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New Strategy for Innovative RD&D in View of Stakeholder Interaction during Climate Technology Transfer

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Abstract: To tackle the global climate change issues, many countries have been interested in technology research, development, and demonstration (RD&D) during climate technology development and transfer processes in terms of technology innovation. According to our previous staged innovation model, technology RD&D is regarded as a crucial stage enabling the transition from technology-push to market-pull innovation. However, the strategic operation of RD&D during the climate technology transfer processes is still inactive. Thus, in the present work, we first elucidated innovative features by reviewing the RD&D activities during the climate technology transfer processes in terms of three elements of innovation: technology, market, and regulation. Moreover, innovative barriers to participating in the RD&D projects were identified by analyzing brief survey for various stakeholders from academia, private sectors, and governments. Based on both findings from case study and survey, new strategies were proposed for innovative RD&D facilitation, considering the interactions between the technology transfer matchmaker and Triple Helix during transferring climate technology.

Keywords: climate change; RD&D; technology innovation; Triple Helix

Citation: Lee, W.-J.; Mwebaza, R. New Strategy for Innovative RD&D in View of Stakeholder Interaction during Climate Technology Transfer. *Sustainability* **2022**, *14*, 8363. https://doi.org/10.3390/su14148363

Academic Editors: Baojie He, Ayyoob Sharifi, Chi Feng and Jun Yang

Received: 16 June 2022
Accepted: 4 July 2022
Published: 8 July 2022

1. Introduction

According to Intergovernmental Panel on Climate Change, technology transfer is a process covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change amongst different stakeholders [1]. Many UN agencies, the scientific communities, and academia have been delivering various innovative climate solutions, via effective climate technology transfer processes of: climate technology research, development, demonstration (RD&D), market development and commercial diffusion at the request of developing countries [2,3].

RD&D is the process through which brand new, fundamental, and cheap technologies are developed and demonstrated in a real-world context [4]. Among the components of RD&D, 'Research' refers to the search for new knowledge and solutions—in other words, the starting point for the emergence of new technologies. 'Development' refers to the next step where concrete technologies with improved performance or usable product are generated from the research phase by refining through repetitive testing in the laboratory or simulated field conditions. Then, the next phase, 'Demonstration' stage refers to the use of the product in actual field conditions where its performance and feasibility can be tested from prototypes to full-scale models and evaluated by actual or potential users.

Generally, RD&D is regarded as an innovative step because it needs simple modification of technology to various local context, which is more efficiently time-saving and lower cost compared to the long-time taking R&D process [5]. Moreover, RD&D is known to play innovative roles for developing countries to build their own endogenous capacities for sustainable development [6]. Hence, it is notable that benefits of international collaboration on RD&D expand to include cost savings, accelerated learning, harmonization of standards and approaches, and elimination of overlapping [7].

To accelerate innovative RD&D action especially on climate change, the Paris Agreement requests "collaborative approaches to climate technology RD&D and facilitating access to technology, in particular for early stages of the climate technology transfer cycle, to developing countries" [4]. Responding to the Paris Agreement, the Technology Executive Committee (TEC) as a policy arm of the Technology Mechanism has analyzed the overview of international collaborative RD&D, with an aim of sharing knowledge and experiences on innovative technologies or capabilities towards a low-emission, climate-resilient society and economy [8]. On a practical level, the Climate Technology Centre and Network (CTCN), as an implementation arm of the Technology Mechanism, has been providing technology RD&D activities as a "matchmaker for climate technology transfer" by supporting developing countries through its main service of technical assistance at their requests on various climate issues since its inception in 2013.

Therefore, the present research aims to elucidate the innovative features and barriers to RD&D, by reviewing technology transfer cases in view of three innovation elements which are technology, market and regulation, and by analyzing a short survey for major stakeholders who took part in previous climate technology RD&D projects, respectively. Then, we propose new innovative RD&D strategy to tackle the urgent global climate issues, based on the innovative interactions between the CTCN as a technology transfer matchmaker and various active stakeholders, i.e., academia, local private sectors, and governmental policy makers (Triple Helix) during the climate technology transfer processes.

2. Methods

During complex and multidisciplinary innovation processes, many individuals and organizations are presumed to engage with external actors such as customers, suppliers, competitors, research centres, universities, or public authorities. This is because these linkages provide access to novel ideas, knowledge and technologies, suggestions for product or process improvement, and solutions to technical or organizational problems. In other words, the constituents of innovation are a set of components and the relations among these components, which are shaped by laws, rules, norms, and routines. According to North's research [9], there are three structural elements of an innovation system: technology, market, and regulation. Thus, in order to examine the innovative features and the barriers to RD&D, it is important to more carefully assess the innovation flow during the 'demonstration' stage just after the R&D process, considering the interactions among the Triple Helix, e.g., academia/research institutions as providers of innovative "technologies", private sectors as creators of "market", and governments as makers of "regulation" (see Figure 1).

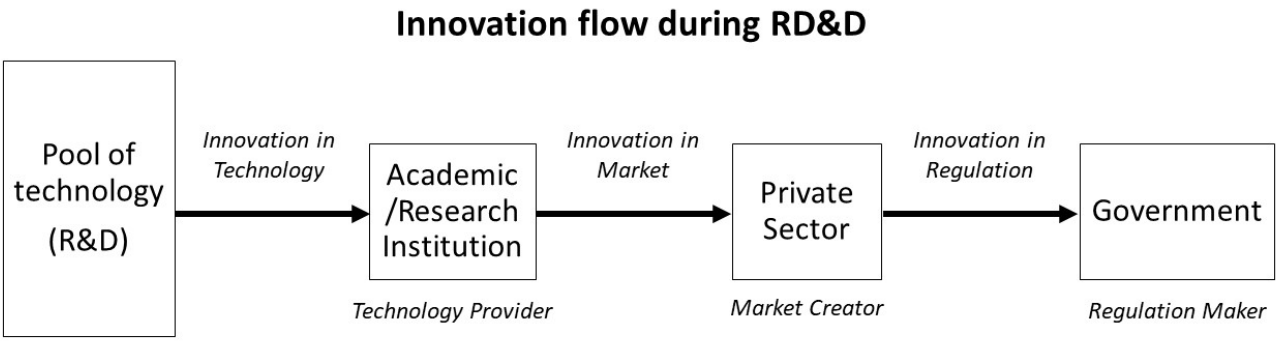

Figure 1. The structure elements of an innovation during RD&D process.

2.1. Innovative Features of RD&D: Case Studies

To identify the innovative features of the RD&D process, we analyzed 6 RD&D case studies among previous climate technology transfer processes of the CTCN technical assistance activities, based on three structural elements of innovation: technology, market, and regulation. These 6 examples were carefully chosen by the CTCN technical assistance specialists among the projects regarding the RD&D stage of technology transfer cycle, such

as "Piloting and deployment of technologies in local conditions", "Research and development of technologies", and "Private sector engagement and market creation" among all the previous technical assistances cases (256 as of June 2022). Table 1 gives each two examples are applicable for three consecutive innovation flows (Figure 1) of technology, market, and regulation, respectively.

Table 1. Technical Assistance examples targeted for RD&D.

Innovation Element in	Title of Technical Assistance
Technology	Application of the gravity-driven membrane (GDM) technology for supplying sustainable drinking water to rural communities [10]
	Improving Capacity for Recycling of Waste & Organic Materials [11]
Market	A Community based early Warning System in every pocket from Santo Domingo, D.N. [12]
	Catalyzing low-cost green technologies for sustainable water service delivery in northern Kenya [13]
Regulation	Support for e-mobility transition in Jakarta [14]
	Towards a circular economy of local governments in Costa Rica: The case study of Turrialba [15]

2.2. Innovative Barriers to RD&D: Stakeholders Quick Survey

In order to identify the major barriers to RD&D facilitation for climate technology cooperation with developing countries, we have conducted a quick survey for the previous RD&D project implementors, particularly from the Republic of Korea, on current issues, major interests, barriers, and policy demands of RD&D. Among various climate technology providers and users from academia, research institutions, private sectors, and governments, we selected 93 target respondents who have experience of such technology RD&D projects with various developing countries: (1) CTCN technology assistance under United Nations Framework Convention on Climate Change; (2) climate technology localization project organized by the Korean Ministry of Science and ICT (MSIT); and (3) other overseas climate technology cooperation projects organized by public institutes, such as the Korea Institute of Energy Technology Evaluation and Planning and the Korea Energy Agency.

The survey questions contain basic information on target respondents and their major barriers to the participation in the RD&D projects with considering the phases of 'preparation', 'implementation', and 'completion', as summarized in Table 2.

Table 2. Questionnaire of survey related to identifying barriers of RD&D cooperation.

Respondents		Key Questionnaires
Academia, Research Institutions, Private Sectors, Governments	Basic Information	Number of RD&D experiences vs. Budget size
		Number of RD&D experiences vs. Type of financial support
		Number of RD&D experiences vs. Technology
	Major Barriers	Barriers to the preparation phase of the RD&D
		Barriers to the implementation phase of the RD&D
		Barriers to the completion phase of the RD&D

3. Results and Discussion

3.1. Innovative Features of RD&D in View of Technology, Market, and Regulation

According to our previous research on the types of the CTCN technical assistances [16], the CTCN has focused more than 80% on prioritization and feasibility access of technologies, and establishment of climate policies, which are mostly within earlier stages of technology

transfer process. Still, the later stages like RD&D (approx. 15%) and market creation (approx. 5%) are not fully considered in previous technical assistances. Recognizing that the R&D process normally takes a long time and draws little interest from the markets, it seems to be more realistic and innovative for accelerating the RD&D implementation by directly focusing on the 'demonstration' stage of the existing technologies, rather than to 'develop' new technologies. In the following sections, these innovative features of the RD&D were clearly explained in terms of technology, market and regulation, by reviewing the actual models for climate technology transfer.

3.1.1. Technology Innovation

In order to supply sustainable fresh drinking water to rural community in Cambodia, the CTCN provided RD&D technical assistance using the innovative filtering technology governed by gravity force, called Gravity-Driven Membrane (GDM) [10]. Through this RD&D activity for installment and operation of the GDM incorporated rainwater collection tanks in various locations, the GDM is definitively validated to very innovative and promising technology to produce clean drinking water from rainwater with minimum energy over 10-year maintenance under climate change and frequent drought conditions.

Figure 2 shows the schematic of the GDM filtration system using hydrostatic pressure mode. While the rainwater feeds to the GDM system, various organic materials can be screened on vertically installed membrane modules, and only clean water permeates through it. Consecutively, new RD&D projects are now under implementation through a little modification of technology to other Asian Pacific countries which have similar local contexts (i.e., lack of drinking water, using rainwater as a major source, lack of energy to be used for water treatment, etc.) such as Myanmar [17].

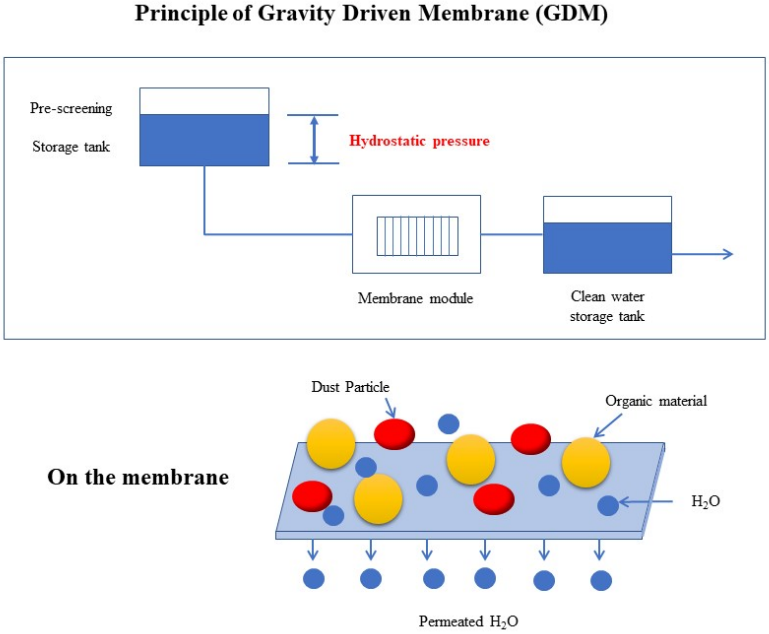

Figure 2. The principle of Gravity-Driven Membrane filtration technology [10].

As the second technical assistance example, the government of Gambia requested the development of a training program for 15 communities on innovative recycling technologies to produce charcoal briquettes out of dry leaves, saw dust, and coconut shells. Charcoal is generally produced by pyrolysis of biomass, the irreversible chemical change during heating without oxygen. Given the specific requirements in many developing countries for cooling and heating purpose, production efficiency is still necessary to be improved through technological innovations.

Responding to the request, the technical assistance aimed to develop a methodology of sustainable waste management for energy and livelihoods that can be scaled up to national

levels [11]. Then, the technical assistance provided a training program for utilizing biomass residues and wastes to produce charcoal briquettes and established a value chain to make it competitive compared to traditional fossil fuels. Moreover, it can be easily reproduceable in other countries that have similar conditions (i.e., lack of waste treatment technology and system, still using primary stage fossil fuel as energy source, etc.).

It is notable that GDM is considered as an innovative technology for household drinking water developed by academia/research institutions [18] and becomes easy to be modified and replicated to other areas that have similar conditions. Furthermore, new methodology to enhance Gambian women's capacity to fabricate briquette from wastes shows possibility for scale-up and easy adjustment to other locations. Therefore, in accomplishing technology-push innovation, the above two technical assistance examples have similarity: well-proven technologies are chosen especially from academia/research institutions, and then simply modified during RD&D process, instead of the long-time taking conventional R&D process.

3.1.2. Market Innovation

In order to transfer from technology-push to market-pull innovation, the combination of climate RD&D actions with various digital technologies is regarded as one of the fast, agile, and innovative strategies for climate technology-based business and new market creation [19]. For example, early warning system (EWS) in the Dominican Republic can be one typical example of RD&D actions to meet the market-pull innovation [12]. The technical assistance aimed to improve the EWS of the northern part of Santo Domingo, Dominican Republic through (1) reviewing the current conditions of early warning on natural disasters and (2) analyzing innovative methods, e.g., smartphones and mobile applications etc., introducing digital technology for providing information to cover wider regions of the community. Furthermore, the EWS is expandable to larger scale demonstration to raise private financing for new markets by combining with innovative digital technology applications such as (1) artificial intelligence, big data, cloud computing for more accurate analysis of hydro-meteorological risks and (2) development of early warning mobile application with 5G network and other IoT sensing [20].

To secure sustainable water supplies in Kenya, technical assistance has conducted to prioritize suitable technologies for the market-friendly area. Through this technical assistance, business models were developed on the basis of feasibility study for three low-cost technologies: (1) solar water pumping system, (2) wind powered pumping system, (3) water pans (small surface rainwater storage) with Public-Private-Partnership (PPP) consideration of related stakeholders such as Kenya ministries, private companies and banks as shown in Figure 3 [13]. Further support to develop concept note is under consideration for triggering external funding which may help the large-scale RD&D and new market creation involving the private sector. Here, it is suggested that additional sources of funding and financing, and long-term investment perspectives based on various experiences are complementary helped by the provision of the private sector.

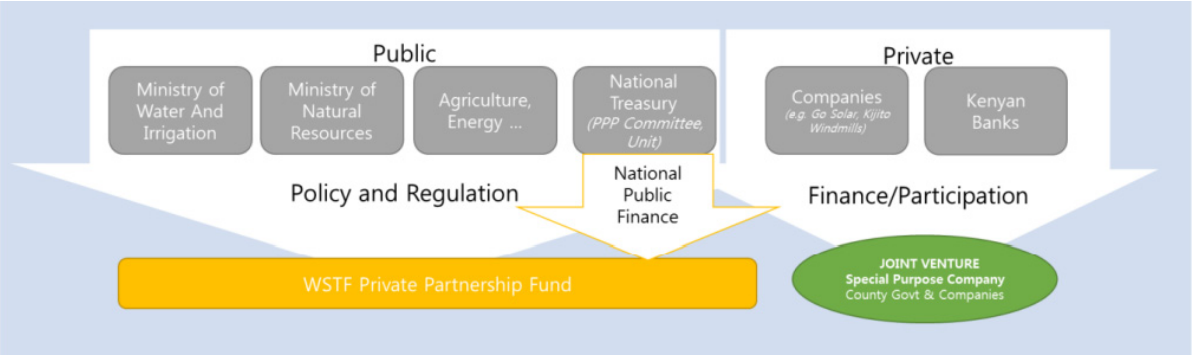

Figure 3. Water services business model with Public-Private-Partnership [13].

From the above two technical assistance examples, it is worthwhile to note that the RD&D process during climate technology transfer plays a similar role of 'market-pull innovation' in creating new businesses and markets by facilitating the collaboration with the local private partners providing skilled services in form of technical manpower, know-how, or in-kind supports [21]. For this purpose, it is prerequisite that those RD&D items ready for business incubation should be selected specifically among the private sectors, which makes them exclusive for the market-pull innovation.

3.1.3. Regulation Innovation

Final technical assistance case is RD&D project to develop requirements and actions for an investment policy to introduce e-mobility in public and government vehicles in Jakarta [14]. In this project, flexible policy recommendations to promote e-buses and related infrastructure were proposed as fiscal and non-fiscal incentives for the technology provider through close collaboration with the Indonesian government. Furthermore, to deploy and upscale the e-mobility, many technical assistances in other countries such as Cambodia, Nigeria, Ghana, and Zimbabwe are aiming to create and review the flexibility of national policy and regulations on the electric vehicles and supporting charging infrastructure. Through this multi-national approach, the CTCN proposed various regulation innovation of subsidies, resilient standards, and other policy recommendations.

Like other developing countries, Costa Rica has an issue to protect natural resources from overexploitation, and to recover and reuse them in various ways. The objective of the technical assistance requested from Costa Rica on circular economy is to keep scarce and valuable resources in circulation for longer periods of time, promoting recycling and avoiding loss of materials [15]. Achieving these objectives requires gathering regulations with the support of local governments to achieve Costa Rica's Nationally Determined Contribution and climate policy goals, not to mention key information on the effectiveness of relevant technologies (waste disposal and recycling, valorization), business models (reuse, remanufacturing, and product-as-service). In 2020, the CTCN expanded its technical assistance on circular economy in Antigua and Barbuda, Costa Rica, Brazil, Chile, Mexico and Uruguay, Ecuador, Dominican Republic, Cuba, El Salvador and Paraguay.

Considering the above two technical assistance examples, RD&D also enables technology providers to specifically demonstrate or deploy "innovative, but overlooked climate technology" under the less complicated or exempted regulations through collaboration with local government in developing countries. This means that resiliency of local institutional regulatory framework can be stressed as a unique and innovative feature in employing the RD&D process to build local countries' own endogenous capacities for new green business opportunities and sustainable development. This signifies that without proper regulations and standards, the RD&D process becomes frequently useless even though the technology and market are sufficiently innovative and matured.

In summary, it is valuable to note that technology innovation happens within the case of innovative technology demonstration to the actual field, mostly coworking with academia/research institutions. And innovation in market corresponds to the case of establishing business model for market commercialization with the help of private sectors. Moreover, regulation innovation originates from the government's critical role in making or improvement of regulation for emerging technologies and businesses during RD&D process.

3.2. Analysis of Quick Survey on Innovative Barriers to RD&D

3.2.1. Basic information of Survey Respondents

From the basic information questions to the survey respondents, we found that most of the organizations that have RD&D experiences were private companies (76.9%) and the others were universities and research institutions (23.1%), and more specifically, approximate 60% of the organizations that responded to the survey have only 1-time RD&D experience. According to our previous analysis on the role of the CTCN in the climate technology and

innovation [16], the CTCN has mainly played its role as a "matchmaker for technology prioritization (about 80%)", rather than as a "matchmaker for technology RD&D (less than 15%)", which originates from the low requests on RD&D from the developing countries. This means that RD&D has still limited cases in implementation.

Figure 4 shows the number of RD&D experiences based on project budget size. Here, among the total 26 experiences of RD&D, we found that most of the project budget size was less than 0.3 billion KRW (approx. 230,000 USD) with 15 cases (57.7%), from 0.3 up to 0.5 billion KRW (approx. 400,000 USD) was 3 (11.5%), and more than 0.5 billion KRW was 8 (30.8%). In addition, the dominant financial support was from the Korean government (19 cases, 79.2%), and others were from their own funding (3 cases, 12.5%), international organizations (1, 4.2%), private companies (1, 4.2%), and other blended cases (2, 8.3%), (Figure 5). This indicates that most of the RD&D projects are still funded in small scale mostly by the public sector, which signifies the necessity of a market-oriented strategy innovation considering the different roles and interests of the private sectors.

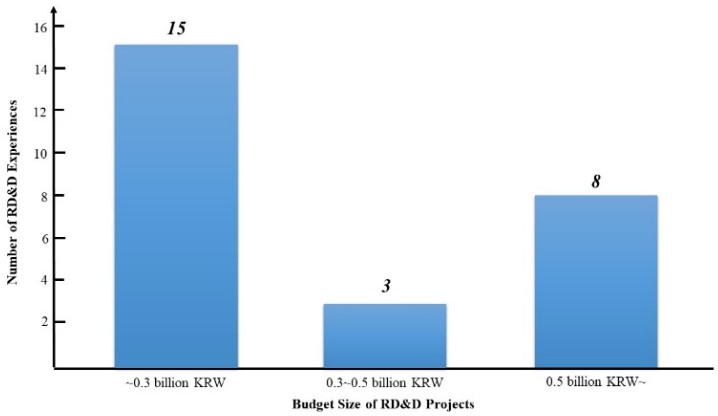

Figure 4. Number of experiences based on project budget size.

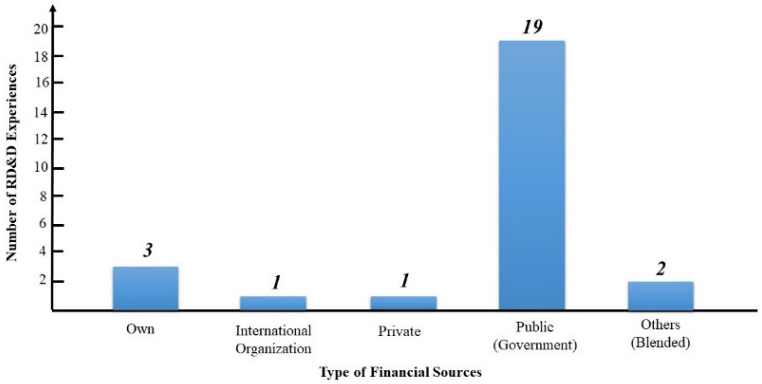

Figure 5. Number of experiences based on type of financial support.

Furthermore, as depicted in Figure 6, more than half of the RD&D projects are related to renewable energy (15 cases, 57.7%), followed by energy efficiency (4, 15.4%), greenhouse gas (GHG) reduction (2, 7.7%), adaptation technologies (2, 7.7%), and other technologies (3, 11.5%). This can be understood that RD&D projects mostly focused on technologies with active market share, not yet highlighted for "innovative, but overlooked" technologies enabling future markets. Therefore, though the basic information survey to respondents, we discovered that the RD&D is still not so prevalent in numbers of implementation due to lack of budget, funding source, innovative technology etc., which desperately requires the enabling environment by overcoming current limitation or challenges from technology, finance, market, policy, regulations, etc.

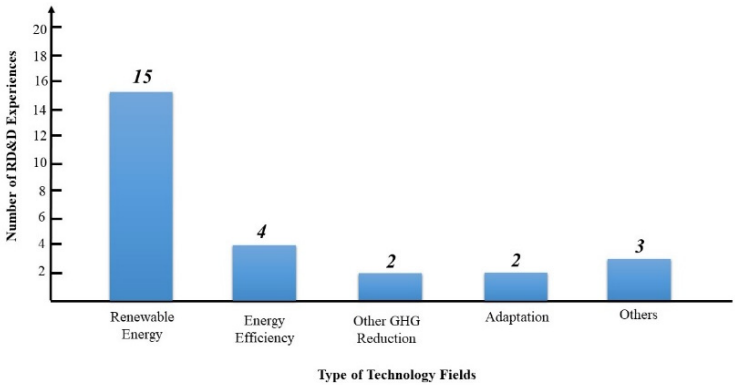

Figure 6. Number of RD&D projects experienced by technology field.

3.2.2. Major Barriers to RD&D in View of Innovation

Through the major barrier questions to respondents during survey, we identified various barriers to participating in the previous RD&D projects, and then categorized them into three phases of preparation, implementation, and completion. As the preparation barriers, there are (1) disadvantageous infrastructure in developing countries; (2) lack of information such as environment, collaborative local partners, and technology needs; and (3) disadvantageous market conditions. There are other new challenges such as (1) lack of technical capacity including technology level and human resources, (2) uncooperative government and (3) different regulation issues appear in the following implementation phase. Finally, at completion phase, the major barriers were related to (1) lack of further linkages such as financial and human resource supports, (2) uncertainty of future regulations and market condition, and (3) lack of regulations to secure intellectual rights.

Considering the RD&D processes from the perspective of three innovation elements, finally, we can extend the major barriers to RD&D phases identified from the Republic of Korea to the countries presented in the case studies. This means empirically identified RD&D barriers are well correlated with each challenge for RD&D innovation in technology, market, and regulation: (1) preparation barriers become 'resource barriers' from technology immaturity; (2) implementation barriers are converted to 'commercialization barriers' from lack of market information; and (3) completion barriers are developed to 'sustainability barriers' from rigid regulation. This is summarized in Table 3.

Table 3. Key barriers for RD&D in terms of innovation element.

Phase Barriers	Innovation Barriers
Disadvantageous infrastructure in developing countries (e.g., poor power system)	Resource barriers from technology immaturity
Lack of information on environment, collaborative local partners, technology needs	
Lack of capacity in developing countries (e.g., human resource, technology level)	
Disadvantageous market environment	Commercialization barriers from lack of market information
Lack of subsequent linkages like sustainable financing, human resource	
Uncertainty of future market condition	
Different regulation issues	Sustainability barriers from rigid regulation
Uncooperative central/local government	
Uncertainty of future regulation change	
Difficulty in resolving Intellectual Rights between countries	

3.3. New Strategy for Facilitating Innovative RD&D

In order to employ innovation as one of focused areas under the Technology Framework for Paris Agreement in tackling global climate issues [22], we propose a new strategy to facilitate innovative RD&D by considering the active interactions between the CTCN as innovative matchmaker and Triple Helix during technology transferring from technology providers and local users in developing countries. These strategies are based on so-called '3C' interactions for three innovation elements: categorization (for technology innovation), customization (for market innovation), and collaboration (for regulation innovation).

3.3.1. Categorization Strategy for Technology Innovation: Overcoming Resource Barriers

In order to overcome resource barriers to implementation of innovative RD&D, identification, evaluation, and prioritization of existing technology should be conducted with the close cooperation of technology experts. This technology needs information from various developing countries, and it has been explored and constantly evolved through technology needs assessment (TNA) process based on technology users' circumstance since 2001 [23].

Moreover, categorization of the technology expertise of the providers is a prerequisite for the outsourcing of the promising candidate technologies in initiating RD&D, especially through innovative interaction between the CTCN and technology experts such as the current 730 Network members and 14 Consortium partners (As of June 2022). In other words, it is necessary to identify highest priority sectors, and to prioritize candidate technologies either "scalable" by adjustment to local country's context or "reproduceable" by replication from one country to another with similar conditions within these sectors. In terms of the readiness level of innovative technologies (TRL) [24], this technology categorization strategy for the RD&D may focus on the demonstration of technologies with tested climate change mitigation and adaptation potential but not yet operational technologies, ranging from TRL 4 (early prototype, proven in laboratory environmental conditions) to TRL 8 (first of a kind commercial, commercial demonstration) as described in Figure 7. (Technology readiness levels (TRL) scale, as originally developed by NASA and eventually modified by the International Energy Agency (IEA), is a common framework applied to assess maturity of technologies. It is a scale ranging from 1 (initial idea, basic principles defined) to 11 (mature technology, proof of stability reach). See Energy technology perspective 2020 by the IEA available at https://bit.ly/38MGeSR (accessed on 20 April 2022).

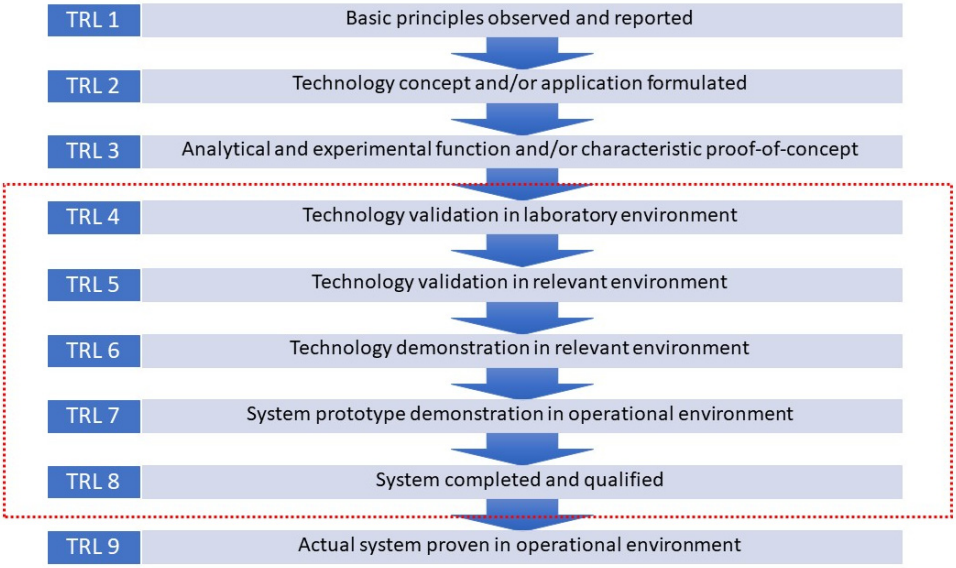

Figure 7. TRL categorization for RD&D [24].

As the source of new knowledge and technologies that underpin innovation, the CTCN technology experts play a central role in RD&D for climate technology as well as

in widely disseminating the RD&D results by transforming highly technical information from universities and research laboratories into real formats that are understandable and regionally relevant. Thus, we can state that the CTCN should make proactive engagement of academic/research institution Network members in prioritizing and recommending their technologies "worth to be RD&D" and "ready to be RD&D", considering this technology categorization strategy scaled from 4 to 8 in TRL framework.

3.3.2. Customization Strategy for Market Innovation: Overcoming Commercialization Barriers

Overcoming commercialization barriers to innovative RD&D means that technology should be matured enough to build a possible business model for new market creation in various climate applications. For this purpose, technology should be customized to various local contexts via the matchmaker's critical effort to engage more local private sectors in the early stage during the RD&D process.

According to our previous publication, which dealt with the PPP strategies in various stages of the technology cycle [21], typically, private sectors usually tend to get involved in the demonstration, incubation, commercialization, and diffusion phases, which are too late for a proper incorporation of local customers' needs for new market creation. Engaging the private sectors in customizing RD&D initiatives can bring a beneficial access to timely commercialization of innovative technologies through (1) identification of new applications and markets for climate technologies; (2) use of additional investments to advance the commercialization of climate technologies; (3) reduction of financial risks that research and innovation entail for the private sector; (4) opportunities for capacity-building inside the local recipients; and (5) enhanced competitiveness, technological competence, and innovation capability.

To implement this customization strategy, the CTCN has been running a special incubation programme for local private sectors, called SME technology clinic [16]. This programme intends to assist local industrial SMEs in overcoming commercialization barriers by (1) introducing innovative climate technologies and global climate technology providers, (2) developing financial linkages, and (3) building the local endogenous capacities. Therefore, this is a good opportunity for the dormant local private SMEs to participate in market-oriented RD&D programs as local information providers [21].

3.3.3. Collaboration Strategy for Regulation Innovation: Overcoming Sustainability Barriers

In order to create a supportive environment to encourage climate technology innovation, policy makers, from local or national government, are essential in bridging gaps that hinder the long-term sustainability of international RD&D initiatives for climate change and their successful delivery, by incentivizing policies for supporting RD&D; these incentives include: (1) facilitation of a high-level political buy-in, (2) assurance of proper governance and management processes that are inclusive and enable equal participation to the international RD&D initiative, and (3) assistance of local private sector involvement to translate RD&D results into market deployment. For example, Colorado extends tax credits to investors targeting frontier technology demonstration a range of advanced industries, including clean energy [25].

Moreover, in certain conditions, the regulations become a major barrier for innovative technologies both to be demonstrated and to be incubated. Therefore, the technology implementors may try to pilot test/demonstrate/scale-up their technologies under more flexible (or free) regulations, through close collaboration with policy makers of technology recipient countries or regions. In July 2020, the Ministry of SMEs and Startups in the Republic of Korea announced the third designation of seven regulation-free special zones across the country. This is mainly determined to create a flexible business environment in the face of the fourth industrial revolution wave. Regulation-free special zones are areas designated to allow private companies to carry out innovative technology RD&D and to start related business freely without restrictions from regulations. Moreover, innovative

private companies will be fostered through support incentives such as R&D funding and tax breaks. Seven regulation-free special zones designated are depicted in the Figure 8.

Figure 8. New seven regulation-free zone in ROK as of July 2020.

This is proactive collaboration strategy to boost RD&D, which can provide a supportive and stable environment through flexible regulations for innovation, consistent with economic development and public policy objective. If the chances to scale up or modification of technology to local flexible regulation are regarded as worthy incentives for the technology providers, then collaboration will be very smooth through the tight partnerships of the CTCN with 730 Network members and 164 governments (As of June 2022).

Figure 9 shows innovative '3C' interactions between climate technology transfer matchmaker, the CTCN, and Triple Helix during RD&D process, which was proposed in this study. First, RD&D innovation can be accelerated during prioritizing or recommending the most appropriate technology categorized by CTCN Network members and Consortium partners from academia/research institutions, in order to overcome the technology resource barriers to RD&D (categorization strategy). Then, the best CTCN RD&D item for incubating new climate business is chosen in customized ways with local private partners like SMEs, venture capitals, and various start-ups, to gather and utilize local resources for new future market creation (customization strategy). Finally, through the collaboration with government policy makers, the CTCN endows regulation-free incentives both for innovative technology providers' implementing RD&D projects and for developing countries' building endogenous capacity pursuing long-term sustainable innovation (collaboration strategy).

Due to the limitation of the previous RD&D research and lack of related data, we could find only a few RD&D cases from the CTCN technical assistances, and survey respondents simply from the Republic of Korea. However, we succeeded in correlating our limited 'empirical' data with 'theoretical' innovation perspective, and in suggesting the innovation strategy for RD&D facilitation by defining individual role of Triple Helix and innovative interaction between the CTCN and them during climate technology transfer. Future research on the effective impact of the 3C strategies suggested in the study on the RD&D facilitation will be elaborated in a future publication by using digitalized in-situ monitoring & evaluation methodology for the real-time Triple Helix review.

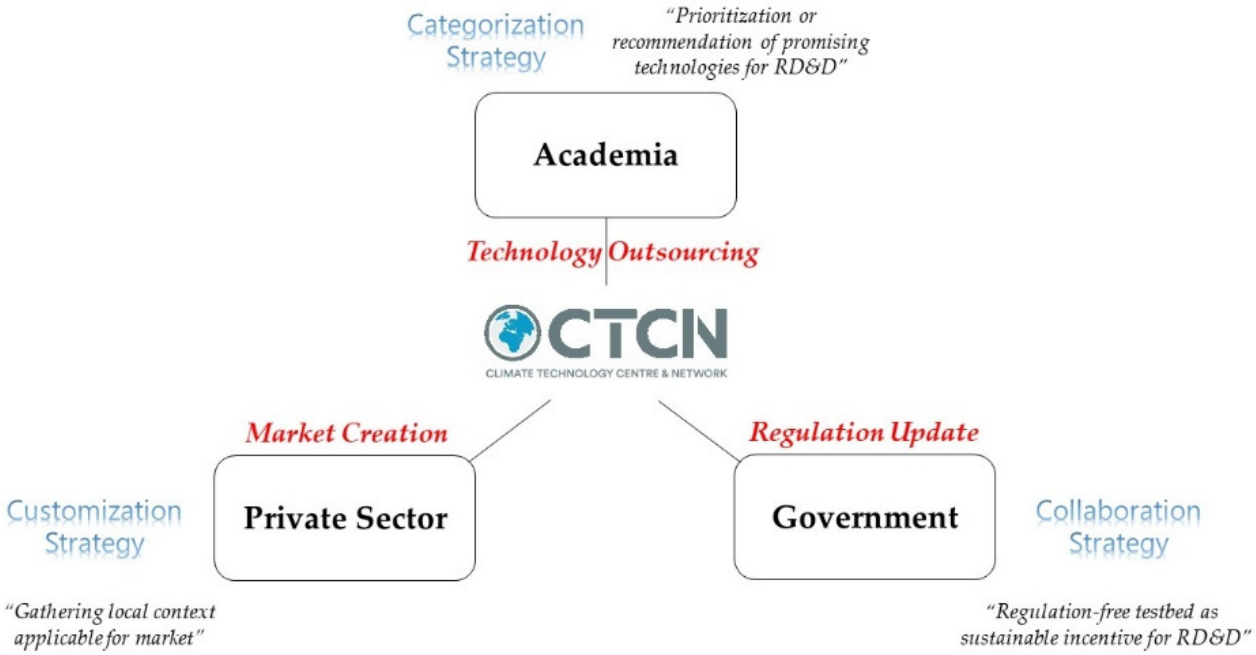

Figure 9. Innovative interactions between matchmaker and other stakeholders during RD&D process.

4. Conclusions

This work first analyzed the previous technology RD&D stages during the United Nations Climate Technology Centre and Network (CTCN) technical assistance activities for transferring climate technology from the perspective of three innovation elements of technology, market, and regulation. This analysis defines each role of active Triple Helix, i.e., academia, local private sectors, and governmental policy makers. Moreover, the RD&D's innovative features were revealed for solving various climate issue requested by developing counties, in that its rapidity and effectiveness by simple scaling up or modifying pre-existing technologies to local contexts, by incubating new business for new market creation, and by providing regulation-free incentives for building sustainable local endogenous capability. Furthermore, based on the survey results for major RD&D stakeholders, we identified three kinds of innovative barriers to RD&D participation as technology resource, market commercialization, and regulation sustainability barriers. Finally, futuristic strategies for facilitating RD&D were suggested based on the innovative '3C' interactions between the CTCN as a matchmaker and Triple Helix for climate technology transfer: technology 'categorization' with networking academia, 'customization' to local market with private sectors, and 'collaboration' with local governments enabling the regulation incentive.

Author Contributions: Conceptualization, W.-J.L.; methodology, W.-J.L.; writing-original draft preparation, W.-J.L.; supervision, R.M. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the secondment program in Ministry of Science and ICT (MSIT) and Ministry of Personnel Management (MPM), Republic of Korea.

Institutional Review Board Statement: Ethical review and approval were waived for this study due to the Informed Consent Statement.

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

Data Availability Statement: Not applicable.

Acknowledgments: Author expressed special thanks to S.E. Bae and Jae's for their helpful comments on earlier drafts of this article.

Conflicts of Interest: The authors declare no conflict of interest.

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