number of people among these groups with low digital or project management skills. To lower this barrier a life-long learning approach has to be implemented such that citizens adapt their skills sets to today's fast-paced technology developments.

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Appendix 1

Benefits	Perception	Involvement
Benefits related to the individual (economic, social, educational)	✓	
Benefits related to knowledge and skills	✓	✓
Benefits derived when considering citizen science as a hobby		
Benefits related to new professional/career opportunities	✓	✓
Benefits related to society and/or natural environment	✓	✓
Drivers		
Continuous feedback and updates about the progress of the project	✓	✓
Acknowledgement of the contribution		✓
The project is well-organized and managed		
Inspiring coordination team		✓
Clear guidelines and instructions on the tasks	✓	✓
Barriers		
Lack of the necessary skills and knowledge to be involved in such activities		
Lack of the technological equipment that might be required		
Belong to a socio-demographic group that is underrepresented in the scientific community	✓	
Lack of receiving the necessary guidelines and feedback	✓	
Low participation rate		
Fear that the contribution will be exploited by scientists/policymakers		
Fear of leading to wrong or harmful scientific or policy decisions		✓
Lack of time to participate in such activities		✓
Lack of financial incentives to participate		
Fear of not finding an interesting research topic		✓
Scepticism about cooperating with other stakeholder groups	✓	✓
Fear that the project will not be properly organized and managed	✓	✓

Table A1. Identified benefits, drivers and barriers related to perceptions and the involvement in citizen science projects for academics and researchers

Appendix 2

Benefits	Perception	Involvement
Benefits related to the individual (economic, social and educational)		
Benefits related to knowledge and skills		
Benefits derived when considering citizen science as a hobby		
Benefits related to new professional/career opportunities		
Benefits related to society and/or natural environment	✓	✓
Drivers		
Continuous feedback and updates about the progress of the project	✓	✓
Acknowledgement of the contribution		
The project is well-organized and managed		
Inspiring coordination team		✓
Clear guidelines and instructions on the tasks	✓	
Barriers		
Lack of the necessary skills and knowledge to be involved in such activities		
Lack of the technological equipment that might be required		
Belong to a socio-demographic group that is underrepresented in the scientific community		
Lack of receiving the necessary guidelines and feedback		✓
Low participation rate		
Fear that the contribution will be exploited by scientists/policymakers		✓
Fear of leading to wrong or harmful scientific or policy decisions		
Lack of time to participate in such activities		
Lack of financial incentives to participate		
Fear of not finding an interesting research topic		
Scepticism about cooperating with other stakeholder groups	✓	✓
Fear that the project will not be properly organized and managed		

Table A2. Identified benefits, drivers and barriers related to perceptions and the involvement in citizen science projects for policymakers

Appendix 3

Benefits	Perception	Involvement
Benefits related to the individual (economic, social and educational)	✓	✓
Benefits related to knowledge and skills	✓	✓
Benefits derived when considering citizen science as a hobby		
Benefits related to new professional/career opportunities	✓	
Benefits related to society and/or natural environment	✓	✓
Drivers		
Continuous feedback and updates about the progress of the project	✓	✓
Acknowledgement of the contribution		
The project is well-organized and managed	✓	
Inspiring coordination team		
Clear guidelines and instructions on the tasks		
Barriers		
Lack of the necessary skills and knowledge to be involved in such activities		
Lack of the technological equipment that might be required	✓	
Belong to a socio-demographic group that is underrepresented in the scientific community	✓	
Lack of receiving the necessary guidelines and feedback	✓	
Low participation rate		✓
Fear that the contribution will be exploited by scientists/policymakers		
Fear of leading to wrong or harmful scientific or policy decisions		
Lack of time to participate in such activities		✓
Lack of financial incentives to participate		
Fear of not finding an interesting research topic		
Scepticism about cooperating with other stakeholder groups	✓	
Fear that the project will not be properly organized and managed		

Table A3. Identified benefits, drivers and barriers related to perceptions and the involvement in citizen science projects for business and private sector

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