



# International R&D diffusion in disaster management: a systematic review

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## Abstract

There are several challenges to the international diffusion of research and development (R&D) in disaster management. The present study aimed to examine a paradigm shift in international R&D diffusion in the field. Qualitative content analysis was used as the methodology in comparing commercialization-based versus humanity-based international R&D diffusion in terms of international organizations, developed nations, and developing nations. A key finding is that the field needs to shift from commercialization-based to humanity-based international R&D diffusion, while enhancing international cooperation, equality and human rights, and networking, among other factors. Compared with previous studies, this research reviewed a paradigm shift in international R&D diffusion in disaster management in a more comprehensive and timely manner.

**Keywords** Diffusion of innovation · Paradigm shift · International collaboration · Commercialization · Humanity

## 1 Introduction

The issue of R&D has considerably influenced the direction of various scientific fields. Whereas basic research investigates the characteristics of nature without a specific purpose(s), applied research uses the results of basic research for a specific purpose(s). Development includes revised (or new) processes and products in the related production process. Since the beginning of the 1950s, the subject of R&D has been widely recognized in major nations (Traver 2020). More recently, R&D has been considered as a starting point for cutting-edge disaster management alternatives.

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**Table 1** Numerical data on international R&D diffusion in disaster management from 2005 to 2020 (UNDRR 2021)

Units	Numbers	Related information
Programs of international R&D diffusion	1,113 programs	About 69.6 programs were implemented yearly
Origin countries	12 United Nations (UN) member countries	7 of 12 countries (about 58%) contributed US\$ 394 million
Host countries	20 UN member countries	20 countries positively benefited from 395 of 1,113 programs (about 36%)

Table 1 shows the reality of international R&D diffusion in the field of disaster management. In adjusting to climate change as a natural hazard, many nations have tried to innovate and then apply appropriate R&D (Fichter and Clausen 2021). Specific R&D areas include weather forecasting, new energy, crop variety or resilience, irrigation systems, and low-carbon technologies. Nevertheless, as long as climate change R&D pursues only monetary benefits, human beings will continue to suffer from the impacts of climate change.

In dealing with the outbreak of coronavirus disease 2019 (COVID-19) as a man-made emergency, various nations have tried to redefine their R&D agendas. However, as long as the international community is dependent on the traditional ways of international R&D diffusion, the world may not be successful in dealing with COVID-19 (Melluso et al. 2020). That is, if R&D does not react to the emergence of coronavirus variants in a timely manner, the whole world will suffer from the continuous impacts of COVID-19 infection. The current situation thus urgently demands extraordinary ways of international R&D diffusion.

Given the above discussion, a clear concern is increasing the effectiveness of international R&D diffusion in the field of disaster management toward dealing with not only natural hazards but also man-made emergencies. Accordingly, how the field of international disaster management can enhance international R&D diffusion to achieve its ultimate goal of decreasing the psychological impacts, human losses, and economic damages resulting from all hazards emerges as a research question.

The present work aims to study a paradigm shift in international R&D diffusion in disaster management toward attaining the ultimate goal of the field. Two paradigms are compared, namely, commercialization-based and humanity-based international R&D diffusion, in terms of three analytical units: international organizations, developed nations, and developing nations. An important finding is that the field needs to shift from the former to the latter paradigm or at least supplement the former with the latter, while extensively addressing international cooperation, equality and human rights, and networks, among others.

## 2 Literature review

Diffusion of innovation is “the process in which an innovation is communicated through certain channels over time among the members of a social system” (Roger 2003). In this work, R&D diffusion refers to the process of not only passively spread-

ing (spontaneously or unplanned) but also actively disseminating (planned) R&D between/among countries in the field of disaster management. Thus, R&D diffusion involves various stakeholders, as well as their ideas and politics, economies, cultures, strategies, environments, and technologies.

Retrospectively, R&D diffusion has been a precondition of technological innovation at the international level (Prokhorova et al. 2019). Toward effective R&D diffusion, participants carry out optimal interactions in international markets, taking all objectives into account. R&D information is actively exchanged among various participants, thus increasing the R&D scope, and various factors are included in the actual mechanism of international R&D diffusion. Ultimately, potential innovation is greatly boosted by international R&D diffusion.

In general, two distinctive aspects have been considerably supported in international R&D diffusion (Blackman 1997). First, not all potential users have simultaneously adopted new R&D at the beginning stage. In fact, it has taken about five to fifty years to completely embody R&D diffusion between/among countries. Second, the diffusion of international R&D has shown a predictable sequence, beginning with slow adoption, which then turns rapid but eventually slows again. Over time, international R&D diffusion reaches the adoption ceiling.

The term “open innovation” has been recently advocated during the occurrence of disasters (Bogers et al. 2020). Whereas closed innovation is done within organizational boundaries, open innovation incorporates not only self-contained knowledge but also the external environment into its processes. A high level of cooperation between R&D suppliers and R&D customers is vital for the success of open innovation (Schroll and Mild 2012). Fully relying on external personnel, funds, and other resources, open innovation creates and then efficiently distributes international R&D in the field of disaster management. The costs and risks of related R&D are also distributed between/among countries.

Gaps in international R&D result from differences in the R&D done or used between two or more countries; these include the digital divide, foreign reaction lag, and COVID vaccine inequality. Such gaps have clearly increased in recent years (OECD 2021) and have presented a unique challenge to R&D participants or countries that cannot afford appropriate R&D in the international field of disaster management. Moreover, the increasing R&D gaps are bound to delay modernization efforts around disaster management.

Other challenges around international R&D diffusion have emerged, such as negative social factors, brain drain, rigid education, poor knowledge production, lack of R&D funding, too much competition, and lack of transparency. Many countries have not realized the impacts of such challenges in international R&D diffusion (Mazurkiewicz et al. 2019), thus preventing its efficient implementation.

The concept of a paradigm shift has been much demanded in many scientific areas since around the early 1960s. Such paradigm shift, which replaces underlying assumptions or ways of thinking, is not considered as a simple change but rather as a rudimental one (Kuhn 2012). The call for a paradigm shift in international R&D diffusion has also been supported, that is, that international R&D diffusion should not provide new knowledge merely through linear scientific accumulation but instead should refer to related frames for a paradigm shift.

The field of disaster management also substantially required a paradigm shift in the 21st century (Peduzzi 2019). Until the 1970s, the occurrence of natural hazards was regarded as a purely natural event. Many researchers and practitioners have since proven that such occurrences are also influenced by the social dimension of natural hazards or human behaviors. In addition, due to the complicated human interactions in a globalized world, the frame of man-made emergencies has been accordingly altered.

In this research, a paradigm shift between commercialization and humanity is processed. Commercialization-based international R&D diffusion returns monetary benefits to origin countries by selling or diffusing related R&D to host countries. Various partnerships between/among countries have contributed to the extent of commercialization (Min et al. 2020). R&D origin nations may access knowledge and resources or even overcome related shortcomings through joint investments, licensing, collaborative R&D projects, and contract-based R&D. As a whole, commercialization has a negative image in this work in that its focus is monetary gain.

Humanity basically refers to “the quality or state of being kind to other people or to animals,” according to the Merriam-Webster dictionary. Humanity being practically synonymous to people, humankind, humanness, and the public, humanity-based international R&D diffusion is thus oriented not toward inhumanity and cruelty but toward all humans in this work. Hence, humanity-based international R&D diffusion exerts efforts not for the purpose of gaining monetary benefits but toward the achievement of the goals of disaster management.

The topic of international R&D diffusion is neither fixed nor homogenous (Leake 2019). Instead, given that economy, engineering, politics, culture, and other areas influence its direction, international R&D diffusion is approached as a multidisciplinary study. The scope of disaster management also includes multiple disciplines because a specific discipline may not sufficiently address the complicated disaster issues in the field (Izumi et al. 2019). A paradigm shift from commercialization to humanity is thus firmly based on various disciplines.

The issue of urgency as a characteristic of disaster management is considerably reflected in international R&D diffusion (Sheek-Hussein et al. 2021). Because disasters occur within a short period, people require governments to take appropriate measures in a timely manner. Further, the phase of disaster response should be promptly carried out within a given time period. Appropriate international R&D therefore has to be diffused in a timely fashion, in particular during the disaster response; otherwise, the impacts of disasters would be critically doubled.

Sectoral differences have long existed in international R&D diffusion in the field of disaster management (Turner and Zaichenko 2016). For instance, the economic risk of applying new international R&D diffusion may have opposite effects in different sectors. A sector without a distinctive vision may consider an economic risk as a barrier, whereas other sectors may view it as a blessing. Some elements may have the same effect in multiple sectors, but the extent of such effect may vary. Collaborative international R&D diffusion shows sectoral differences as well.

Several researchers and practitioners have discussed either the significance of a paradigm shift in international R&D diffusion or the necessity of a paradigm shift in disaster management. Notwithstanding, little research has attempted a rigorous study

on a paradigm shift in international R&D diffusion in the field of disaster management. Therefore, the frame of this study between commercialization and humanity has potential merit, in particular as a comprehensive and timely investigation of the topic.

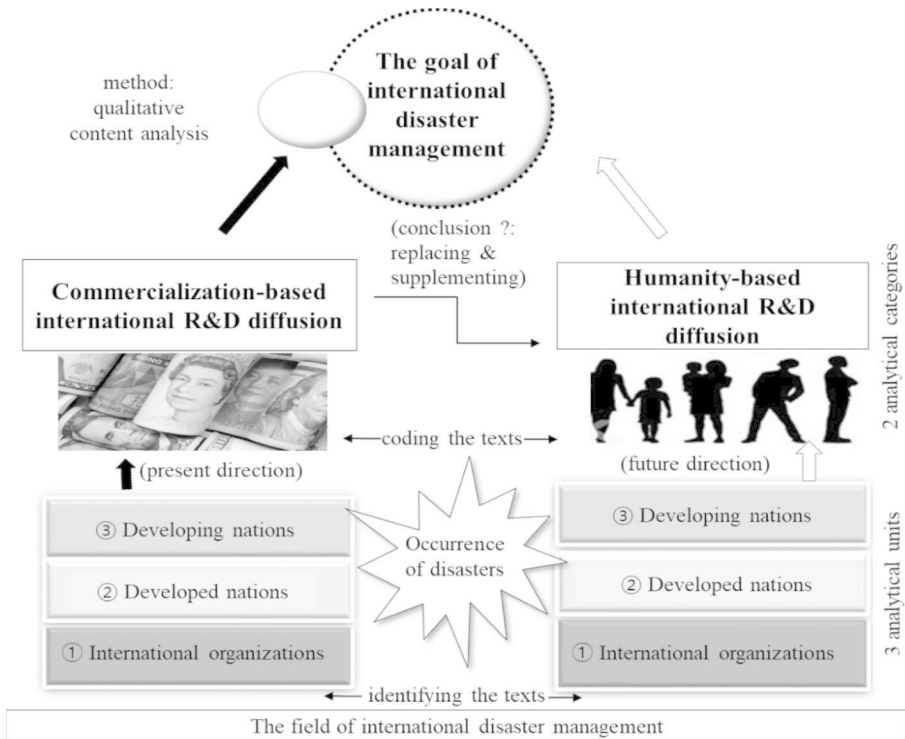
### 3 Methodology

Qualitative content analysis entails a gradual examination of the topic, in this case international R&D diffusion in the field of disaster management (Kensi and Santos 2019). Without this method, this research would have mainly included innovative or massive R&D production without equally considering the contribution or impact of international R&D diffusion. Further, qualitative content analysis helps provide a holistic framework of the topic while flexibly interpreting and defining multiple concepts, cases, and other theories. Vice versa, a multilevel framework that includes various determinants, variables, and contexts plays a more significant role in facilitating a holistic perspective compared with a single-focused framework (AlMalki and Durugbo 2022).

The process of qualitative content analysis consists of four major steps: identifying texts, defining units and categories for analysis, coding the texts, and analyzing the results toward drawing conclusions (Luo 2021). Texts were identified based on the research question: How can the field of disaster management enhance international R&D diffusion to help achieve its ultimate goal? Several search terms, including “technology transfer” (meaning the process of transferring new technology from a developer(s) to other users), “R&D diffusion and COVID-19” (indicating the activity of spreading and disseminating R&D during COVID-19 outbreak), “international technology transfer in disaster management” (referring to technology transfer between/among nations in the field of disaster management), and “technology transfer between North and South” (suggesting technology transfer between developed nations and developing nations), were used in internationally recognized databases, such as Google.com, ScienceDirect, Oxford University Press, and Yahoo.com (Fisch and Block 2018). All texts were written in English. The majority of the texts came from research reports; the rest were from books, government documents, and websites. The criterion for inclusion or exclusion was whether or not a specific text was related to international R&D diffusion, disaster management, and science and technology policy (Kuckertz and Block 2021).

The definition of units and categories for analysis was based on the assumption that the issue of international R&D diffusion has not fully embraced the role of stakeholders in the field of disaster management. In fact, international R&D diffusion clearly requires all stakeholders, such as governments, industries, universities, and international organizations, to play particular roles (Dillette and Ponting 2021). Without specifying the stakeholders and their respective responsibilities, the whole picture of international R&D diffusion cannot be firmly outlined.

Figure 1 shows, among other stakeholders, the three key stakeholders in international R&D diffusion in disaster management as three analytical units, namely, international organizations, developed nations, and developing nations. These three



**Fig. 1** Analytical framework

include all players in terms of geographic levels, such as international mutual area, rich area, and poor area. After analyzing the three units, two analytical categories were proposed: commercialization-based and humanity-based international R&D diffusion, which were compared by considering the same three analytical units.

Coding the texts required that the text data be carefully read and their meanings be manually recorded under appropriate categories. In particular, the three analytical units were classified under either of two categories. During the analysis of the results and the drawing of conclusions, focus was given to identifying appropriate implications in the process of responding to the research question. In so doing, a conclusion was drawn regarding the inevitable shift between the two distinctive categories.

## 4 Commercialization-based international R&D diffusion

### 4.1 International organizations

The Sendai Framework for Disaster Risk Reduction 2015–2030 directly supports international R&D diffusion in the field of disaster management, potentially based on the commercialization effect (UNDRR 2016). It also emphasizes the exchange of technological information among nations and the integration of traditional knowl-

edge into disaster management R&D. Nonetheless, the Sendai Framework does not adequately address other thorny issues on international R&D diffusion except the importance of international cooperation.

The European Innovation Council recently initiated a three-day online hackathon called “EUvsVirus” to help deal with the COVID-19 outbreak while facilitating international R&D diffusion beyond a single institution (Bertello et al. 2022). The hackathon was regarded as a collaborative and collective effort among multiple actors (or volunteers) to diffuse R&D in a timely manner. Hence, the program tried to maximize the potential of various individuals within a short period.

Many innovators, investors, civil societies, and international partners participated in EUvsVirus; however, they experienced difficulties in communicating with one another, in particular due to the lack of appropriate software. In addition, the majority of participants focused on the benefits for their own organizations, such as monetary gains. As a result, the hackathon did not succeed in obtaining a societal solution against coronavirus infection.

## 4.2 Developed nations

The extent of disaster management R&D diffusion between/among nations varies depending on the gross domestic product (GDP) of the countries concerned (Dechezlepretre et al. 2020). For example, R&D in developed nations is often diffused to other developed nations and rarely to developing nations. Similarly, R&D in developing nations is rarely diffused to developed nations. Thus, the diffusion of disaster management R&D to the international community has occurred mainly among developed nations.

In times of disasters, key R&D institutions in developed nations do not consider the related crisis as an adverse impact but as a good opportunity for their businesses, as they take advantage of patents, copyrights, or intellectual property rights (Guderian et al. 2021). The decision makers in these institutions quickly analyze the market situation and then make ad hoc decisions on their R&D diffusion. In a sense, these R&D institutions exploit market needs in initiating appropriate international R&D diffusion.

The majority of developed nations have attempted to diffuse their R&D to other countries under the big picture of commercialization. During this process, developed nations hollow out their R&D base, decrease their R&D jobs, or leak out crucial technologies. In light of these strategies, concerns for national security have emerged. Hence, R&D diffusion in developed nations has been geared toward increasing economic benefits even at the cost of national security.

## 4.3 Developing nations

Some Asian developing countries have adopted disaster management R&D to deal with frequent disasters and improve their resilience (Basher 2013). In China, frequent typhoons accompanied by floods resulted in the loss of millions of human lives between 1931 and 1959. Thanks to international R&D diffusion on early warning and evacuation systems, the nation has managed to decrease the impacts of such disasters.

Bangladesh has similarly been able to decrease disaster impacts in the region after adopting flood warning technologies.

Notwithstanding, several developing countries have yet to fully realize the implications of international R&D diffusion (Djoumessi and Mbongo 2022). Many players in African countries are aware that the use of information and communication technology, including cellular phones and the Internet, may contribute to mitigating the effects of climate change. However, they have been hesitant to diffuse related R&D in their nations, partly due to the immense challenges involved, such as poverty and the health crisis. For these stakeholders, the subject of disaster management is not a top priority.

The majority of R&D institutions in developing nations face limited finances during the phase of disaster response. Because of the lack of R&D funding, these institutions have decreased their reliance on international R&D diffusion. They consider the occurrence of disasters to be ambiguous, unpredictable, and uncertain. Hence, due to budget constraints, they either sell their ideas and proprietary rights or negotiate licensing deals, thus the limited patent applications for disaster management R&D.

## 5 Humanity-based international R&D diffusion

### 5.1 Major implications

The effects of R&D diffusion have been examined in several researches (Jiafu et al. 2018). Related topics include the methods that have facilitated R&D diffusion, the factors that have influenced the direction of R&D diffusion, and the models that have advocated R&D diffusion. Thus, the level of organizational performance has been considerably supported. In addition, qualitative analysis has been applied more frequently than quantitative analysis to determining how to measure the effects of R&D diffusion considering different variables.

The effects of international R&D diffusion have improved productivity in the field of disaster management, with each case having a unique context (Han et al. 2016). International firms or research institutions have gained vital technologies through international R&D contracts, R&D licensing, equipment purchases, mergers and acquisitions, and the employment of experts, among others. In particular, patent transfer has helped increase the extent of productivity in disaster management.

Nevertheless, the field of disaster management needs to expedite international R&D diffusion for the sake not of commercialization but of humanity. Disaster management will not fully achieve its goal if it sticks to commercialization-based international R&D diffusion. The field should therefore replace commercialization-based international R&D diffusion with humanity-based international R&D diffusion to decrease the impacts of disasters in various regions, as shown in Table 2, or at least supplement the former with the latter, considering the practical reality.

The finding of the need to shift toward humanity-based international R&D diffusion has practical implications. Considering the faster speed of international R&D diffusion that such transition would bring about, the human losses and casualties resulting from the impacts of various emergencies will be considerably decreased.



**Table 2** How to adopt humanity-based international R&D diffusion

Analytical units	Specific alternatives
International organizations	<ul style="list-style-type: none"> <li>- The Sendai Framework needs to further discuss intellectual property rights on international R&amp;D and prioritize the list of potential disaster victims toward the goal of international disaster management.</li> <li>- The European Innovation Council should focus on societal benefits rather than organizational monetary benefits in dealing with the regional impact of the COVID-19 outbreak.</li> </ul>
Developed Nations	<ul style="list-style-type: none"> <li>- Developed nations must make further efforts to diffuse R&amp;D to developing nations and other developed nations.</li> <li>- Developed nations must not consider disaster management R&amp;D diffusion as an issue of national security but of humanity, given that the occurrence of disasters may impact all nations.</li> </ul>
Developing Nations	<ul style="list-style-type: none"> <li>- Developing nations must realize the significance of international R&amp;D diffusion in disaster management, particularly by referring to the cases of China and Bangladesh, among others.</li> <li>- Developing nations should prioritize the issue of disaster management, to mitigate both economic damages and human losses, and then increase patent applications for international R&amp;D diffusion.</li> </ul>

Saving human lives is much more important than any other goal in the field of disaster management (FEMA 2021), and emergency management is intended to provide assistance to local residents before, during, and after the occurrence of disasters.

The transition toward humanity-based international R&D diffusion may have other practical implications. The finding of this work will allow stakeholders to reconsider the significance of humanity amid the prevalent materialism in the world. In doing so, education in the scientific communities and the emergency management field will be further advocated. In addition, the extent of diversity, such as of race, age, and national origin, among others, will be amplified toward caring for humanity (Ben-Nun 2021). Although the finding of this research is strongly related to science and technology, its implications will have practical influence in the fundamental aspects of human society.

By theoretically providing a paradigm shift between two distinctive approaches, the present research contributes to the expansion of the literature in the field of international R&D diffusion in disaster management. By providing specific insights on the topic or contexts within a frame change, this work fills a salient gap between/among international R&D diffusion, disaster management, or neighboring theories. That is, the present findings expand the boundaries of international R&D diffusion within disaster management.

The issue of techno-nationalism links international R&D diffusion and technological innovation to the movement of each nation toward economic benefits, national security, or social stability (Manen et al. 2021). The majority of nations have made efforts to maintain or obtain competitive advantages by substantially utilizing international R&D diffusion. The fierce competition between/among nations at present

has created a new trend of techno-nationalism, which has allowed major countries to dominate international R&D diffusion in disaster management.

Despite the prevalence of techno-nationalism, humanity-based international R&D diffusion requires a high extent of international collaboration among all stakeholders (Guimon and Narula 2020). National pride, regional interests, geopolitical tensions, and monetary goals, under the banner of techno-nationalism, have somewhat diluted the pure goal of international disaster management; thus, nations need sincere collaboration with one another to achieve a successful transition.

International R&D diffusion may ultimately increase the level of equality among various nations in the field of disaster management. Technological innovation has been a source of socioeconomic inequality, with the strongest emerging victorious in a winner-take-all battle. Nonetheless, those who have later adopted international R&D (e.g., developing nations) have obtained more benefits from related R&D diffusion than those who have earlier adopted the same (e.g., developed nations) because international R&D diffusion has helped the former more than the latter (Qureshi 2021). International R&D diffusion has thus compensated for disadvantages in technological innovation.

The occurrence of disasters has not only physical impacts (e.g., visible human losses and economic damages) but also social impacts (e.g., invisible social inequality) in human society. International R&D diffusion has contributed to decreasing these disaster impacts regardless of national boundaries. However, how exactly international R&D diffusion helps decrease inequality and increase equality is admittedly very complicated. Over time, international R&D diffusion may steadily eliminate inequality among nations.

The transition process toward humanity-based international R&D diffusion involves certain aspects similar to the issue of equality. Hence, the topic of humanity is on the same track as the issue of equality and human rights (Schafer et al. 2020). The human rights of disaster victims have been frequently and seriously violated in several nations. Many cases of human rights violation can be systematically overcome by applying alternatives of equality through humanity-based international R&D diffusion, including information sharing, equal pay, and equal opportunity.

There are various challenges to the adoption of humanity-based international R&D diffusion, among them language differences, lack of communication, and lack of trust. To decrease the extent of these barriers, networking should be established among all stakeholders, including scientists and researchers, decision makers, international lobbyists, and international communities (Bednarz and Broekel 2019). Besides, these networks should be based on interdependent, cross-cultural, and multilevel relations.

The subject of an integrated emergency management system can be flexibly applied to the evolution of humanity-based international R&D diffusion. Such system creates various networks among stakeholders to effectively deal with a crisis (Purdue University 2021). All integrated stakeholders under humanity-based international R&D diffusion should thus coordinate regarding contentious issues, regardless of national boundaries, while regularly sharing international R&D diffusion and related information and knowledge before, during, and after the occurrence of disasters.

## 5.2 Future research agenda

The evolution of this systematic review has directly or indirectly suggested a plethora of research opportunities toward advancing the base of international R&D diffusion in the field of disaster management. According to the literature review, research results, and major implications, three recommendations have emerged regarding the direction of future studies and related research agenda.

First, researchers may further expand the application of a paradigm shift in the domain of science and technology (Li and Huang 2019). Such paradigm shift may help address certain urgent issues that have not been resolved with the use of existing data or traditional methods. In other words, researchers may attempt to develop non-traditional approaches for scientific communities by applying a paradigm shift while dealing with global challenges, such as the collapse of economic systems, climate change, and the outbreak of new pandemics.

Second, the frame used in this work may be applied more fully to international R&D diffusion in future research. The category of flexible frames has played a role in overcoming various constraints in international R&D diffusion and thus has been adopted by innovators more frequently than expected (Raffaelli et al. 2019). In embracing the transition from commercialization-based to humanity-based international R&D diffusion, researchers may contribute to providing better alternatives in the field.

Third, researchers may delve into sector-specific studies from the perspective of international R&D diffusion in disaster management field (Nouman et al. 2022). The wide spectrum of these technological sectors includes early warning systems, weather forecasting, earthquake prediction, satellite communication, geographic information systems, and vaccines for pandemics, to name a few. The same sector in different nations has different features. Hence, researchers may devote time and resources to these sectoral differences, in particular toward providing concrete answers to relevant issues.

## 6 Conclusion

The goal of this research was to provide a paradigm shift on international R&D diffusion in the field of disaster management. The challenges, alternatives, and implications were analyzed in terms of three analytical units, namely, international organizations, developed nations, and developing nations. Two distinctive paradigms were presented: commercialization-based and humanity-based international R&D diffusion, toward achieving the research goal.

Considering the unique features of the disaster management sector, such as urgency, human losses, and psychological impacts, the main finding of this work is that the field should shift from commercialization-based to humanity-based international R&D diffusion. Toward this end, the three above-mentioned units or stakeholders need to carry out specific tasks, including protecting intellectual property rights, carrying out international R&D diffusion to developing nations, and prioritizing disaster

management. Moreover, the field has to champion the benefits of international R&D diffusion, international cooperation, equality and human rights, and networking.

The advantage of this research lies in its review of a paradigm shift in international R&D diffusion in the field of disaster management. The suggestion of a frame for such paradigm shift is timely, given the outbreak of COVID-19. However, whereas international R&D diffusion is an essential part of international disaster management, the contents of this work may not be applicable to all disaster management technologies. Rather, this research provides a macro-perspective of international R&D diffusion in the field.

Future researchers may apply the paradigm shift in international R&D diffusion provided in this study to their respective research domains, in particular to subjects related to human losses or human lives. To address the limitation of this work, sector-specific studies on international R&D diffusion in the field of disaster management may be carried out. All future efforts will ultimately contribute to the goal of decreasing human losses, economic damages, and psychological impacts resulting from disasters in various regions.

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## Declarations

**Conflict of interest** The author has no relevant financial or non-financial interests to disclose.

## References

- AlMalki HA, Durugbo CM (2022) Systematic review of institutional innovation literature: Towards a multi-level management model. *Manage Rev Q*. <https://doi.org/10.1007/s11301-022-00259-8>
- Basher R (2013) Science and technology for disaster risk reduction: A review of application and coordination needs. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland
- Bednarz M, Broekel T (2019) The relationship of policy induced R&D networks and inter-regional knowledge diffusion. *J Evol Econ* 29:1459–1481. <https://doi.org/10.1007/s00191-019-00621-2>
- Ben-Nun L (2021) The role of humanity for human life. B. N. Publication House, Israel
- Bertello A, Bogers MLAM, Bernardi PD (2022) Open innovation in the face of the COVID-19 grand challenge: Insights from the Pan-European hackathon ‘EU vs Virus.’ *R&D Manage*. 52:178–192. <https://doi.org/10.1111/radm.12456>. 2
- Blackman A (1997) The economics of technology diffusion: Implications for greenhouse gas mitigation in developing countries. Resources for the Future, Washington, D.C.
- Bogers M, Chesbrough H, Strand R (2020) Sustainable open innovation to address a grand challenge: Lessons from Carlsberg and the Green Fiber Bottle. *Br Food J* 122(5):1505–1517. <https://doi.org/10.1108/BFJ-07-2019-0534>
- Dechezleprete A, Fankhauser S, Glachant M, Stoeber J, Touboul S (2020) Invention and global diffusion of technologies for climate change adaptation: A patent analysis. World Bank, Washington, D.C.

- Dillette A, Ponting SSA (2021) Diffusing innovation in times of disasters: Considerations for event management professionals. *J Convention & Event Tourism* 22(3):197–220. <https://doi.org/10.1080/15470148.2020.1860847>
- Djoumessi YF, Mbongo LBE (2022) An analysis of information communication technologies for natural disaster management in Africa. *Int J Disaster Risk Reduct* 68:102722. <https://doi.org/10.1016/j.ijdrr.2021.102722>
- Federal Emergency Management Agency (FEMA) (2021) 2022–2026 FEMA strategic plan: Building the FEMA our nation needs and deserves. FEMA, Washington, D.C.
- Fichter K, Clausen J (2021) Diffusion of environmental innovations: Sector differences and explanation range of factors. *Environ Innov Societal Transitions* 38:34–51. <https://doi.org/10.1016/j.eist.2020.10.005>
- Fisch C, Block J (2018) Six tips for your (systematic) literature review in business and management research. *Manage Rev Q* 68:103–106. <https://doi.org/10.1007/s11301-018-0142-x>
- Guderman CC, Bican PM, Riar FJ, Chattopadhyay S (2021) Innovation management in crisis: Patent analytics as a response to the COVID-19 pandemic. *R&D Manage* 51(2):223–239. <https://doi.org/10.1111/radm.12447>
- Guimon J, Narula R (2020) Ending the COVID-19 pandemic requires more international collaboration. *Res-Technol Manage* 63(5):38–41. <https://doi.org/10.1080/08956308.2020.1790239>
- Han J, Kwon Y, Lee ST (2016) The impacts of technology transfer on productivity growth of firms based on Malmquist productivity index. *Asia Pac J Inf Syst* 26(4):542–560. <https://doi.org/10.14329/apjis.2016.26.4.542>
- Izumi T, Shaw R, Djalante R, Ishiwatari M, Komino T (2019) Disaster risk reduction and innovations. *Prog Disaster Sci* 2:100033. <https://doi.org/10.1016/j.pdisas.2019.100033>
- Jiafu S, Yu Y, Tao Y (2018) Measuring knowledge diffusion efficiency in R&D networks. *Knowl Manage Res & Pract* 16(2):208–219. <https://doi.org/10.1080/14778238.2018.1435186>
- Kensi VM, Santos GL (2019) Qualitative research on educational technology in Latin America. *Oxford Res Encycl Educ*. <https://doi.org/10.1093/acrefore/9780190264093.013.1279>
- Kuckertz A, Block J (2021) Reviewing systematic literature reviews: Ten key questions and criteria for reviewers. *Manage Rev Q* 71:519–524. <https://doi.org/10.1007/s11301-021-00228-7>
- Kuhn TS (2012) *The structure of scientific revolutions*. University of Chicago Press, Chicago, Illinois
- Leake ML (2019) *A Study of the diffusion of innovations and hurricane response communication in the U.S. Coast Guard*. Master thesis, Old Dominion University
- Li J, Huang W (2019) Paradigm shift in science with tackling global challenges. *Nat Sci Rev* 6(6):1091–1093. <https://doi.org/10.1093/nsr/nwz155>
- Luo A (2021) Content analysis: A step-by-step guide with examples. Scribbr. <https://www.scribbr.com/methodology/content-analysis/>. Accessed 14 July 2022
- Manen H, Gehrke T, Thompson J, Sweijts T (2021) Taming techno-nationalism: A policy agenda. The Hague Centre for Strategic Studies, Hague, Netherlands
- Mazurkiewicz A, Poteralska B, Walaszczyk L (2019) Technology transfer barriers in strategic research programmes. *Adv Econ Bus Manage Res* 106:317–320. <https://doi.org/10.2991/feb-19.2019.64>
- Melluso N, Bonaccorsi A, Chiarello F, Fantoni G (2020) Rapid detection of fast innovation under the pressure of COVID-19. *PLoS ONE* 15(12):e0244175. <https://doi.org/10.1371/journal.pone.0244175>
- Min J, Kim Y, Vonortas NS (2020) Public technology transfer, commercialization and business growth. *Eur Econ Rev* 124:103407. <https://doi.org/10.1016/j.eurocorev.2020.103407>
- Nouman M, Yunis MS, Atiq M, Mufti O, Qadus A (2022) ‘The forgotten sector’: An integrative framework for future research on low-and medium-technology innovation. *Sustainability* 14(6):3572. <https://doi.org/10.3390/su14063572>
- Organisation for Economic Co-operation and Development (OECD) (2021) Gross domestic spending on R&D (indicator). OECD, Paris
- Peduzzi P (2019) The disaster risk, global change, and sustainability nexus. *Sustainability* 11(4):957. <https://doi.org/10.3390/su11040957>
- Prokhorova V, Reznik N, Bozhanova O, Slastianykova K (2019) Technology transfer as a perquisite of innovative development of enterprises. *SHS Web Conf* 67:01011. <https://doi.org/10.1051/shsconf/20196701011>
- Purdue University (2021) Integrated emergency management plan. Department of Education, West Lafayette, Indiana
- Qureshi Z (2021) *Technology, growth, and inequality: Changing dynamics in the digital era*. Economy and Development at Brookings, Washington, D.C.

- Raffaelli R, Glynn MA, Tushman M (2019) Frame flexibility: The role of cognitive and emotional framing in innovation adoption by incumbent firms. *Strategic Manage J* 40(7):1013–1039. <https://doi.org/10.1002/smj.3011>
- Roger EM (2003) *Diffusion of innovations*. The Free Press, New York, New York
- Schafer L, Kunzel V, Jorks P (2020) *A human rights-based approach to climate and disaster risk financing*. Germanwatch, Berlin, Germany
- Schroll A, Mild A (2012) A critical review of empirical research on open innovation adoption. *J fur Betriebswirtschaft (Manage Rev Q)* 62:85–118. <https://doi.org/10.1007/s11301-012-0084-7>
- Sheek-Hussein M, Abu-Zidan FM, Stip E (2021) Disaster management of the psychological impact of the COVID-19 pandemic. *Int J Emergency Med* 14(19). <https://doi.org/10.1186/s12245-021-00342-z>
- Thurner TW, Zaichenko S (2016) Sectoral differences in technology transfer. *Int J Innovation Manage* 20(2):1650020. <https://doi.org/10.1142/S1363919616500201>
- Traver E (2020) Research and development (R&D) vs. product development. Investopedia. Investopedia. <https://www.investopedia.com/ask/answers/042815/what-difference-between-research-and-development-and-product-development.asp>. Accessed 11 June 2022
- United Nations Office for Disaster Risk Reduction (UNDRR) (2016) *UNISDR science and technology conference on the implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030*. UNDRR, Geneva, Switzerland
- UNDRR (2021) *International cooperation in disaster risk reduction*. UNDRR, Geneva, Switzerland

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