Environmental Science and Pollution Research (2023) 30:33124–33132
https://doi.org/10.1007/s11356-022-24405-7

RESEARCH ARTICLE

Ecological risks and innovative-investment projects

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Received: 9 August 2022 / Accepted: 22 November 2022 / Published online: 7 December 2022

Abstract

Market competition is becoming fiercer all around the world and countries pay considerable attention to their innovative-investment environment. Rapid global economic development and infinite resource extraction have damaged the environment and the harmful environmental effect has become increasingly significant. Thus, technological innovation occupies an important place in the discussion of developmental issues. Previous studies on innovative projects were focused largely on how technological innovations allow us to prevent financial risks and enter the market. However, it is necessary to pay attention to environmental risks arising from successful technological innovations. Thus, this study focused on the nexus between ecological risks and innovative investment. Specifically, the study considers the environmental risks of innovation. The findings reveal that investment in innovations and environmental protection measures can be carried out simultaneously for both ecological and economic targets. To control and prevent environmental risks of technological innovations, there should be a shift from industrial technological innovations to environmental technological innovations to achieve the unity of economic benefits and environmental interests. Such an approach preserves social and public interests and ensures sustainable development.

Keywords Innovative investment · Environment protection · Environmental risks · Carbon-reduction

Introduction

Over the years, rapid economic development has led to the deterioration of the environment and ecosystem, which has drawn the attention of the whole humankind and all the stakeholders (Li et al. 2022; Sarkodie 2022; Sarkodie et al. 2020). In recent years, environmental protection requirements have become increasingly insistent, and the reduction of carbon emissions and the use of clean energy have become questions of crucial importance (Bilgili et al. 2022; Farooq et al. 2022; Usman 2022). In this regard, it is submitted that technological innovation in the areas of energy sources enhances environmental sustainability and energy sources without the deployment of environmental technologies promotes (Alola and Onifade 2022; Onifade and Alola 2022; Onifade et al. 2022). Also, ICT minimizes the negative effect of carbon emissions on the environment (Gyamfi et al. 2022).

The world economy has moved from rapid growth to quality development which is reflected in the campaign of United Nations Sustainable Development Goals (UNSDGs-12, 13). Economic growth is becoming indistinguishable from scientific and technological development, and technological innovation investments are becoming a driving force of rapid economic growth and continued social progress. Although traditional technological innovations have contributed to economic growth, they damage the environment, which is evidence of green development failure in general. Rapid economic growth was provided by the reckless use of the environment. At present, quality economic growth urgently requires destroying an old innovative-investment

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model, implementing advanced concepts of green economy and directing technological innovations to resource conservation and ecologization (Nchofoung and Asongu 2022; Shobande and Asongu 2022).

However, due to the rapid development of production, the problem of environmental pollution has become increasingly serious and required an urgent solution (Huang et al. 2022; Bilgili et al. 2022). In 1962, Rachel Carlson described the issues of modern ecology in her book "Silent spring". In 2005, Kemp defined innovations in the field of green technologies as the use of new or improved technologies, products, processing methods, and systems of preventing and reducing environmental risks in the innovation process (Kemp et al. 2019). In 2007, Kemp and Pearson redefined "green technological innovations" explaining that in processes of production, processing techniques, services, and management, green innovations can reduce environmental pollution, resource, and energy use. Environmental innovations denote the lowering of environmental risks in the innovative-investment process. Furthermore, many countries have enacted legislation for environmental protection, environmental safety, and carbon emissions. This legislation makes enterprises include environmental risks in the system of prevention and control risks during innovations to prevent violations of ecological and environmental legislation. Ecological legislation in Russia started developing quite recently — after the adoption of the Constitution in 1993. Several laws governing nature protection have been adopted. For example, Federal law #7 – FZ on environmental protection of 10.01.2002, #96 – FZ on the protection of the atmospheric air, about 30 environmental laws in total. Ecological problems have begun to take an important place in innovative activity. Thus, this study provides an expository analysis of the nexus between innovative investment and ecological risk.

Literature review

The connection between technological innovations and the environment has raised concerns among stakeholders for environmental sustainability (Grima et al. 2020; Khan et al. 2020). There is an intrinsic link between the potential of regional technological innovations and the environment. Economic growth and technologies have not considered environmental damage. However, in recent years, frequent natural disasters, excessive carbon emissions, rising sea levels, and other ecological problems influenced human activity. Carbon peak and carbon neutrality have become initial topics of economic growth and environmental protection which became significantly intensive. Innovations of green technologies are actively promoted and investments in research and development of environmental energy technologies have become a priority for investors (Ollo-López and Aramendía-Muneta 2012; Katircioglu et al. 2018; Fahimi et al. 2021; Olasehinde-Williams et al. 2022).

For clarity, it is worth to highlight the main types of ecological risk. Ecological risk is the likelihood of adverse effects on the environment arising from human activity. Through innovations in the field of green technologies, the bad effects of excessive resource use and environmental pollution can be reduced; production efficiency can be improved via energy saving. Technological innovation induces ecological conservation, reduces carbon emissions, and ensures sustainable economic development (Alola et al. 2021; Usman et al. 2021a, b; Ullah et al. 2021). For instance, previous studies have submitted that this could contribute to effective regional economic development and an integrated approach to the problems of economic development, social progress, and environment protection (Shahbaz et al., 2018; Balsalobre-Lorente et al. 2019; Aldieri et al. 2021). The notion of innovation — "use of existing resources in new ways" — was introduced by Schumpeter in 1921 (Hagedoorn 1996; Moors et al. 2005; Shi et al. 2021). Innovations include new products, a new organization of production, new technologies, and new market outlets. In 1960, Rostow offered a model which postulates 5 main stages of economic growth of varying durations. In 1971, he added the sixth stage — the search for life quality. It alters the notion of "innovation" to "technological innovation" (Diyar et al. 2014; Rostow 1960, 1971).

At an early stage of investment-innovative engineering, risk assessment of a project is compulsory; the likelihood of completion and possible losses are calculated; and in doing so, it is necessary to assess the effects of the project on the environment. When assessing environmental risks, a questionnaire of experts is conducted, the questionnaires are processed by relevant mathematical methods, and then methods of making decisions under risk and uncertainty are applied. As a result, the degree of negative impact on the environment, which can arise in the implementation of this project, is identified. Exceeding the predicted outcome over regulatory one will demand changes in the project. When assessing ecological risks, it is necessary to consider the following aspects: the number of inevitable losses in nature; the number of minimal losses in nature; the possibility of ecological restoration; the absence of health harm; the proportion of economical effects; and ecological harm.

In investment-innovative project development, environmental risks do not contribute to economical profits; moreover, consideration of ecological risks and measures for neutralizing them reduce profit, but they are very important to human life.

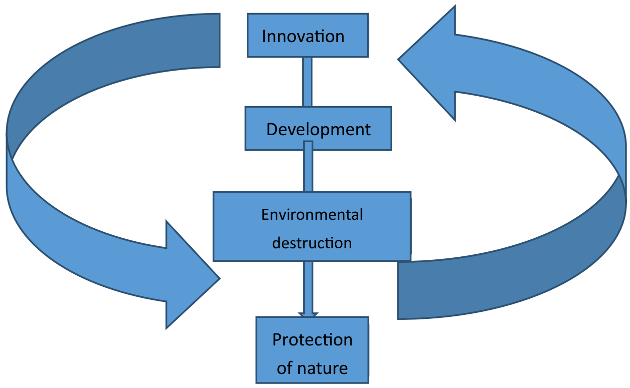

Fig. 1 Ignoring environmental risks in the design

Strategies to enhance environmental security

General concepts

The readiness of high-tech enterprises to manage risks in an ecosystem in the innovation process is stimulated and controlled by the government. Investment into environmental risks management, risk assessment, and human, materialistic, financial, and other resources used for risk management are important indicators that reflect corporate social responsibility.

At present, due to the rapid economic growth, the majority of investment projects ignore environmental risks. Firstly, the environment is polluted and later they take measures of environmental cleaning (Fig. 1). Due to the gradual improvement of legislation and raising environmental protection awareness, ecological risks have been taken under control.

The influence of ecological risks on an innovative-investment activity is mainly divided into 2 aspects: subjective and objective. The subjective aspect affects the environment where a person lives, so this aspect causes a sense of guilt, loss of confidence, and aspiration to innovative activity. The objective aspect is limited by different laws and legal acts in the country or the world. The legislation makes innovative activity bankrupt, causing it to spend a lot of resources to change the investment plan. These measures result in excessive budget overruns, team disbanding, and other negative consequences.

Environmental risk management must be carried out during the whole innovative-investment process. Risk assessment and analysis take place in the pre-project stage. A so-called preliminary analysis is the identification of risk factors, such as water, gas, biology, and technologies, which are closely connected with human survival and development and heavily influence human life and production activities. The identified factors allow us to assess the environmental risks of the project. Based on the results of the analysis, they choose a variant of an innovative-investment project aimed at environmental risk minimization. In the next stage, intraproductive supervision is carried out when risk factors are monitored to keep them in the controllable range. If some parameters go out of the range, the relevant managerial decisions on project plan correction are made to provide compliance of the results to the standards. The final stage aims to compare actual results and expected outcomes on the completion of the project. If they are below expectations, emergency plans are implemented which requires additional investment. Environmental risk management does not contradict innovative investment activity. At present, governments of many countries actively promote the use of clean energy and innovations in the field of green technologies. The majority of environmental risk management costs are fully compensated by government subsidies.

Mathematical model of environmental risk and social importance assessment

An environmental risk assessment must identify the probability of the most adverse event, such as disasters or emissions of harmful pollutants, diseases, or loss of human life, and also it must include the assessment of the negative effects of such events.

It is worth noting that the expected number of diseases represents a relative assessment of the likelihood of the specified negative effects on human life and health, which is connected with the certain level of toxic substance concentration that depends on time and space. The first step of environmental risk assessment is to identify it.

For environmental risk identification, the following input data is used:

(1) flowsheets, the equipment used, materials;
(2) technology regulations and other documents providing information about technological process characteristics, equipment used, raw materials, and other materials;
(3) laboratory studies and material of trials made within production monitoring the compliance of sanitary conditions and ecological control;
(4) measurement protocols of dangerous and harmful factors, difficulty and intensity of work process;
(5) epidemiological data assessment made by a state sanitary and epidemiological service;
(6) data on industrial safety inspections, occupational safety, and environmental protection including inspections made by state supervisory authorities;

Table 1 Expert assessments

Risk identification Versions of the draft	(1)	(2)	(3)	(4)	(5)	(6)	(7)	The weighted sum of assessments
Version of draft 1	a_{1j}^1	a_{1j}^2	a_{1j}^3	a_{1j}^4	a_{1j}^5	a_{1j}^6	a_{1j}^7	$\widetilde{A}_{1j} = \sum_{k=1}^{7} \lambda_k a_{1j}^k$
Version of draft 2	a_{2j}^1	a_{2j}^2	a_{2j}^3	a_{2j}^4	a_{2j}^5	a_{2j}^6	a_{2j}^7	$\widetilde{A}_{2j} = \sum_{k=1}^{7} \lambda_k a_{2j}^k$
…								
Version of draft N	a_{Nj}^1	a_{Nj}^2	a_{Nj}^3	a_{Nj}^4	a_{Nj}^5	a_{Nj}^6	a_{Nj}^7	$\widetilde{A}_{Nj} = \sum_{k=1}^{7} \lambda_k a_{Nj}^k$

(7) data on investigations of disasters, incidents, accidents, and occupational diseases.

The environmental risk assessment is offered to be made with multidimensional methods of expert assessment (Table 1). In the first stage, every expert j identifies the environmental risks of every variant of the project ($i=1,\ldots, N$) and completes the following table on a scale from 1 to 10.where a_{ij}^k is an assessment of the draft version I made by the expert j on k ($k=1,\ldots,7$) input data written above. The number a_{ij}^k=1 characterizes minimal risk, a_{ij}^k=10 – maximal. $\widetilde{A}_{ij}$ is a weighted sum of environmental risk assessments of the draft version i made by expert j. λ_k are weightings characterizing the importance level of input data given above for environmental risk identification?

Let us carry out the received assessment normalization:

$$A_{ij} = \frac{\widetilde{A}_{ij} \cdot N}{\max\limits_{i,j} \widetilde{A}_{ij}} \tag{1}$$

In the second stage, we calculate the dimension of agreement of the project assessment results by every pair of experts using the modified Spearman's rank correlation coefficient. Modification lies in the fact that as drafts rank we take their normalized weighted sums of environmental risk assessments calculated by Formula (1). Spearman's correlation coefficient R is defined by the following formula:

$$R = 1 - \frac{6 \sum\limits_i d_i^2}{N^3 - N}, \tag{2}$$

where N is the number of compared draft versions, and $d_i = (A_{ij_1} - A_{ij_2})$ is the difference between the weighted sums of assessments of the draft version i made by random experts j_1 and j_2.

The maximal amount of dimension of agreement is + 1 (reached when the ranks of both experts coincide), and the minimal amount is – 1 (reached when the experts' opinions are opposite).

Therefore, let us calculate Spearman's correlation coefficients for all the pairs of the experts (the number of pairs is C_N^2).

In the next stage, we calculate the concordance coefficiency defining the agreement of the experts' opinions. To calculate that, we complete Table 2 with the ranks given by N experts for m drafts (objects, phenomenons). In the bottom line of the table, there are sums of ranks made by all the experts for each draft. The average value of ranks on every draft is defined using $\overline{A}_i$.

$$\overline{A}i = \sum_{j=1}^{m} A_{ij} \text{ /m.} \tag{3}$$

We denote the average value of all the rank sums as L.

The sum of the squared deviation can be calculated as follows:

$$S = \sum_{j=1}^{m} \left(\sum_{i=1}^{N} a_{ij} - L \right)^2. \tag{4}$$

For calculating the agreement of expert opinions, it is offered to calculate the concordance coefficiency as follows:

$$W = \frac{12 \cdot S}{N^2 (m^3 - m)}. \tag{5}$$

Table 2 Ranks are given by m experts

Experts	Ranks for draft			
	A1	A2	…	Am
First	a11	a12	…	a1m
Second	a21	a22	…	a2m
…	…	…	…	…
N-й	aN1	aN2	…	aNm
Sums	$\sum_{i=1}^{N} a_{i1}$	$\sum_{i=1}^{N} a_{i2}$	…	$\sum_{i=1}^{N} a_{im}$

Changing W from 1 to 0 points to reduce the agreement of expert opinions.

Thus, the work with the group of experts on environmental risk assessment of drafts is performed as follows. At first, environmental risk assessments of all the draft versions made by all experts are determined. They are normalized. Then Spearman's pair correlation coefficiencies are determined and analyzed, and work to identify and exclude incompetent and corrupt experts from the group is carried out. Further by Formula (5), the concordance coefficiency is calculated, and the organizational work with experts (informing them, filtering them out, and making consequential recalculations) continues until we get a value $W \geq 0.85$, which points to a high opinion consistency. Then $\overline{A}$, determined by Formula (3), will be the generalized environmental risk assessments of drafts.

During the long preparation of a difficult project, environmental risk assessments can be different from year to year, then the procedure described above should be done separately for each year, getting assessments $\overline{A}_i^t$.

Mathematical model of optimization of benefits and losses based on taxation and social and environmental requirements

Given: Nt is a taxation scheme. Financial stages V_t^k are profit from the implementation of the annual stages of the kth project implementation option. These indicators are formed by the project management team. Additionally, the project team together with the regional or sectoral authorities draws up a list of positive and negative characteristics of each project option (for the entire life cycle) and evaluates them.

The list of positive characteristics (a + q, there are 5 in total) includes the following:

i. creating new jobs;
ii. producing attractive, more competitive products;
iii. increasing the budgetary deductions for the production of new products;
iv. ensuring solutions to social issues;
v. improving the quality of transport conditions in the region.

The list of negative characteristics (a–q, there are 3 in total) includes the following:

i. poor enforcement of environmental requirements;
ii. deterioration and pollution of the area;
iii. deterioration of the sanitary and epidemiological situation.

The assessment of the above characteristics is significantly affected by the financial results of the individual phases of the project options. The mathematical model of the task looks as follows: it is compulsory to find such version of project implementation kef, when:

$$n_t V_t^{k \ni \phi} \geq N_t, \tag{6}$$

$$\sum_{q=1}^{5} a_q^{+}(V_t^{k \ni \phi}) - \sum_{q=1}^{3} a_q^{-}(V_t^{k \ni \phi}) \geq \sum_{q=1}^{5} a_q^{+}(V_t^{k}) - \sum_{q=1}^{3} a_q^{-}(V_t^{k}), \forall k \tag{7}$$

Optimization of profits and losses based on taxation and social and environmental requirements, that is the version of project implementation, which in taxation (at an annual rate nt) provides the most impartial assessment of positive and negative aspects, must be chosen.

A multicriterial mathematical model (minimization of environmental risks and maximization of taxes)

Let maximal possible funding levels $Q = \sum_{t=0}^{T} Q^t$ be known on the interval [0, T]. These funds can be used for investing in one of the draft versions i ($i = 1, \ldots, N$), which demands funds V_i^t for period t. Let the profit of the implementation of the project t at the end of period t is $P\,V_i^t$, projection of environmental risk is $\overline{A}_i^t$. It is necessary to choose the version of project implementation which could provide the maximal expected value of taxes for some (close to minimal) value of environmental risk and level of social importance.

The problem of choice of a draft version can be formulated as the following three-criteria integer programming problem with Boolean variables. Find:

$$x_i = \begin{cases} 1, \textit{if choose draft version } i, \\ 0, \textit{ if otherwise}. \end{cases} \tag{8}$$

Subject to the constraints:

$$\sum_{i=1}^{N} V_i^t \cdot x_i \leq Q^t, \forall t \in [0, T]. \tag{9}$$

Respective cost functions:

1) maximization of the expected volume of taxes:

$$F_1 = \sum_{t=1}^{T} \left(\sum_{i=1}^{N} x_i \cdot n_i \cdot NPV_i^t \right) (1 + d)^{-t} \to max; \tag{10}$$

2) minimization of the environmental risk:

Table 3 International cooperation on ecological problems

Year	International negotiations and actions	Content
1992	United Nations Framework Convention on Climate Change	Limit greenhouse emissions in developed countries and offer financial assistance to developing countries
1997	Kyoto Protocol	Setting national targets (for developed countries) for reducing emissions, reforms of China Development, economical development, industrial development, and carbon emissions
2005	Kyoto Protocol enters into force	CDM and other project-based mechanisms, European Union Emission Trading Scheme (EUETS) The initial phase starts
2009	UN Climate Conference in Copenhagen	Position of the developing countries (major issuers) in the negotiations
2010	The Cancun Conference	Developing countries such as India and China must assume responsibility for reducing emissions
2011	The Durban Platform	It was confirmed that the Kyoto Protocol would extend the second commitment period. Concrete measures to reduce and control greenhouse emissions for solving the problem of global climate change
2014	The UN Climate Conference in New York	Intensifying measures to combat climate change
2015	Paris Climate Conference	• Before Paris 119 countries submitted their independent contributions • In the Parisian agreement, it is said that all sides will strengthen a comprehensive understanding of climate change threats

$$F_2 = \sum_{t=1}^{T} \left(\sum_{i=1}^{N} x_i \cdot \overline{A}_i^t \right) (1+d)^{-t} \rightarrow min; \qquad (11)$$

Environmental risk assessment $\overline{A}_i^t$ of draft version i, implemented for period t in investment V_i^t, is formed by an algorithm described in 3.2. Discount rate d is considered the desired minimum rate of return on government investment. It can be applied for the second objective function as equivalence measures of risk assessment, and for the third objective function as equivalence measures of social importance assessment of projects for different periods.

To meet the target, it is offered to use a method of successive assignments which is described in Gelrud and Cuj (2022). The proposed models implement problems of mathematical programming with linear and non-linear constraints and objective functions. At present, there is a wide range of software for solving similar tasks; it is sufficient to indicate a package Solver included in Excel. Examples of environmental risk prevention in innovative investment engineering.

Public authorities carry out ecological management, attaching requirements for project influence (harming the environment by emitting poisonous substances, dumping wastes into the water, solid waste disposal, etc.). Besides, countries all over the world carry out actions as illustrated in Table 3.

Tesla's case of innovative-investment and environmental protection

Tesla creates rockets, new energy vehicles, and self-driving cars. In 2020, Tesla accelerated its growth through capacity expansion, price reduction, and sales growth. The total sales for the year are 449,550 cars, which has been the highest total for Tesla since its establishment. For the first quarter of 2021, the Tesla company's revenue amounted to $10,389, increased at an annual rate of 74%, where automobile business revenue reached $9002 bln, increasing at an annual rate of 75%, net profit made up $438 mln.[1] It should be noted that the most significant part of Tesla's profit is carbon credits. Carbon credit is a general term for any selling certificate or permission providing the right to emit 1 ton of carbon dioxide or an equivalent amount of other greenhouse gas.[2] According to the current legislation in some countries, automakers need carbon credits to get permission for carbon emissions for conventional car manufacturing and they also can purchase carbon credits from electric car manufacturers and sellers.[3]

Apple's case of innovative-investment and environmental protection

The declaration of Apple renouncing earphones and plugs, which are part of the iPhone package, was widely criticized: "It is called environmental protection but it is an expense

[1] Financial reports of Tesla 2021.https://caibaoshuo.com/companies/TSLA/financials(access date: 10.04.2022).

[2] https://en.m.wikipedia.org/wiki/Carbon_credit, (access date: 6.04.2022).

[3] Atomic expert. URL: https://atomicexpert.com/page3178319.html (access date: 6.04.2022).

Fig. 2 Carbon credit income balance

reduction”. However, it will annually reduce carbon emissions by 2 mln tonnes, which is equivalent to the liquidation of 450,000 cars per year. Investment in innovations and environmental protection measures can be carried out simultaneously for both ecological and economic targets.

Alibaba’s case — Internet-based innovative-investment and environmental protection

There is a technological innovation based on the Chinese Internet brand Alibaba, which made a software innovation in August of 2016 which is called “Ant Forest”. It represents a paid software tool called Alipay, which implements environmental protection and low-carbon lifestyle conception. While using the program, it is possible to earn power and later use it for buying trees, and seedlings, watering, and fertilizing them. If there is a shortage of energy for planting a tree on the virtual platform, the company Alibaba will plant a real tree in the desert in the northwest of China on your behalf. If you have time, you can see it yourself, also you can see virtual trees which were planted online. It helps Alipay to increase brand awareness, and user activity, protect the environment, and get carbon credits. Carbon credits are also invested in public welfare events.

In August 2006, the Ant Forest project was officially launched. According to the data of 2021 published by Alipay, 500 mln users of Ant Forest reduced carbon dioxide emissions by 7.92 tons and planted 122 mln of real trees in the desert. The square of the area is equivalent to 1.5 of the square of Singapore which shows the big potential of the project Fig. 2

Conclusion and policy direction

At present, environmental protection is the main priority and every person, every enterprise, and every country are involved in this process. Environmental protection includes ecological awareness rising both in society and on the governmental level. Thus, environmental risk assessment is a key link in the process of innovative investment activity. The findings of this study reveal that investment in innovations and environmental protection measures can be carried out simultaneously for both ecological and economic targets. These findings are in tandem with the submission of recent studies including Alola and Onifade (2022), Onifade and Alola (2022), Gyamfi et al. (2022), and Onifade et al. (2022). Also, ICT minimizes the negative effect of carbon emissions on the environment (Gyamfi et al. 2022) who submitted that technological innovation enhances environmental sustainability. Environmental protection does not contradict economic growth and even can complement economic profit.

It can also make some additional profit which can be even higher than the profit which the innovative project makes itself. Environmental analysis and ecological risk prevention will require coordination of all levels of project management. Therefore, it is necessary to intensify the development of innovative programs on the highest level and constantly increase the level of innovation to make a reliable production system for low-carbon innovation development.

Acknowledgements Author gratitude is extended to the prospective editor(s) and reviewers that will/have spared time to guide toward a successful publication.

The authors of this article also assure that they follow the springer publishing procedures and agree to publish it as any form of access article confirming to subscribe access standards and licensing.

Author contribution The first author Prof. Gelrud Yakov D. was responsible for the conceptual construction of the study's idea. The second author Dr. Jianan Cui handled the literature section, and the third author Dr. Festus Victor Bekun managed the data gathering, and preliminary analysis and was responsible for proofreading and manuscript editing.

Availability of data and materials The data for this present study are sourced from WDI as outlined in the data section.

Code availability All codes for the analysis are available in STATA and E-views statistical software.

Declarations

Ethical approval The authors mentioned in the manuscript have agreed to authorship and read and approved the manuscript and given consent for submission and subsequent publication of the manuscript.

Consent to participate Not applicable.

Consent to publish Applicable.

Competing interests The authors declare no competing interests.

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