sustainability

MDPI

Article

How Open Innovation Practices Deliver Societal Benefits

Elisabeth Eppinger

Faculty 5—Design and Culture, Campus Wilhelminenhof, University of Applied Sciences for Technology and Economics Berlin, 12459 Berlin, Germany; elisabeth.eppinger@htw-berlin.de

Abstract: Open innovation practices have the potential to benefit society greatly. Bridging the research on open innovation, diffusion of innovation and responsible innovation, this study investigates how open innovation practices can foster societal benefits. Elaborating on potential benefit gaps and detrimental effects of innovation, the study proposes six distinct innovation attributes to deliver societal benefits: (I) adequate information and communication channels, (II) affordability, (III) appropriateness and availability, (IV) anticipation in terms of appropriate and reflexive risk assessment, (V) accountability in terms of adequate cost allocation of detrimental side effects, and (VI) sustainable path creation for transitions towards societal and environmental sustainability. Ten different open innovation practices are assessed drawing on our own and other published empirical insights. This assessment provides insights into which features of the practices support social benefits. Based on this assessment, we propose a typology of three different practices in relation to societal benefits and discuss how they address the six innovation attributes. Providing rich insights into which practices deliver societal benefits through which features, this study makes a significant contribution to existing research on open innovation, responsible innovation, inclusive and social innovation. Some practical implications and directions for further research are provided.

Keywords: diffusion of innovation; inclusive innovation; open innovation; responsible innovation; social benefit; social sustainability

check for updates

Citation: Eppinger, E. How Open Innovation Practices Deliver Societal Benefits. *Sustainability* **2021**, *13*, 1431. https://doi.org/10.3390/su13031431

Academic Editor: Yuya Kajikawa
Received: 19 December 2020
Accepted: 27 January 2021
Published: 29 January 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

While innovations in general solve problems and fulfil previously unserved needs, they can also foster exclusion and limit access for members of a social system, especially people with low socioeconomic status (SES) [1,2]. Social innovation research shows that participatory innovation approaches may help to identify and tackle the needs of poor communities [3]. Research on responsible innovation emphasizes inclusion as a key principle which could be achieved with open innovation approaches [4]. Accordingly, open innovation practices such as open source, co-creation platforms, and product development partnerships (PDPs) [5,6] may enable innovation that delivers high societal benefits.

Despite the enormous challenges that society faces, such as climate change, poverty and incurable diseases, research on how to utilize open innovation to increase societal impact has been scarce [7]. A few exceptions are in the field of social innovation, under the umbrella term of "social open innovation," demonstrating that open innovation methods can even be used for governments and social enterprises [3,7–9]. Open innovation practices refer to activities of purposive inflow and outflow of resources such as knowledge, patents, and funding, as well as coupled processes that are carried out by a collective of individuals and organizations. The objective of the study presented here is to improve our understanding of how open innovation can increase social benefits. By this, it contributes to academic debates and investigations of open innovation and responsible research and innovation but also provides guidance for businesses and policy makers to select suitable innovation approaches and assess the social impact of innovation. Accordingly, the study includes profit-oriented enterprises. To begin this investigation, we pose the following

questions: (1) Which features of innovation increase societal benefits? (2) How do different open innovation practices deliver societal benefits?

We answer the first question by building on insights from research on the diffusion of innovation, responsible innovation, inclusive innovation, and social innovation. Research on the diffusion of innovation has developed concepts to assess the impact of innovation, including the societal impact [1]. In interdisciplinary science and technology studies, an ongoing debate about how to achieve sustainable and responsible innovation is taking place, with the objective of developing science and technology governance capable of addressing the societal grand challenges [4,10]. Inclusive innovation and design research investigates how a wider group of a population might be served, including poorer communities and people with special needs [11,12]. Research on social innovation explores how and under which conditions organizations, whose primary purpose is social, are addressing social needs [8]. These organizations cover social enterprises, governmental organizations, and civil society [13]. Combining insights from these fields, we derive six attributes of innovation that foster societal benefits. We address the second question by developing a typology of open innovation practices, highlighting inherent features that can deliver societal benefits. The typology is derived from an analysis of ten practices, drawing on a combination of original case data and a meta-analysis of published cases. The six attributes we have identified that increase the social benefits of innovation are then applied to rank the open innovation approaches in our typology.

Answering these questions contributes to the research on open innovation, inclusive innovation and social innovation, by identifying distinct features of open innovation practices that contribute to achieving benefits for society; the research on innovation diffusion and on responsible innovation, by providing insights into how different innovation practices generate a positive societal impact while mitigating detrimental effects. Recommendations for managers and policy makers that target social benefits include the six innovation attributes and the typology of open innovation approaches. The six attributes can act as a guideline to assess the social impact of innovation. The typology with its specific descriptions of the ranking allows for selecting open innovation approaches that support beneficial innovations.

The article is structured as follows: Section 2 defines potential benefit gaps at the innovation diffusion, differentiating between members of a social system that benefit, are excluded from benefits, and are negatively affected. Following a short capture of different reasons that lead to these benefit gaps, innovation attributes that mitigate these gaps are derived from theories and concepts in the interdisciplinary fields of adoption and diffusion of innovation, social innovation, and science and technology studies. In Section 3, following the description of the method, literature, and database, ten different open innovation practices and how they deliver societal benefits are outlined. Building on the innovation practices and the innovation attributes, a typology of three distinct open innovation practices that deliver societal benefits is proposed. Section 4 provides a discussion and some conclusions on societal impact of open innovation practices, arguing that companies, innovators, research funders, citizens, and politicians have a collective responsibility to direct innovation efforts towards societal beneficial innovation. The article concludes with limitations and suggestions for further research in Section 5.

2. Innovation Features That Increase Societal Impact

While sustainability reporting standards make it possible to assess the environmental and social impact of innovation, it is necessary to consider the impact all along the trajectory of the innovation, even in its early stages [11,14]. The successful diffusion of an innovation does not necessarily imply benefits for society at large. All of the members of a social system that are directly and indirectly affected should be considered when evaluating the impact of an innovation. Accordingly, we define social benefits of innovation as the most positive impact for the widest possible number of people which contributes to overcoming inequalities. Negative consequences can also arise for the innovators, e.g.,

through environmental pollution. Accordingly, it is worth noting that the innovators are members of the society, hence, part of the social system. For providing a foundation and reference for interpreting open innovation practices and their social benefits, we identify issues that lead to benefit gaps. Building on insights of research on innovation diffusion, responsible innovation, inclusive and social innovation, we propose six attributes that mitigate these gaps and foster higher benefits.

2.1. Societal Impact of Innovation: Benefits, Exclusion, Detrimental and Cumulative Effects

Innovation by commercially driven enterprises often reaches people with a higher SES first [1]. Although reports of social and inclusive innovation provide examples of organizations that address otherwise excluded people [9,11], most products and services are designed for upmarket customer segments, even in the field of sustainable innovation [15]. This can lead to a benefit gap between adopters and non-adopters. Later in the process poorer people might benefit because innovations eventually become more affordable and accessible [2]. This trickle-down assumption from neo-classical economics is being challenged by concepts and research from ecological economics, arguing for a shift from growth to development that includes improvement in sustainable human well-being, recognizing negative effects of economic growth, limited resources, and tipping points [16,17]. In some instances, innovation may even result in negative consequences for some members of a social system. We discuss different mechanisms that can lead to negative impact, using a figure for illustrative purposes. Figure 1 does not have numeric scales, as it does not draw on quantitative data but on Rogers' illustration of the effects of knowledge gaps [1] (p. 459).

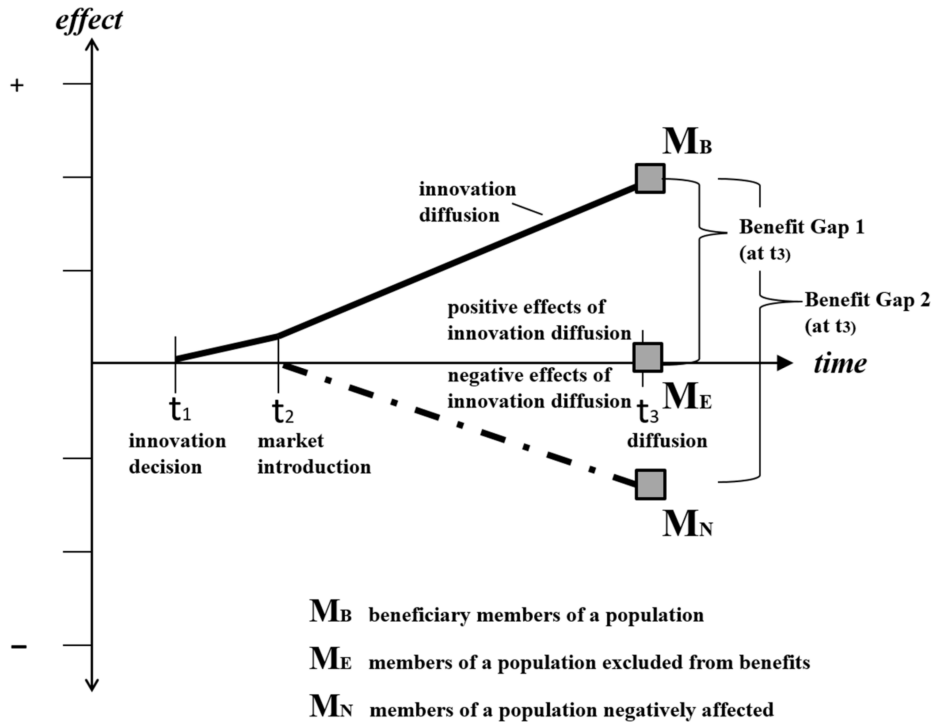


Figure 1. Benefit Gaps at Innovation Diffusion (own elaboration, building on [1]).

One example of a benefit gap in which some members of society are worse off due to an innovation is the case when banks introduce charges for offline bank services. While online bank services themselves have positive effects for customers, society, and the environment, such as reduced traffic to branch banks, instant service, banking for people with reduced mobility who cannot go to bank branches, and the fee encourages people to switch to online services, the fees penalize people who are not capable of using online services that are free of charge, e.g., due to digital illiteracy. This example illustrates that an innovation which provides benefits to society can pose negative consequences for some of its members.

While private enterprises are free to design the features of a private good—within limits of consumer protection principles and regulations—the concept of liberal markets assumes that due to competition the fee will be moderate, as otherwise customers would change to another bank [18]. Another example is the pollution of larger cars which affects the population at large, but the environmental costs and public health costs are not fully allocated to owners or manufacturers. In economics, this type of benefit gap is discussed as a negative externality of a private good [19], usually addressed with policies to restrict pollution to a specific minimum [20].

Figure 1 illustrates the effects. To use the first example above in explaining Figure 1: In Benefit Gap 1 between adopters and non-adopters, charges for online banking services are dropped. The beneficiaries (M_B) are the ones who use these services, but the non-adopters are excluded (M_E). Benefit Gap 2 describes the situation where banks implement charges for offline services, negatively affecting the non-adopters (M_N), including all the people who lack the ability to use the online services.

In the car example, M_N would be all of the people affected by increased pollution creating issues in other domains of societal impact, e.g., health issues, or driving prohibitions as some cities react to high smog, or higher taxes to cover the environmental costs of mitigating climate change [20]. While health problems and driving prohibitions are examples of direct negative impact for specific actors, climate change effects could be labelled as indirect, since the overall consequences can hardly be measured. The overall impact of pollution is part of an ecological system, and it depends on a number of factors, such as weather conditions and levels of pollution from other sources, making it difficult to assess the impact of cars on the environment. Hence, pollution can be considered a part of the "cumulative impact" of the incremental but successive and combined impacts of different sources [21]. Accordingly, both the positive and the detrimental impacts "can accrue in time and space and can interact in synergistic ways" [21] (p. 679).

Investigating the reasons for benefit gaps can guide adequate responses to reduce them. While some may be best addressed by the innovators, others need to be addressed by governments on national or through multinational agreements on a global scale. Research on diffusion of innovation has identified three main reasons why innovation can lead to these benefit gaps: (i) The communication channels and messages are designed to reach only members with specific financial or social capital [22,23]. (ii) Only some of the members can afford the innovation [24]. (iii) The innovation addresses the needs of members with a high SES [12,15], e.g., when budgets for drug development are only directed towards lucrative new therapies against cancer instead of less profitable mass diseases [25]. In science and technology studies, as well as in economics, three other reasons have been identified that can lead to benefit gaps: (iv) The innovation has (unforeseen) negative consequences that affect some of the members of society [26]. (v) The costs of mitigating the negative consequences are not distributed adequately amongst the beneficiaries [4]. The last issue is not a mere benefit gap but the worst-case scenario of the benefit gap (iv) detrimental side effects: (vi) The detrimental impact is cumulative, and the effects are so drastic that they outweigh benefits for innovators and users, also discussed as tipping points [27]. Negative consequences of an innovation (benefit gap (iv)) can affect the users, e.g., when plant-based disposable mugs contain substances that increase the risk of cancer [28], or affect non-users, when the manufacturing process incorporates environmental pollution with regional impact and the products are consumed in other countries, also discussed as pollution havens [29]. At the benefit gap (vi), the cumulative detrimental effects such as environmental pollution associated with innovations, e.g., from traffic, may reach tipping points [20], affecting the world as a whole. Accordingly, the transition between (iv) detrimental effects, and (vi) cumulative detrimental effects is gradual and determined amongst other factors by an increase in consumption of the given innovation and by a lack of (v) adequate distribution of costs amongst the beneficiaries.

2.2. Innovation Attributes That Mitigate Benefit Gaps

All of the six issues can be addressed by different strategies. Research on innovation diffusion provides recommendations that overcome the first three issues. Insights from science and technology studies, in particular responsible innovation, inclusive innovation, and social innovation, provide strategies to address all six problems. From these mitigation strategies we derive six attributes of innovation features that deliver higher societal benefits and some corresponding propositions.

Strategies to tackle issue (i), also known as the knowledge gap, include designing information and channels that target members of society who otherwise would not learn about the innovation [22]. Not only differences in wealth, but also social capital such as networks, institutions and values, are decisive for an adoption decision [23]. Accordingly, the knowledge gap can be bridged by user and other stakeholder integration approaches for developing the information in appropriate language and choosing the right communication channels. These participatory, inclusive practices have been extensively studied and advanced in science and technology studies [30,31] and in developmental studies [32,33]. In general, different stakeholders from civil society, industry, and governmental organizations may jointly develop appropriate communication strategies, including the information, media, and dissemination programs. Accordingly, we derive the first innovation attribute: (I) Adequate information and effective communication channels makes a higher societal impact possible.

Differences in capital amongst the members of a social system can affect those members who cannot afford the innovation (ii). According to Rogers [1], this can be tackled with ex-post solutions that support members with lower SES in obtaining the necessary resources to adopt the innovation, e.g., through regulations for redistribution of wealth [34]. Research on responsible innovation, inclusive innovation, and social innovation proposes strategies involving profit and non-profit-oriented enterprises which are prerequisites for addressing affordability [4,11,33]. We conclude that (II) affordability is a second distinctive attribute of innovation to foster societal benefits.

Innovation often addresses the needs of richer members of society (iii). The related benefit gap occurs already at t_1, when companies take decisions to innovate in favor of people with more purchasing power. This issue can be tackled with ex-ante strategies [1] by directing R&D activities towards members with a lower SES. The framework of responsible innovation provides inclusion, reflexivity, and responsive deliberation about the purpose and benefits of an innovation as core principles for fostering innovation for society at large, but also for reducing inequalities [4,14]. Research in the fields of inclusive and social innovation provides many examples of directing the innovation focus towards poorer members, e.g., through collaborations between non-profit organizations and companies [5,24] and through supporting technology transfer from research institutes to reach members with low SES [35]. Following from this, (III) appropriateness and availability make up a third innovation attribute which would increase the societal impact of innovation.

Strategies to overcome the issue (iv) that the innovation has negative consequences are a central topic of responsible innovation. Thorough ethical assessment needs to be anticipated in advance before the actual design of a technology is materialized [36]. Participatory and inclusive mechanisms for risk assessment can minimize detrimental consequences [35,37,38]. Although the impact of new technologies might be difficult to predict [10], innovators should still take their responsibility seriously and minimize any negative impact on an individual level [39], and on the organizational and policy levels [10,14]. Consequently, innovations should include (IV) anticipation in terms of appropriate and reflexive risk assessments in order to mitigate detrimental impact.

The responsible innovation framework also addresses issue (v), that the costs for the negative consequences are not distributed amongst the beneficiaries, through its emphasis particularly on responsiveness and to some degree on reflexivity and anticipation [4]. Some studies on corporate social responsibility indicated that companies also aim to bear the negative impacts of their products and services [40]. Researchers argue that we cannot

rely on companies for mitigating all environmental and societal issues because they might not have the long-term perspective or incentive for doing so [41]. Von Schomberg argues that accountability of modern innovation is sometimes impossible, as in many cases there is no single creator and "the negative consequences are often neither foreseeable nor intentional" [10] (p. 59). However, some detrimental impact such as waste and pollution can be allocated to the producers and users, rather than making society at large bear the costs of negative environmental impact [20,42]. Accordingly, a fifth essential attribute of innovation with positive societal impact is (V) accountability in terms of adequate cost allocation of detrimental side effects.

Detrimental cumulative impact (vi) occurs for technology trajectories that are neither ecological nor societally sustainable. While some technological trajectories such as a fossil fuel-based transportation system are not sustainable in the face of climate change, transitions towards environmentally friendly technologies have become pressing [43], but it is rather difficult to allocate ownership of cumulative impact. In some cases, it is even impossible to disentangle how much individual hazards contribute, especially when effects are synergistic [10]. Accordingly, deliberation, reflexivity and responsiveness may support sustainable transitions [4]. Hence, a sixth feature of innovation that fosters societal benefits is (VI) sustainable path creation, with the potential to mitigate cumulative detrimental impact, e.g., through enabling transitions of technologies and market logics.

To sum up how innovation can lead to greater societal benefits, we can derive the following six attributes of innovation approaches provided in Table 1.

Table 1. Innovation Attributes that Mitigate Benefit Gaps.

Innovation Attribute	Benefit Gap
(I) Adequate information and communication channels	(i) The communication channels and messages are designed to reach only members with specific financial or social capital
(II) Affordability	(ii) Only some of the members can afford the innovation
(III) Appropriateness and availability	(iii) The innovation addresses the needs of members with a high SES
(IV) Anticipation	(iv) The innovation has (unforeseen) negative consequences that affect some of the members of society
(V) Accountability	(v) The costs of mitigating the negative consequences are not distributed adequately amongst the beneficiaries
(VI) Sustainable path creation	(vi) The detrimental impact is cumulative and the effects are so drastic that they outweigh benefits for innovators and users (tipping points)

3. Open Innovation and Societal Impact

3.1. Method and Data

In order to develop a typology of open innovation practices, practices were analyzed that have been well described in research articles and further original case studies were added. The cases were selected for the purpose of pattern definition rather than theory testing based on an extensive literature review of open and participatory innovation processes. The first string in our topic search (title, keywords, abstract): (open OR collab* OR participat* innovation) AND soc* (benefit OR impact) in the databases webofscience and sciencedirect captured about 30 journal articles. Dropping the "soc*" increased the findings to 400 articles. Analyzing the articles starting with the 30 and then adding on basis of unrelatedness (different journals, different keywords), an inductive approach was used to define categories of open innovation practices, grouping similar approaches under ten umbrella terms that best described the approach: co-creation, crowdfunding, crowdsourcing, open access, open source, open source science, patent pools, public private partnerships, problem-centered innovation networks, technology platforms (see Table 1). With the labels and synonyms, we performed further searches to derive additional articles for the specific open innovation practices. As the aim was to investigate how open innovation delivers

social benefits in practice, the key selection criterion was that it should be empirical research rather than a conceptual discussion, hence, restricting the search to "research articles." The majority of these umbrella terms delivered more than 10,000 and some even more than 100,000 academic journal publications in the years 1995–2018 (co-creation: ~114,000, crowdfunding: ~8500, crowdsourcing: ~28,000, open access ~500,000, open source ~855,800, open source science ~470,000, patent pools ~2230, public private partnerships: ~32,700, problem-centered innovation networks: ~under 10 plus additional articles from public private partnerships and open source science, technology platforms with social benefit: ~50 plus additional articles from public private partnerships and crowdsourcing and co-creation). To extract relevant articles, a search within the results was performed, reducing the findings to "empirical" research and "social benefits": co-creation: ~500, crowdfunding: ~70, crowdsourcing: ~150, open access ~1300, open source ~2100, open-source science ~1500, patent pools ~90, public private partnerships: ~120, problem-centered innovation networks: ~under 10, technology platforms with social benefit: ~10. When the searches produced very few articles (under 10), forward and backward citations were assessed to identify further relevant articles (for an extract of findings and corresponding search strings see Appendix A). For each open innovation practice, we analyzed on average about 20 research articles, starting with the ones most cited. Usually after about 20 articles the findings on characteristics which might foster benefits to society were saturated and did not reveal any new insights. Accordingly, additional articles were only analyzed when some new aspects could be coded within the last three. For each open innovation practice, some key articles are listed in Appendix A Table A1.

Given the limited insights into patent pools and technology platforms in terms of social benefits, these approaches were complemented with our own, original data. For patent pools and technology platforms, we interviewed a total of eight initiators and participants and collected 78 relevant documents such as strategy papers, licensing agreements, and news releases (see Table 2). The articles, interviews, and documents were coded using interpretive content analysis: identifying relevant passages, paraphrasing, grouping by themes, comparing for similarities and differences [13]. To form the categories, data analysis was conducted in an iterative process of inductively identifying characteristics of open innovation practices. In the second round, the characteristics were deductively ordered into the six innovation attributes that increase societal impact (see Appendix B Table A2 for coding examples). The characteristics of open innovation practices were compared with one another using a three-measure ordinal scale of low, medium, and high. For inclusiveness, the scale began with "restricted" instead of "low." The values were only comprehensive relative to other values of the same characteristic within the set of open innovation practices. The next step was to group open innovation practices according to their societal benefits and to summarize if and how they addressed the six innovation attributes.

3.2. Findings on Open Innovation Practices That Deliver Societal Impact

We identified initiators and participants, degree of openness for contribution and use, sharing and mitigating innovation risks and investments, and the potential to change the market logic as decisive features for delivering societal benefits. Table 3 provides an overview of the main findings. It describes the initiators and participants, differentiating between citizens in general and direct users of the innovation. While the term crowd in open innovation practices refers to a general, not directly known user-base, hence, crowdsourcing or crowdfunding is an open request for participation, user-innovation and co-creation processes are more specifically targeted to known users and customers [50]. The term crowd is used in management studies. The term citizen is dominant in co-creation practices in urban studies and sociology, referring to a pre-selection of citizens as stakeholders or self-organizing citizens as initiators and drivers of innovation [30].

Table 2. Open Innovation Practices.

Name	Short Description and Examples	Sources (Extract)
Co-creation	User integration, user innovation, inbound innovation involving users in the ideation and prototyping process	[44,45]
Crowdfunding	Funding of innovation and cultural projects, usually via online platforms, e.g., kickstarter	[46,47]
Crowdsourcing	Often with online tools, idea platforms or idea contests, sourcing ideas from a defined or undefined crowd, depending on the objective and initiator	[48,49]
Open access	Knowledge content development, also open online courses, e.g., open map project, massive open online courses (MOOCs), e.g., from Harvard University	[50,51]
Open source	Open source usually for software development, e.g., Linux but also for hardware	[52,53]
Open source science	Citizen science, crowd science, science commons, open contribution and sharing of knowledge around a specific topic, e.g., Foldit, Galaxy Zoo, Open Genome Project	[54,55]
Patent pools *	Collaboration and licensing organization for technology-related intelelctual property rights, e.g., Medicines Patent Pool, Pool for Open Innovation on Neglected Diseases	Own data: 5 interviews, 46 documents: licensing contracts, press releases, policy briefings; and [56]
PDPs	Development partnerships and public private partnerships, usually for health technologies for developing countries, e.g., DNDi (Drugs for Neglected Disease initiative)	[5,57]
Problem-centred innovation networks	Innovation networks and larger public–private partnership for societal benefits, e.g., in development and climate mitigation technologies for strategic niche management	[21,23]
Technology platforms	Licensing platforms for technology transfer, clearing houses, outbound innovation, e.g., Eco Patent Commons, WIPO Green	Own data: 3 interviews, 32 documents: licensing contracts, press releases brochures; and [58,59]

* In this study we include only patent pools that are initiated for the purpose of solving specific environmental or societal issues.

Open innovation practices differ in terms of who initiates them and who participates in them. In general, we found that open innovation approaches employed by citizens and scientists, such as open access, open source and open-source science, have the highest potential to deliver societal benefits. They have the highest degree of openness in terms of use, because everyone can access the results. They may have resulted in high appropriateness and availability, as the process of formulating problems that require solutions are more collective and open to participants. Sharing of development risks and investments are high as many participants contribute, and they have the highest potential to change the market logic. Market logic referred to company development of innovations aiming for investment return rather than targeting social needs and addressing grand challenges. Open source is an example of a practice that might change the market logic, in that it influences a company's business model. This approach of building on others' innovations and sharing innovations free of charge while earning money through services such as consultancy work to implement eGovernment tools increased the digitalization of development countries using open-source software [60,61]. It is worth noting that some free of charge internet services are often "paid" with exposure to advertisement or with data for consumer profiling, associated with privacy issues. Hence, free of charge is not a benefit itself and needs careful assessment of the underlying business model.

Problem-centered innovation networks, patent pools, PDPs, and technology platforms ranked second. However, they came very close to the practices ranked first. Most of them are driven by NGOs and governmental organizations, but also by some profit-oriented

companies. Amongst them are different types of innovation networks for mitigating pollution in mining areas [21] and for developing affordable drugs to target HIV in developing countries [62]. The participation and use are open, and the development risks and investments are shared. Although not driven by profit-oriented enterprises, these participatory initiatives act as system integrators, tapping into companies' resources and capabilities. The potential to change the existing market logic is somewhat less because the practices allow companies to continue their operations as usual. The practices that companies use most, namely co-creation, crowdfunding and crowdsourcing, have the lowest impact, mainly due to restricted access to the results. For all three practices, the societal benefit is strongly connected to the innovation at stake.

Table 3. Characteristics of Open Innovation Practices that Deliver Societal Benefits.

Open Innovation Practice	**Co-Creation**	**Crowd-Funding**	**Crowd-Sourcing**	**Open Access**	**Open Source**
Initiators	companies	social enterprises, citizens, companies	companies	citizens, NGOs, education institutes	citizens
Participants	users	citizens	users, companies, engineers, research institutes	citizens, education inst., social enterprises, NGOs, research inst.	citizens, companies
Inclusiveness: -contribution	medium (restricted: lead user)	high	high *	high	high *
-use	restricted	restricted	restricted	high	high
Sharing and reducing: -innovation risks	medium	medium	medium	high	high
-investments	low	high	low	high	high
Potential to change market logic	low	medium	low	high	high
Open Innovation Practice	**Open Source Science**	**Patent Pools**	**PDPs**	**Problem-Centered Inno. Networks**	**Technology Platforms**
Initiators	scientists and research institutes	NGOs, companies	NGOs	governmental organizations, NGOs	companies, international organisations
Participants	citizens, scientists, education inst., companies	companies, research institutes	companies, research institutes	companies, NGOs, citizens (users), research inst.	companies, research institutes
Inclusiveness: -contribution	high *	high *	high **	medium-high **	high *
-use	high	high **	high **	medium-high **	high
Sharing and reducing: -innovation risks	high	high	high	high	medium
-investments	high	high	high	high	high
Potential to change market logic	high	medium	medium	medium, depends on topic	medium

* Requires relevant skills or Intellectual Property; ** open to relevant stakeholders, issue specific.

Based on the commonalities and differences, we identified three different types of open innovation practices in relation to societal benefits. Table 4 below outlines whether they contribute to delivering societal benefits according to the six innovation attributes. As shown, Type 1—inclusive open innovation practices—aims at integrating everyone who could potentially contribute to the innovation. Hence, information and communication channels are developed accordingly. All of them are coupled processes and they reach the highest affordability by proving the innovation free of charge. This is supported by sharing development investments and risks amongst the largest number of contributors possible. The levels of appropriateness and availability can be extremely high, depending on the initiators and the topic they pose. Only crowd science includes high anticipation,

and accountability is not addressed by any of the practices. However, the potential for creating sustainable paths by developing new technology and market paradigms is the highest amongst the three open innovation types. This is mainly due to the open access principle, as it challenges the market logic of making profit with the innovation. Hence, the innovation itself may be directed to the segments less upmarket.

Table 4. Typology of Open Innovation Practices Delivering Societal Benefits.

Type	**Type 1—Inclusive Open Innovation Practices**	**Type 2—Societal Open Innovation Practices**	**Type 3—Crowd Open Innovation Practices**
Practices / Innovation Attribute:	open access, open source (software and hardware)	patent pools, PDPs, problem-centred innovation networks, technology platforms	co-creation, crowdfunding, crowdsourcing
(I) Adequate information and communication channels	high	high	medium-high *
(II) Affordability	high	high	low-medium **
(III) Appropriateness and availability	high *	high	low-medium *, high * in crowdfunding
(IV) Anticipation	n.a., high * in crowd science	medium, high * in problem-centred innovation networks	n.a.
(V) Accountability	n.a.	n.a., high * in problem-centred innovation networks	n.a.
(VI) Sustainable path creation	high	medium, high *** in problem-centred innovation networks	low *

* depending on topic; ** depending on companies' price structures; *** depending on governmental support and companies; n.a.: not applicable.

Delivering benefits to society is at the core of Type 2—societal open innovation practices. They aim at and usually achieve high affordability, appropriateness, and availability. All of them are coupled processes. However, only problem-centered innovation networks achieve high anticipation, allocating accountability, and sustainable path creation. This is because this participatory practice is used solely for solving environmental and societal issues such as pollution or transmission of infectious diseases. Accountability is not addressed by patent pools, PDPs, or technology platforms. Their potential to create sustainable pathways is ranked medium, as they involve companies in addressing societal challenges and accordingly have the potential to influence companies by making corporate social responsibility more important.

Type 3—crowd open innovation practices—is ranked third and covers inbound open innovation processes. All crowd practices develop targeted information and communication channels. Accordingly, they address otherwise excluded members only when the purpose of the innovation is to provide something for them. Crowdsourcing with online tools supports reaching more members of society because information about innovation spreads widely. Crowdfunding is special as it is usually employed by social enterprises or to create niche products and enables companies to innovate with focusing on social returns. Accordingly, high availability, affordability, and appropriateness can be reached. Risk anticipation and accountability are not addressed by this type. Neither do they make a significant contribution to sustainable path creation.

4. Discussion and Conclusions on Societal Impact of Open Innovation Practices

We identified initiators and participants, degree of openness for contribution and use, sharing and mitigating innovation risks and investments, and the potential to change the market logic as decisive features for delivering societal benefits. The findings of the analysis illustrated characteristics of open innovation practices that foster societal benefits. First, based on different research fields, six innovation attributes were proposed that increase

benefits. Second, we identified characteristics of practices that contribute to a positive impact and developed a typology of three types of practices, each of them contributing differently to the six attributes of innovation. In doing so, this study provides insights into how open innovation practices can deliver societal benefits.

As presented in the findings, most of the open innovation practices have inherent features that support the first three innovation attributes. Amongst them are (I) developing adequate information and communication tools for addressing a wider audience, e.g., with open access and open science practices; enabling (II) affordability, e.g., through crowdfunding and PDPs; and participatory approaches that support innovation endeavors towards (III) appropriateness and availability for otherwise neglected members of a social system, e.g., through patent pools and technology platforms. Hardly any of the practices address the three other attributes. (IV) Anticipation in terms of appropriate and reflexive risk assessment is only considered within specific crowd science projects and problem-centered innovation networks. (V) Accountability in terms of adequate cost allocation of detrimental side effects, and (VI) sustainable path creation is only addressed by problem-based innovation networks. This is probably related to the fact that the attributes (IV) anticipation, (V) accountability, and (VI) sustainable path creation are more difficult to accommodate. The findings hint that companies are not the actors to initiate practices to address anticipation or accountability, while path creation is definitely something that companies aim for when creating sustainable innovation. Some of these companies certainly use open innovation practices. However, path development is then a matter of innovation strategy and not of the innovation practice itself. This underlines research on social and inclusive innovation which suggests that providing for otherwise excluded communities is a goal that companies deliberately chose [8,9]. Establishing accountability and sustainable path creation requires collective action, whereas one organization alone often lacks the long-term, broad perspective or the means to achieve this. Accordingly, and in-line with responsible innovation scholars [4,10,41], we argue that companies, innovators, research funders, citizens and politicians have a collective responsibility to direct innovation efforts towards societally beneficial innovations.

This article is intended to serve as a bridge to the research on open innovation, diffusion of innovation, and inclusive, social, and responsible innovation, and to expand upon that research in the following ways: We have demonstrated which open innovation practices can foster higher societal benefits, and which attributes of those practices play a decisive role. Comparing ten different practices and identifying relevant properties improves our understanding of which features of different practices are relevant for targeting innovations that spur social benefits. While coupled processes rank higher in inherent features for societal benefits, inbound processes may function as well when applied with beneficial goals. Rogers [1] has demonstrated that the processes of adoption and diffusion are accompanied by a number of encouraging and hindering factors at the level of innovation and of the system. This study advances these findings by demonstrating that the innovation practice itself can support adoption and diffusion, some with the potential to address specific benefit gaps. By engaging relevant users in the innovation process, e.g., through co-creation or open-source practices, the process of knowledge diffusion about the innovation has already begun with the creation of the innovation and this makes it possible to shape the features of the products into desired outcomes. The study presented here also adds detailed insights into social, inclusive, and responsible innovation that research proposes as a tool to increase inclusion [4]. It spells out which innovation attributes increase societal benefits, and through which features different types of open innovation practices address societal needs.

This study has several implications. The elaboration of different benefit gaps, innovation attributes, and the typology can serve as a practical guideline for enterprises, governmental, and non-profit organizations. It can assist them in considering the societal impact of their innovation and in choosing the appropriate innovation practice. Policymakers can use it as a guide to choose specific open innovation approaches for research

funding programs. The findings that accountability is not ordinarily addressed, and sustainable path creation only to a small degree, enforces the argument in favor of responsible innovation—that responsible innovation should be implemented as a strategy [10,56]. The goal and setting for creating social benefits are prerequisite and can only be supported by adequate innovation approaches.

5. Limitations and Further Research

Building on research on the diffusion of innovation, responsible innovation, inclusive, and social innovation, this paper identified six attributes of innovation which lead to greater societal benefits. The study has limitations: The list of innovation attributes is not exhaustive. The list could be complemented with further attributes by drawing on additional research streams. The conceptual discussion has not provided any ranking or discussed the linkages between or cumulative effects of the innovation characteristics. The assessment of open innovation practices is based on secondary data and qualitative insights. It is therefore limited to these ten approaches and the corresponding settings of their cases.

Though limited to a conceptual discussion and qualitative insights, the study provides a basis for developing measures to evaluate the societal impact of different open innovation practices. While the six attributes of innovation are all important to have a greater societal impact, further inquiries are needed to distinguish which kinds of innovation matter the most, and to assess the relative importance of each of the attributes. The open innovation practices themselves require further quantitative investigations to confirm the proposed ranking and to include a greater variation of settings and outbound innovation processes.

The typology as well as the description of benefit gaps and measures to address them may serve as an analysis of adequate policy measures, including action plans to enforce the effectiveness of regulations. It certainly deserves a careful assessment of policy mixes at the intersection of incentivizing innovation (e.g., intellectual property rights, tax benefits, publicly funded R&D programs), environmental regulation (e.g., circular economy and eco-design guidelines, best available technique, waste, pollution, chemical regulation), economic policies (anti-competitive regulations, consumer protection), and social policies (e.g., welfare, health sector regulations) to derive an appropriate policy package for shaping the outcome of innovation.

Funding: This research was funded by Belmont Forum and NORFACE Joint Research Programme on Transformations to Sustainability, which is co-funded by DLR/BMBF (FONA), grant number 01UV1812A, GCRF, ESRC, VR, and the European Commission through Horizon 2020.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Data availability of primary data was not agreed by subjects involved in this study.

Acknowledgments: The author thanks Andreas Tauber for assisting with the review and analysis, and numerous colleagues and researchers for fruitful discussions at conferences.

Conflicts of Interest: The author declares no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A

Table A1. Open Innovation Practices.

Open Innovation Approach	Key Articles—Sources (Authors and Year of Publication)
Co-creation	Aarras, N., Rönkä, M., Kamppinen, M., Tolvanen, H., & Vihervaara, P. (2014). Environmental technology and regional sustainability—The role of life-based design. *Technology in Society*, **36**, 52–59. Franke, N., & Von Hippel, E. (2003). Satisfying heterogeneous user needs via innovation toolkits: the case of Apache security software. *Research Policy*, **32**, 7, 1199–1215. Franke, N., Keinz, P., & Steger, C. J. (2009). Testing the value of customization: when do customers really prefer products tailored to their preferences? *Journal of Marketing*, **73**, 5, 103–121. Franke, N., Schreier, M., & Kaiser, U. (2010). The "I designed it myself" effect in mass customization. *Management Science*, **56**, 1, 125–140. Füller, J., Mühlbacher, H., Matzler, K., & Jawecki, G. (2010). Consumer empowerment through Internet-based co-creation. *Journal of Management Information Systems*, **26**, 3, 71. Keeys, L. A., & Huemann, M. (2017). Project benefits co-creation: Shaping sustainable development benefits. *International Journal of Project Management*, **35**, 6, 1196–1212. Thomke, S., & Von Hippel, E. (2002). Customers as innovators—A new way to create value. *Harvard Business Review*, **80**, 4, 74–81. Von Hippel, E. (1998). Economics of product development by users: The impact of "sticky" local information. *Management Science*, **44**, 5, 629–644. Von Hippel, E. (2001). Perspective: User toolkits for innovation. *Journal of Product Innovation Management*, **18**, 4, 247–257. Von Hippel, E., & Katz, R. (2002). Shifting innovation to users via toolkits. *Management Science*, **48**, 7, 821–833.
Crowdfunding	Belleflamme, P., Lambert, T., & Schwienbacher, A. (2014). Crowdfunding: Tapping the right crowd. *Journal of Business Venturing*, **29**, 5, 585–609. Burtch, G., Ghose, A., & Wattal, S. (2013). An empirical examination of the antecedents and consequences of contribution patterns in crowd-funded markets. *Information Systems Research*, **24**, 3, 499–519. Calic, G., & Mosakowski, E. (2016). Kicking off social entrepreneurship: how a sustainability orientation influences crowdfunding success. *The Journal of Management Studies*, **53**, 5, 738. Dragojlovic, N., & Lynd, L. D. (2014). Crowdfunding drug development: the state of play in oncology and rare diseases. *Drug Discovery Today*, **19**, 11, 1775–1780. Hildebrand, T., Puri, M., & Rocholld, J. (2017). Adverse incentives in crowdfunding. *Management Science*, **63**, 3, 587–608. Mollick, E. (2014). The dynamics of crowdfunding: An exploratory study. *Journal of Business Venturing*, **29**, 1, 1–16. Mollick, E., & Robb, A. (2016). Democratizing innovation and capital access: the role of crowdfunding. *California Management Review*, **58**, 2, 72–87. Ordanini, A., Miceli, L., Pizzetti, M., & Parasuraman, A. (2011). Crowd-funding: transforming customers into investors through innovative service platforms. *Journal of Service Management*, **22**, 4, 443–470. Stanko, M. A., & Henard, D. H. (2017). Toward a better understanding of crowdfunding, openness and the consequences for innovation. *Research Policy*, **46**, 4, 784. Younkin, P., & Kashkooli, K. (2016). What problem does crowdfunding solve? *California Management Review*, **58**, 2, 20–43.
Crowdsourcing	Afuah, A., & Tucci, C. L. (2012). Crowdsourcing as a solution to distant search. *Academy of Management Review*, **37**, 3, 355–375. Barbier, G., Zafarani, R., Gao, H., Fung, G., & Liu, H. (2012). Maximizing benefits from crowdsourced data. *Computational and Mathematical Organization Theory*, **18**, 3, 257–279. Brabham, D., Ribisl, K., Kirchner, T., & Bernhardt, J. (2014). Crowdsourcing applications for public health. *American Journal of Preventive Medicine*, **46**, 2, 179–187. Dodgson, M., Gann, D., & Salter, A. (2006). The role of technology in the shift towards open innovation: the case of Procter & Gamble. *R & D Management*, **36**, 3, 333–346. Garcia Martinez, M. (2015). Solver engagement in knowledge sharing in crowdsourcing communities: Exploring the link to creativity. *Research Policy*, **44**, 8, 1419–1430. Lee, S., Hwang, T., & Choi, D. (2012). Open innovation in the public sector of leading countries. *Management Decision*, **50**, 1, 147–162. Luengo-Oroz, M. A., Arranz, A., & Frean, J. (2012). Crowdsourcing malaria parasite quantification: an online game for analyzing images of infected thick blood smears. *Journal of Medical Internet Research*, **14**, 6, 207–219. Piller, F. T., & Walcher, D. (2006). Toolkits for idea competitions: a novel method to integrate users in new product development. *R & D Management*, **36**, 3, 307–318. Sutherlin, G. (2013). A voice in the crowd: Broader implications for crowdsourcing translation during crisis. *Journal of Information Science*, **39**, 3, 397–409. Swan, M. (2012). Crowdsourced health research studies: An important emerging complement to clinical trials in the public health research ecosystem. *Journal of Medical Internet Research*, **14**, 2, 1–9.

Table A1. *Cont.*

Open Innovation Approach	Key Articles—Sources (Authors and Year of Publication)
Open access	Al-Atabi, M., & Deboer, J. (2014). Teaching entrepreneurship using Massive Open Online Course (MOOC). *Technovation*, **34**, 4, 261–264. Albors, J., Ramos, J. C., & Hervasa, J. L. (2008). New learning network paradigms: Communities of objectives, crowdsourcing, wikis and open source. *International Journal of Information Management*, **28**, 3, 194–202. Annabi, C. A., & Wilkins, S. (2016). The use of MOOCs in transnational higher education for accreditation of prior learning, programme delivery, and professional development. *The International Journal of Educational Management*, **30**, 6, 959–975. Feess, E., & Scheufen, M. (2016). Academic copyright in the publishing game: a contest perspective. *European Journal of Law and Economics*, **42**, 2, 263–294. Hansen, J. D. N., & Reich, J. (2015). Democratizing education? Examining access and usage patterns in massive open online courses. *Science*, **350**, 6265, 1245–1248. Hew, K. F., & Cheung, W. S. (2014). Students' and instructors' use of massive open online courses (MOOCs): Motivations and challenges. *Educational Research Review*, **12**, 45–58. Huang, L., Zhang, J., & Liu, Y. (2017). Antecedents of student MOOC revisit intention: Moderation effect of course difficulty. *International Journal of Information Management*, **37**, 2, 84–91. Kaplan, A. M., & Haenlein, M. (2016). Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster. *Business Horizons*, **59**, 4, 441–450. Kop, R., Fournier, H., & Mak, J. (2011). A pedagogy of abundance or a pedagogy to support human beings? Participant support on Massive open online courses. *International Review of Research in Open and Distance Learning*, **12**, 7, 74–93. Nwagwu, W. E. (2013). Open access initiatives in Africa—structure, incentives and disincentives. *Journal of Academic Librarianship*, **39**, 1, 3–10.
Open science	Bagla, P. (2012). Crowd-sourcing drug discovery. *Science*, **335**, 6071, 909–909. Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. *Bioscience*, **59**, 11, 977–984. Cook-Deegan, R. (2007). The science commons in health research: structure, function, and value. *Journal of Technology Transfer*, **32**, 3, 133–156. Franzoni, C., & Sauermann, H. (2014). Crowd science: The organization of scientific research in open collaborative projects. *Research Policy*, **43**, 1, 1–20. Johnson, M., Hannah, C., Acton, L., Popovici, R., Karanth, K., & Weinthal, E. (2014). Network environmentalism: Citizen scientists as agents for environmental advocacy. *Global Environmental Change-Human And Policy Dimensions*, **29**, 235–245. Jong, S., & Slavova, K. (2014). When publications lead to products: The open science conundrum in new product development. *Research Policy*, **43**, 4, 645–654. Levrel, H., Fontaine, B., Henry, P.-Y., Jiguet, F., Julliard, R., Kerbiriou, C., & Couvet, D. (2010). Balancing state and volunteer investment in biodiversity monitoring for the implementation of CBD indicators: A French example. *Ecological Economics*, **69**, 7, 1580–1586. Price, C. A., & Lee, H.-S. (2013). Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching*, **50**, 7, 773–801. Walsh, J., & Huang, H. (2014). Local context, academic entrepreneurship and open science: Publication secrecy and commercial activity among Japanese and US scientists. *Research Policy*, **43**, 2, 245. West, J. (2008). Commercializing open science: deep space communications as the lead market for Shannon theory, 1960-73. *Journal of Management Studies*, **45**, 8, 1506–1532.
Open source	Bagozzi, R. P., & Dholakia, U. M. (2006). Open source software user communities: A study of participation in Linux user groups. *Management Science*, **52**, 7, 1099–1115. Comino, S., & Manenti, F. (2005). Government policies supporting open source software for the mass market. *Review of Industrial Organization*, **26**, 2, 217–240. Dahlander, L., & Magnusson, M. G. (2005). Relationships between open source software companies and communities: Observations from Nordic firms. *Research Policy*, **34**, 4, 481–493. Henkel, J., Schoberl, S., & Alexy, O. (2014). The emergence of openness: How and why firms adopt selective revealing in open innovation. *Research Policy*, **43**, 5, 879–890. Lakhani, K. R., & Von Hippel, E. (2003). How open source software works: "free" user-to-user assistance. *Research Policy*, **32**, 6, 923–943. O'Mahony, S., & Ferraro, F. (2007). The emergence of governance in an open source community. *Academy of Management Journal*, **50**, 5, 1079–1106. Pisano, G. (2006). Profiting from innovation and the intellectual property revolution. *Research Policy*, **35**, 8, 1122–1130. Vitharana, P., King, J., & Chapman, H. S. (2010). Impact of internal open source development on reuse: participatory reuse in action. *Journal of Management Information Systems*, **27**, 2, 277–304. Wang, J., Hu, M. Y., & Shanker, M. (2012). Human agency, social networks, and FOSS project success. *Journal of Business Research*, **65**, 7, 977–984. Wu, C.-G., Gerlach, J. H., & Young, C. E. (2007). An empirical analysis of open source software developers' motivations and continuance intentions. *Information & Management*, **44**, 3, 253–262.

Table A1. *Cont.*

Open Innovation Approach	Key Articles—Sources (Authors and Year of Publication)
Patent pools *	Cox, K. L. (2012). The Medicines Patent Pool: promoting access and innovation for life-saving medicines through voluntary licenses. *Hastings Science & Technology Law Journal*, **4**, 293–381. Delcamp, H. (2015). Are patent pools a way to help patent owners enforce their rights? *International Review of Law & Economics*, **41**, 68–76. Hoen Ellen 'T, Berger Jonathan, Calmy Alexandra, & Moon Suerie. (2011). Driving a decade of change: HIV/AIDS, patents and access to medicines for all. *Journal of the International AIDS Society*, **14**, 1, 15. Joshi, A. M., & Nerkar, A. (2011). When do strategic alliances inhibit innovation by firms? Evidence from patent pools in the global optical disc industry. *Strategic Management Journal*, **32**, 11, 1139–1160. Lerner, J., & Tirole, J. (2004). Efficient patent pools. *American Economic Review*, **94**, 3, 691. Pascual, F. (2014). Intellectual property rights, market competition and access to affordable antiretrovirals. *Antiviral Therapy*, **19**, 57–67. Rey, P., & Salant, D. (2012). Abuse of dominance and licensing of intellectual property. *International Journal of Industrial Organization*, **30**, 6, 518. Vakili, K. (2016). Collaborative promotion of technology standards and the impact on innovation, industry structure, and organizational capabilities: evidence from modern patent pools. *Organization Science*, **27**, 6, 1504–1524. van Zimmeren, E., van Neste, S., Matthijs, G., van Haverbeke, W., & van Overwalle, G. (2011). Patent pools and clearinghouses in the life sciences. *Trends in Biotechnology*, **29**, 11, 569–576. Verbeure, B., van Zimmeren, E., Matthijs, G., & Van Overwalle, G. (2006). Patent pools and diagnostic testing. *Trends in Biotechnology*, **24**, 3, 115–120.
PDPs	Barr, D. (2007). A research protocol to evaluate the effectiveness of public-private partnerships as a means to improve health and welfare systems worldwide. *American Journal of Public Health*, **97**, 1, 19–25. Bishai, D. M., Champion, C., Steele, M. E., & Thompson, L. (2011). Product development partnerships hit their stride: lessons from developing a meningitis vaccine for Africa. *Health Affairs*, **30**, 6, 1058–64. Breitstein, J., & Spigelman, M. (2013). The role of product development partnerships in advancing the development of drugs for unmet needs. *Clinical Pharmacology & Therapeutics*, **93**, 6, 468–470. Chataway, J., Hanlin, R., Mugwagwa, J., & Muraguri, L. (2010). Global health social technologies Reflections on evolving theories and landscapes. *Research Policy*, **39**, 10, 1277–1288. Mahoney, R. (2011). Product development partnerships: Case studies of a new mechanism for health technology innovation. *Health Research Policy and Systems*, **9**, 33. Moran, M., Guzman, J., Ropars, A. L., & Illmer, A. (2010). The role of product development partnerships in research and development for neglected diseases. *International Health*, **2**, 2, 114–122. Munoz, V., Visentin, F., Foray, D., & Gaule, P. (2015). Can medical products be developed on a non-profit basis? Exploring product development partnerships for neglected diseases. *Science and Public Policy*, **42**, 3, 315–338. Nwaka, S., & Ridley, R. G. (2003). Virtual drug discovery and development for neglected diseases through public-private partnerships. *Nature Reviews Drug Discovery*, **2**, 11, 919–928. Pratt, B., & Loff, B. (2013). Linking research to global health equity: The contribution of product development partnerships to access to medicines and research capacity building. *American Journal of Public Health*, **103**, 11, 1968–1978. Reich, M. R. (2000). Public-private partnerships for public health. *Nature Medicine*, **6**, 6, 617.
Problem-centred innovation networks	Behera, S. K., Kim, J.-H., Lee, S.-Y., Suh, S., & Park, H.-S. (2012). Evolution of "designed" industrial symbiosis networks in the Ulsan Eco-industrial Park: "research and development into business" as the enabling framework. *Journal of Cleaner Production*, **29**, 30, 103–112. Eberhard, R., Johnston, N., & Everingham, J.-A. (2013). A collaborative approach to address the cumulative impacts of mine-water discharge: Negotiating a cross-sectoral waterway partnership in the Bowen Basin, Australia. *Resources Policy*, **38**, 4, 678–687. Gupta, A. K., Sinha, R., Koradia, D., Patel, R., Parmar, M., Rohit, P., Vivekanandan, P. (2003). Mobilizing grassroots' technological innovations and traditional knowledge, values and institutions: articulating social and ethical capital. *Futures*, **35**, 9, 975–987. King, A. (2007). Cooperation between corporations and environmental groups: A transaction cost perspective. *Academy of Management Review*, **32**, 3, 889–900. Patala, S., Hamalainen, S., Jalkala, A., & Pesonen, H.-L. (2014). Towards a broader perspective on the forms of eco-industrial networks. *Journal of Cleaner Production*, **82**, 166–178. Poncet, J., Kuper, M., & Chiche, J. (2010). Wandering off the paths of planned innovation: The role of formal and informal intermediaries in a large-scale irrigation scheme in Morocco. *Agricultural Systems*, **103**, 4, 171–179. Selsky, J., & Parker, B. (2005). Cross-sector partnerships to address social issues: challenges to theory and practice. *Journal of Management*, **31**, 6, 849–873. Seuring, S. (2004). Integrated chain management and supply chain management comparative analysis and illustrative cases. *Journal of Cleaner Production*, **12**, 8–10, 1059–1071. Van Der Valk, T., Chappin, M. M. H., & Gijsbers, G. W. (2011). Evaluating innovation networks in emerging technologies. *Technological Forecasting and Social Change*, **78**, 1, 25–39. Wossen, T., Berger, T., & Di Falco, S. (2015). Social capital, risk preference and adoption of improved farm land management practices in Ethiopia. *Agricultural Economics*, **46**, 1, 81–97.

Table A1. *Cont.*

Open Innovation Approach	Key Articles—Sources (Authors and Year of Publication)
Technology platforms	Aoki, R., & Schiff, A. (2008). Promoting access to intellectual property: patent pools, copyright collectives, and clearinghouses. *R & D Management*, **38**, 2, 189–204. Aoki, R., & Schiff, A. (2010). Intellectual property clearinghouses: The effects of reduced transaction costs in licensing. *Information Economics And Policy*, **22**, 3, 218–227. Boudreau, K. (2010). Open platform strategies and innovation: granting access vs. devolving control. *Management Science*, **56**, 10, 1849–1872. Hall, B. H., & Helmers, C. (2013). Innovation and diffusion of clean/green technology: Can patent commons help? *Journal of Environmental Economics and Management*, **66**, 1, 33–51. Proskuryakova, L., Meissner, D., & Rudnik, P. (2017). The use of technology platforms as a policy tool to address research challenges and technology transfer. *Journal of Technology Transfer*, **42**, 1, 206–227. Ricard, L. M. (2016). Aligning innovation with grand societal challenges: Inside the European Technology Platforms in wind, and carbon capture and storage. *Science and Public Policy*, **43**, 2, 169–183. Robinson, D., Rip, A., & Mangematin, V. (2007). Technological agglomeration and the emergence of clusters and networks in nanotechnology. *Research Policy*, **36**, 6, 871. Siedlok, F., Smart, P., & Gupta, A. (2010). Convergence and reorientation via open innovation: the emergence of nutraceuticals. *Technology Analysis & Strategic Management*, **22**, 5, 571–592. Van Hoorebeek, M., & Onzivu, W. (2010). The Eco-Patent Commons and environmental technology transfer: implications for efforts to tackle climate change. *Carbon & Climate Law Review: CCLR*, **4**, 1, 13–29. Van Overwalle, G., van Zimmeren, E., Verbeure, B., & Matthijs, G. (2006). Science and society—Models for facilitating access to patents on genetic inventions. *Nature Reviews Genetics*, **7**, 2, 143–148.

* In this study we include only patent pools that are initiated for the purpose of solving specific environmental or societal issues.

Appendix B

Table A2. Example of Coding (excerpt).

Coded Categories	Short Description	Examples
I-1 Inclusiveness (contribution)	Openness to contribute resources, knowledge, requirements/specification to innovation, scale: restricted, medium, high	'engaging customers/stakeholders', 'firms participating', 'included stakeholders', 'participants'; 'special need groups' highest degree when unconditional to skills and resources restricted: very exclusive targeted groups, e.g., specific lead users without representing unserved groups medium: targeted groups: companies collaborate with specific user group, e.g., co-creation high: all individuals and organizations can contribute, e.g., crowdsourcing, open access, open source
I-2 Inclusiveness (use)	Openness to use the outcome, scale: restricted, medium, high	'free access/use', open access/sharing', 'no cost' 'unrestricted access/use' highest degree when unconditional to skills and resources restricted: use limited to conditions, e.g., only license to manufacture for specific user groups or in specific countries medium: broader use, e.g., social innovations resulting from crowdfunding or PDPs, high: all interested organizations and individuals can use it, e.g., open access, open source, open science
(I-I) Adequate information and communication channels	Information and communication channels are designed to reach all members who could benefit from the innovation	High reach through removing access barriers, deliberate reflexion on goals and purpose, and how to reach the ones that should benefit, high through inclusion in innovation process. E.g.: open access publishing Medium effect: massive open online courses, as they are free of charge but yet have failed to reach poor and uneducated people (no adequate communication channels) Low effect: not identified in open innovation practices, as they all increase information flow and engagement with beneficiaries

References

1. Rogers, E.M. *Diffusion of Innovation*; The Free Press: New York, NY, USA, 2003.
2. Swanson, T.M. *Biotechnology, Agriculture and the Developing World: The Distributional Implications of Technological Change*; Edward Elgar Publishing: Cheltenham, UK, 2002.
3. Bhatt, P.; Ahmad, A.J.; Roomi, M.A. Social innovation with open source software: User engagement and development chal-lenges in India. *Technovation* **2016**, *52*, 28–39. [CrossRef]
4. Stilgoe, J.; Owen, R.; Macnaghten, P. Developing a framework for responsible innovation. *Res. Policy* **2013**, *42*, 1568–1580. [CrossRef]
5. Munoz, V.; Visentin, F.; Foray, D.; Gaulé, P. Can medical products be developed on a non-profit basis? Exploring product development partnerships for neglected diseases. *Sci. Public Policy* **2014**, *42*, 315–338. [CrossRef]
6. Oliveira, P.; Zejnilovic, L.; Canhão, H.; von Hippel, E. Innovation by patients with rare diseases and chronic needs. *Orphanet J. Rare Dis.* **2015**, *10*, 1–9. [CrossRef] [PubMed]
7. Chesbrough, H.; Di Minin, A. Open social innovation. In *New Frontiers in Open Innovation*; Chesbrough, H., Vanhaverbeke, W., West, J., Eds.; Oxford University Press: Oxford, UK, 2014; pp. 169–188.
8. Chalmers, D.M. Social innovation: An exploration of the barriers faced by innovating organizations in the social economy. *Local Econ. J. Local Econ. Policy Unit* **2012**, *28*, 17–34. [CrossRef]
9. Holmes, S.; Smart, P. Exploring open innovation practice in firm-nonprofit engagements: A corporate social responsibility perspective. *R&D Manag.* **2009**, *39*, 394–409. [CrossRef]
10. Von Schomberg, R. A Vision of Responsible Research and Innovation. In *Responsible Innovation*; Owen, R., Bessant, J., Heintz, M., Eds.; Wiley: London, UK, 2013; pp. 51–74.
11. Clarkson, P.J.; Coleman, R.; Keates, S.; Lebbon, C. *Inclusive Design: Design for the Whole Population*; Springer: London, UK, 2003.
12. Kaplinsky, R. Schumacher meets Schumpeter: Appropriate technology below the radar. *Res. Policy* **2011**, *40*, 193–203. [CrossRef]
13. Edwards-Schachter, M.; Wallace, M.L. 'Shaken, but not stirred': Sixty years of defining social innovation. *Technol. Forecast. Soc. Chang.* **2017**, *119*, 64–79. [CrossRef]
14. Owen, R.; Stilgoe, J.; Macnaghten, P.; Gorman, M.; Fisher, E.; Guston, D. A Framework for Responsible Innovation. In *Responsible Innovation*; Owen, R., Bessant, J., Heintz, M., Eds.; Wiley: London, UK, 2013; pp. 27–50.
15. Fichter, K.; Clausen, J. Diffusion Dynamics of Sustainable Innovation: Insights on Diffusion Patterns Based on the Analysis of 100 Sustainable Product and Service Innovations. *J. Innov. Manag.* **2016**, *4*, 30–67. [CrossRef]
16. Le Blanc, D.; Roehri, R.A. Back to Our Common Future: Sustainable Development in the 21st Century (SD21) Project, Summary for Policymakers, United Nations. 2012. Available online: https://sustainabledevelopment.un.org/content/documents/UN-DESA_Back_Common_Future_En.pdf (accessed on 8 December 2020).
17. Wieland, R.; Ravensbergen, S.; Gregr, E.J.; Satterfield, T.; Chan, K.M.A. Debunking trickle-down ecosystem services: The fallacy of omnipotent, homogeneous beneficiaries. *Ecol. Econ.* **2016**, *121*, 175–180. [CrossRef]
18. Arslan, H.; Kachani, S.; Shmatov, K. Optimal product introduction and life cycle pricing policies for multiple product generations under competition. *J. Revenue Pricing Manag.* **2008**, *8*, 438–451. [CrossRef]
19. Chipman, J.S.; Tian, G. Detrimental externalities, pollution rights, and the "Coase theorem". *Econ. Theory* **2011**, *49*, 309–327. [CrossRef]
20. Lehmann, P. Justifying a Policy Mix for Pollution Control: A Review of Economic Literature. *J. Econ. Surv.* **2010**, *26*, 71–97. [CrossRef]
21. Eberhard, R.; Johnston, N.; Everingham, J.-A. A collaborative approach to address the cumulative impacts of mine-water discharge: Negotiating a cross-sectoral waterway partnership in the Bowen Basin, Australia. *Resour. Policy* **2013**, *38*, 678–687. [CrossRef]
22. Witter, S.G.; Robotham, M.P.; Carrasco, D.A. Sustainable adoption of conservation practices by upland farmers in the Dominican Republic. *J. Soil Water Conserv.* **1996**, *51*, 249–254.
23. Wossen, T.; Berger, T.; Di Falco, S. Social capital, risk preference and adoption of improved farm land management practices in Ethiopia. *Agric. Econ.* **2015**, *46*, 81–97. [CrossRef]
24. George, G.; McGahan, A.M.; Prabhu, J. Innovation for Inclusive Growth: Towards a Theoretical Framework and a Research Agenda. *J. Manag. Stud.* **2012**, *49*, 661–683. [CrossRef]
25. Lezaun, J.; Montgomery, C.M. The Pharmaceutical Commons: Sharing and Exclusion in Global Health Drug Development. *Sci. Technol. Hum. Values* **2015**, *40*, 3–29. [CrossRef]
26. Kulve, H.T.; Rip, A. Constructing Productive Engagement: Pre-engagement Tools for Emerging Technologies. *Sci. Eng. Ethic* **2011**, *17*, 699–714. [CrossRef]
27. Lenton, T.M.; Rockström, J.; Gaffney, O.; Rahmstorf, S.; Richardson, K.; Steffen, W.; Schellnhuber, H.J. Climate tipping points—Too risky to bet against. *Nat. Cell Biol.* **2019**, *575*, 592–595. [CrossRef]
28. Zimmermann, L.; Dombrowski, A.; Völker, C.; Wagner, M. Are bioplastics and plant-based materials safer than conventional plastics? In vitro toxicity and chemical composition. *Environ. Int.* **2020**, *145*, 106066. [CrossRef]
29. Dou, J.; Han, X. How does the industry mobility affect pollution industry transfer in China: Empirical test on Pollution Haven Hypothesis and Porter Hypothesis. *J. Clean. Prod.* **2019**, *217*, 105–115. [CrossRef]

30. Davies, S.R.; Selin, C.; Gano, G.; Pereira, Â.G. Citizen engagement and urban change: Three case studies of material deliberation. *Cities* **2012**, *29*, 351–357. [CrossRef]
31. Puente-Rodríguez, D.; Van Slobbe, E.; Al, I.A.; Lindenbergh, D. Knowledge co-production in practice: Enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea. *Environ. Sci. Policy* **2016**, *55*, 456–466. [CrossRef]
32. Baú, V. Citizen engagement in peacebuilding: A communication for development approach to rebuilding peace from the bottom-up. *Prog. Dev. Stud.* **2016**, *16*, 348–360. [CrossRef]
33. Kyamusugulwa, P.M. Participatory Development and Reconstruction: A literature review. *Third World Q.* **2013**, *34*, 1265–1278. [CrossRef]
34. Iversen, T.; Soskice, D. Electoral systems and the politics of coalitions: Why some democracies redistribute more than others. *Am. Polit. Sci. Rev.* **2006**, *100*, 165–180.
35. Eppinger, E.; Tinnemann, P. Technology transfer of publicly funded research results from academia to industry: Societal responsibilities? In *Responsible Innovation, Volume 1: Innovative Solutions for Global Issues*; van den Hoven, J., Romijn, H., Swier-stra, T., Doorn, N., Eds.; Springer: Dordrecht, The Netherlands, 2014; pp. 67–88.
36. Collingridge, D. *The Social Control of Technology*; St. Martin's Press: New York, NY, USA, 1980.
37. Buckley, J.; Thompson, P.B.; Whyte, K.P. Collingridge's dilemma and the early ethical assessment of emerging technology: The case of nanotechnology enabled biosensors. *Technol. Soc.* **2017**, *48*, 54–63. [CrossRef]
38. Kobayashi, M. Participatory sustainability research for risk management and leadership development. In *Sustainable Living with Environmental Risks*; Kaneko, N., Yoshiura, S., Kobayashi, M., Eds.; Springer: Tokyo, Japan, 2014; pp. 239–252.
39. Mitcham, C. Co-responsibility for research integrity. *Sci. Eng. Ethic* **2003**, *9*, 273–290. [CrossRef]
40. Mirvis, P.; Herrera, M.E.B.; Googins, B.; Albareda, L. Corporate social innovation: How firms learn to innovate for the greater good. *J. Bus. Res.* **2016**, *69*, 5014–5021. [CrossRef]
41. Grinbaum, A.; Groves, C. What is "responsible" about responsible innovation? Understanding the ethical issues. In *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*; Owen, R., Bessant, J., Heintz, M., Eds.; Wiley: London, UK, 2013; pp. 119–142.
42. Siegel, D. Green management matters only if it yields more green: An economic/strategic perspective. *Strat. Dir.* **2010**, *26*, 5–16. [CrossRef]
43. Smith, A.; Stirling, A.; Berkhout, F. The governance of sustainable socio-technical transitions. *Res. Policy* **2005**, *34*, 1491–1510. [CrossRef]
44. Frauenberger, C.; Good, J.; Keay-Bright, W. Designing technology for children with special needs: Bridging perspectives through participatory design. *CoDesign* **2011**, *7*, 1–28. [CrossRef]
45. Von Hippel, E. Economics of product development by users: The impact of "sticky" local information. *Manag. Sci.* **1998**, *44*, 629–644. [CrossRef]
46. Mollick, E.; Robb, A. Democratizing Innovation and Capital Access: The Role of Crowdfunding. *Calif. Manag. Rev.* **2016**, *58*, 72–87. [CrossRef]
47. Younkin, P.; Kashkooli, K. What problem does crowdfunding solve? *Calif. Manag. Rev.* **2016**, *58*, 20–43. [CrossRef]
48. Dodgson, M.; Gann, D.M.; Salter, A. The role of technology in the shift towards open innovation: The case of Procter & Gamble. *R&D Manag.* **2006**, *36*, 333–346. [CrossRef]
49. Piller, F.; Walcher, D. Toolkits for idea competitions: A novel method to integrate users in new product development. *R&D Manag.* **2006**, *36*, 307–318. [CrossRef]
50. Albors, J.; Ramos, J.C.; Hervas, J.L. New learning network paradigms: Communities of objectives, crowdsourcing, wikis and open source. *Int. J. Inf. Manag. Sci.* **2008**, *28*, 194–202.
51. Hansen, J.; Reich, J. Democratizing education? Examining access and usage patterns in massive open online courses. *Science* **2015**, *350*, 1245–1248. [CrossRef]
52. Strahilevitz, L.J.; Benkler, Y. The Wealth of Networks: How Social Production Transforms Markets and Freedom. *Yale Law J.* **2007**, *116*, 1472. [CrossRef]
53. Osterloh, M.; Rota, S. Open source software development: Just another case of collective invention? *Res. Policy* **2007**, *36*, 157–171. [CrossRef]
54. Bagla, P. Crowd-Sourcing Drug Discovery. *Science* **2012**, *335*, 909. [CrossRef] [PubMed]
55. Franzoni, C.; Sauermann, H. Crowd science: The organization of scientific research in open collaborative projects. *Res. Policy* **2014**, *43*, 1–20. [CrossRef]
56. Cox, K.L. Investment in energy efficiency: Do the characteristics of investments matter? *Hastings Sci. Technol. Law J.* **2012**, *4*, 293–381.
57. Moran, M.; Guzman, J.; Ropars, A.; Illmer, A. The role of Product Development Partnerships in research and development for neglected diseases. *Int. Health* **2010**, *2*, 114–122. [CrossRef]
58. Hall, B.H.; Helmers, C. Innovation and diffusion of clean/green technology: Can patent commons help? *J. Environ. Econ. Manag.* **2013**, *66*, 33–51. [CrossRef]
59. Van Overwalle, G.; van Zimmeren, E.; Verbeure, B.; Matthijs, G. Science and society: Models for facilitating access to patents on genetic inventions. *Nat. Rev. Genet.* **2006**, *7*, 143–148.

60. Muwanguzi, S.; Musambira, G.W. The adoption of open source software in Uganda: Analyzing stakeholders and their underlying interests. *Technol. Soc.* **2019**, *58*, 101138. [CrossRef]
61. Tella, A.; Edward, I.; Akanbi-Ademolake, H.; Akande, S.O. Perception, use and effectiveness of open source library systems by academic librarians in selected tertiary institutions in Kwara State, Nigeria. *J. Acad. Libr.* **2021**, *47*, 102307. [CrossRef]
62. Dionisio, D. Medicines Patent Pool: Making the difference on access. *Future Virol.* **2011**, *6*, 1147–1150. [CrossRef]