Study of the Factors Affecting Adaption of Sustainable Technology Transfer

Preeti Chawla, Neetu Chhillar

Abstract

Adopting sustainable technology transfer practices is crucial for promoting environmental preservation, efficient resource utilization, socioeconomic progress, and resilience to climate change, thus ensuring a more sustainable and equitable future. This study examines the factors influencing the adaptation of sustainable technology transfer practices by identifying key enablers and barriers within sustainability frameworks, assessing the role of policy and regulatory mechanisms in facilitating technology transfer, and evaluating the impact of stakeholder engagement on its successful implementation. Additionally, it investigates the relationship between environmental considerations and technology transfer adaptation while analyzing the effectiveness of monitoring and evaluation frameworks in ensuring long-term sustainability. Data was gathered from industry experts and practitioners using a mixed methods approach. Structural equation modelling (SEM) was employed with 135 respondents to conduct confirmatory factor analysis using AMOS. The results underscore the significance of prioritizing Monitoring and Evaluation, as well as Policy and Regulation efforts to support the adaptation of technology transfer for sustainable initiatives. Conversely, the negative correlation observed between Stakeholder Engagement and technology transfer adaptation suggests the need to carefully balance engagement activities. Although Environmental Considerations exhibits a positive association with technology transfer adaptation, the lack of statistical significance calls for further investigation. The high R-square value affirms the model's strength in explaining variations in technology transfer adaptation, advocating for a strategic resource allocation strategy that emphasizes effective monitoring and evaluation, supportive policy frameworks, and equitable stakeholder engagement. Collaboration is essential to tackle identified challenges and capitalize on opportunities to advance sustainable technology transfer, drive innovation, and foster resilient communities. This study enriches the existing literature on technology transfer sustainability, providing valuable insights for policymakers, practitioners, and scholars striving to address urgent environmental, social, and economic concerns.

Keywords: Technology transfer, sustainability practices, adaptation of technology transfer, policy and regulation, stakeholder engagement, environmental considerations, monitoring and evaluation, sustainable development.

JEL classification: **O33, Q55, Q56, Q58, F18**

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1. INTRODUCTION

Technology transfer is a key process that spurs innovation towards economic growth and enables social development in a rapidly advancing world. Its potential is enormous for addressing some of humankind's greatest problems and sustainable development to the next level. However, safe ways of distributing technology need to exist, and we need to redesign our present activities so that they are more environmentally friendly, useful to the community, and beneficial to the economy (Li et al., 2018). This exposure is a starting point for understanding the effect of technology transfer coupled with environmentally sustainable practices in various industry sectors. It can consider in deep the great varieties of sustainability dimensions related to issues of technology transfer, mechanisms of financial assistance, regulatory frameworks, involvement strategies, environmental concerns, and many different methodologies of monitoring and evaluation, among others (Salvador et al., 2021).

As we progressively come to comprehend the premises of the long-term sustainability of technology transfer, it clearly indicates that the enablers of success that shall take us there are the serendipity of innovative ideas, strong partnership building, and good governance mechanisms. Thus, we can gift the world with green technology sharing to accelerate inroads in saving equity-based development, minimizing damage to ecology, and securing the health and well-being of societies globally. The objective of the research in sustainable practices for technology transfer is to assess how easily or otherwise a set balance could be achieved between the adoption of new technologies and the concurrent consideration of environmental preservation, equitable distribution of benefits, and economic advancement. We reviewed sustainable technology transfer programs in various areas to obtain an overview of their operational mechanisms. Such objectives include determining useful observations, best methods, and recommendations that can be put in place to create a secure and fair future. Join us to this journey that has taken place in the dynamic field of technology transfer sustainability and harness innovation to make the planet a better place for all people (Fitiu, 2017).

Policy and Regulation and Adaption in Technology Transfer Sustainability

Policies and legislation ensure that technology transfer is viable in the long term. This ensures that inventors are not only given the resources, but also the motivation needed to come up with breakthroughs that are beneficial to society and the environment. Rules and guidelines play the role of setting yardsticks for the development, diffusion, and utilization of technologies that are supposed to foster durability and enable sustainable technology transfer (Bozeman, 2000). In technology transfer sustainability, the crux of policy and regulation strikes a balance in ensuring the protection of the public interest according to innovations. IPR regulations create the sole proprietor of their thoughts and ideas, and this will be an essential strategy to promote innovation. However, such regulations, which could be necessary, should be carefully considered so that they do not become obstacles to the spread of technologies with the potential to overcome major social or environmental problems.

Apart from simply intellectual property, policies, and laws on technology transfer, sustainability entails many other factors, such as environmental conservation, public health, and availability of technologies to all members in an equal and fair manner. For example, laws on environmental protection may set standards and requirements for technology transfer activities, and the amount of waste produced is minimal. In addition, emissions were combined and stopped. Actions included adopting the use of renewable energy, emitting, and publicly not littering. Efforts to spread technology through regulations and legislation may also promote and support continuous innovation. The government can incentivize research and advancement in fields such as clean transportation, green energy, and sustainable farming through measures such as tax breaks, subsidies, and financing support. This can be linked to political institutions,

which can set up sustainable technology markets through mandates that require people to adopt eco-friendly practices or by setting targets for the use of renewable energy sources (McCulloch, 1981).

Policies and norms play a role in defining the supply side of technology transfer sustainability and stimulating the demand for sustainable technologies. Public procurement regulations may increase the probability of procurement of products and services that meet certain environmental requirements (Hoekman et al., 2005), which may create market demand for new concepts. Furthermore, consumer protection regulations can put pressure on corporations to disclose their products' social and environmental impacts. This allows for informed decision-making. Nevertheless, it is imperative to remember that laws and regulations involving the sustainability of technology transfer are valid only if they are logical, coherent, and enforceable (Jeffries, 1977). Dysfunctional or inequitable governance structures can support the creation and transmission of environmentally beneficial ideas and technologies. The design of these rules clearly falls to policymakers; they need to work responsibly in designing the rules that do, as it were, score and promote the playing of technology while protecting the public and encouraging healthy competition.

Stakeholder Engagement and Adaption in Technology Transfer

Stakeholder involvement is important in sustainable technology transfer because it provides for collaboration, inclusivity, and collective decision-making between persons, organizations, and communities involved in the transfer process (Aerts et al., 2022). In relation to the long-term technology transfer process, these stakeholders are represented by entrepreneurs, government agencies, learning institutions, NGOs, community-based groups, and end users of the technology. The participation of effective stakeholders is the process of considering and practicing all desires, views, and requirements set forth by parties involved in a given technology transfer (Salvador et al., 2021). This makes the sustainable technology solution more efficient, acceptable, and influential (Lee & Mwebaza., 2022). One benefit of engaging stakeholders in sustainable technology transfer is that it provides shared responsibility for the results of the technological transfer initiatives. In this regard, decision making can utilize the collective experience and wisdom, ideas, and resources of all stakeholders participating in technology transfer programs so that they are tailored to better suit their specific requirements and circumstances. This approach of participation would greatly increase the effectiveness and utility of the transfer while setting a base for trust, transparency, and therefore social cohesion among stakeholders—something that may help in further collaboration and building relations in the future.

The involvement of stakeholders also contributes to an enabling environment in which creativity can be expressed through the generation of new ideas and sharing of information. This enhances the development of the best strategies, experience, and creativity, leading to innovative solutions. Through communication and consultation, stakeholders can share their experiences, expertise, and resources in collaborative activities. This will enhance the access, spread, and speed of adoption of sustainable technology. An academic institution may enhance technology transfer by disseminating scientific knowledge and the results of research. Alternatively, it would be valuable to obtain information from business partners about the challenges and potential of using technology in real situations. Stakeholder participation is important in ensuring that technology transfer activities are both equitable and inclusive, especially for disadvantaged or vulnerable groups. During technology transfer, decision makers at all levels can ensure an equal share of benefits arising from technology and lead towards inclusiveness by engaging broadly diverse stakeholders, including women, indigenous peoples, and other marginalized groups, at decision-making levels to ensure that their views are known and respected. Whenever stakeholders are committed to engaging, this not only enhances the

credibility of technology transfer programs but also contributes to broadening their objectives in terms of human rights and social justice.

For stakeholders to be genuinely involved in the process of sustainable technology transfer, strategizing, communication, and problem solving should be done in a very stringent manner, considering factors such as imbalanced power relations, conflicting interests, and cultural disparities. In this case, decision-makers need inclusive methodologies, such as foreground dialogue, consensus building, and mutual regard. This will provide an enabling environment for collaboratively and constructively engaging in active engagement. Stakeholders must be provided with the appropriate resources, competence, and authority to enable them to make informed choices, which would greatly help in technology transfer. This ensures that their thoughts and concerns have been assessed and integrated into the decision-making process (Vander Gaast et al., 2009).

Environmental Considerations and Adaption in Technology Transfer Sustainability

The wide diffusion and sustainability of technologies are, therefore, of paramount importance to environmental considerations, making the transfer and acceptance of new technologies a means of protecting, preserving, and enhancing the environment. In the modern world, with the rapid change in climatic conditions, it is essential to consider environmental considerations as far as the transfer of technology is concerned. This will not only help protect the climate and limit emissions but also accelerate the shift to an economy that is low-carbon and resource-efficient. The main pressing issue concerning the environment and sustainability of technology transfer is, therefore, the quantification and minimization of the ecological impact of new technologies. In that respect, LCA and EIA are the tools to analyze prospects of environmental impacts due to technology transfer activities, from cradle to grave. Proceeding seizure of all processes of technology transfer, potential risks to the environment could be identified and addressed earlier by policymakers to avoid negative environmental impacts and to put more emphasis on positive ones.

In addition, technology transfer will be sustainable if it involves or promotes environmentally friendly technologies or reflects the efficient usage of resources. For instance, some examples of sustainable technologies can help reduce GHGs, conserve natural resources, and provide better environmental conditions, including green construction materials, renewable energy systems, and energy-efficient goods (Ferandes et al., 2021). This approach will also address critical environmental issues such as species extinction, climate change, and air and water pollution. Environmental concerns regarding technology transfer sustainability extend beyond the immediate impact of technology on the environment. They range from larger issues of environmental governance, regulatory frameworks, and policy incentives (Pandey et al., 2022). When making decisions, people must consider the broader context encountered during technology diffusion. This should also include the present market conditions, regulatory requirements, and factors that society applies to environmental care. Executives should ensure that the transfer of technology falls within the scope of existing environmental legislation and regulations. This approach not only ensures that the law is complied with, but also verifies the inculcation of attitude towards environmental stewardship and conservation.

The sustainability dimension of technology transfer goes beyond mere reduction of harmful environmental impacts. They also generate positive environmental benefits by applying nature-based solutions, restoring ecosystems, and conserving species. Making environmental considerations an integral part of the process of technology transfer has the potential to help decision-makers harness the power of fast-paced technologies to solve some of the most serious environmental problems and ensure concrete benefits for People and the Planet. This holistic notion of sustainable technology transfer holds that environmental, social, and economic

systems are interrelated. The aim is to identify the synergies among various objectives as opposed to pushing different conflicting agendas (Vander Gaast et al., 2009). If technological sharing or transfer were to be viable and not negatively affect the environment, it would call for leaders to take a leading role and collaborate well in coming up with innovative solutions in many industries and organizations. A good policy by leaders in protecting the environment, treating everyone in a fair manner, and ensuring economic prosperity must be followed (Salvander et al., 2021). In addition, alliances and collaborations between enterprises, local communities, NGOs, and governmental bodies must be generated. Any possible environmental consideration in such diffusion of technology can open up wide avenues for innovation, environmentally related economic growth, and sustainable development. This will further ensure the healthy functioning and cohesiveness of the planet for future generations (Schnerder et al., 2008).

Monitoring and Evaluation (ME) and Adaption of Technology Transfer

Monitoring and evaluation of the sustainable technology transfer program are key to establishing the effectiveness, efficiency, and impact of the activities, but also in making decisions towards attaining sustainability goals and objectives. Through monitoring and evaluation, a setting obtains valuable insights into progress, outcomes, and knowledge acquisition from the activities involved in technology diffusion. It aids in determining what needs adjustment, problems encountered, and where things work well. One of the most important traditions within monitoring and evaluation in the context of sustainable technology transfer is the development of exact and measurable indicators of progress towards the attainment of sustainability goals. Some indicators include the reduction of greenhouse gas emissions, savings in energy costs, jobs created, improved health, and the well-being of the community. By setting clear indicators at the very beginning, the effectiveness of the technology transfer process is easily trackable for policymakers, and they can easily judge whether the processes serve broader environmental objectives (Van Drooge & Spaapen, 2022).

ME will help the stakeholders ascertain the relevance, efficiency, and effectiveness of the long-term technology transfer initiative in achieving what it was set out to do. By collecting and analyzing data on inputs, activities, outputs, and outcomes, decision-makers will have a chance to find bright spots and not-so-bright spots. Accordingly, they have a chance to adjust their plans and strategies to suit such new information. ME provides us with empirically derived knowledge of the factors that contribute to the success or failure of such technology transfer initiatives. Indeed, this information helps us make informed judgments and determine how to use resources in subsequent endeavors. In effect, the monitoring and assessment of long-term technology transfer projects create an environment in which knowledge sharing and learning from all participants is enhanced to create a culture of continuous improvement and innovation. Such lessons, good practices, and success stories should be documented and shared in a consistent manner with the aim of enhancing institutional memory and capacity, encouraging collaboration, and applying effective techniques to other situations (Gandenberger et al., 2016). In addition, monitoring and evaluation provide opportunities for reflective dialogue, exchange of feedback, and collaboration with stakeholders that offer effective and long-term solutions, thereby enhancing the effectiveness and sustainability of technology transfer projects.

Thus, ME s play a key role in increasing accountability, transparency, and civic engagement, but they also assess the impact of activities related to technology transfer over time. In this respect, decision-makers can nurture trust and confidence among project stakeholders, demonstrate accountability to funders and taxpayers, and engage the participation of impacted groups in periodic progress and performance updates. The inclusion of monitoring and evaluation methodologies that are accessed by all guarantees the success of technology transfer projects because it makes the project of utility and significance using stakeholder objectives

and concerns. However, to make the ME of sustainable technology transfer initiatives effective, they must be carefully designed, well-financed, and coordinated to solve problems relating to data accuracy, accessibility, and reliability (Besharati & Rios, 2017). In this regard, monitoring and evaluation can only be comprehensive, dependable, and productive if sufficient commitment of resources is made by the decision makers in establishing sound data collection methodologies while backing them with their supportive capacity-building processes for people and technical assistance for institutions. This needs to go together with inclusive, accessible, and culturally responsive approaches to ME. Moreover, in the protection of the rights and interests of stakeholders, it is not easy to forget different goals and perspectives (Feng & Li, 2014).

While studying the sustainable adaptation of technology transfer, some major facets have emerged that essentially contribute to its effectiveness and long-term significance. Above all, policy and regulation act as important frameworks against which this landscape must be balanced: promotion of innovation versus protection of public interests. Thoughtful consideration of this is needed to ensure that regulatory environments do not hinder but foster the widespread use of sustainable technologies. Moreover, the anchorage of stakeholder involvement in inclusive decision-making and accountability has proven to be an anchor. Initiating transfer processes that involve different categories of stakeholders makes it widely accepted and effective, thereby opening the pathway to more far-reaching effects. Environmental concerns currently stand at the forefront in guiding technological choices and adoptions that have minimal effects on the ecosystem and provide unsubstituted offers to a sustainable future. Finally, monitoring and evaluation have become essential for assessing the impact of technology transfer programs. Continuous improvement and informed decision-making lie in robust monitoring and evaluation practices that enable stakeholders to learn from experience and hence adapt or fine-tune strategies over time. The research is aimed at grounding the systematic identification and analysis of literature-documented factors influencing technology transfer adaptation on an empirical investigation of their effects through comprehensive statistical analysis. This research sought to provide insights that help stakeholders balance their acts in this complex landscape of technology transfer with environmental stewardship and social equity in view of a better tomorrow.

2. LITERATURE REVIEW

Technology transfer holds immense potential for facilitating the uptake of environmentally friendly technologies across the world and is thus necessary if both developed and developing countries are to find their way out of unsustained methods of operation. We analyze a set of issues and opportunities surrounding TT in the new climatic regime, looking more specifically into how the processes of innovation, obstacles that exist in these processes of innovation, and ways in which the diffusion of technology materializes. Furthermore, we present the best practices and analyze the most efficient ways of using renewable energy in both developed and developing countries. This aims to speed up the transition to more eco-friendly and sustainable activities (Karakosta et al., 2014).

Research zeros in one major way to diffuse information, discoveries, and develop into society at large: TT. TT is a multifaceted process embracing key carriers and elements; this is the aspect of nature that holds a key to its complexity in execution. Feasibility studies have become an important tool in looking at the potential for the transfer of technology, possibilities for economic viability, and keeping the window for new ideas open. The dynamic character of TT has kept up with technological changes, offering numerous models and catering to different views. On an international scale, there are differences in the degree of technology transfer and innovation environments across states. Hence, this study attempts to fill this gap by minutely analyzing the TT infrastructure about global TT, technology diffusion, collaborative networks,

and TT regimes. In addition, it evaluates the situation of the status quo of the implementation of TT technology in Romania, indicating the need for improvement and streamlining according to domestic and international laws and the objectives of sustainable development (Craiut et al., 2022).

It examines the evolving linkage between the university, industry, and government sectors in the context of technology transfer, specifically, the role of digital technologies in creating innovation and sustainability. This study attempts to fill this gap by using a co-evolutionary approach to study the dynamics of technology transfer processes within institutions. The current study seeks to investigate more deeply the role of multi-level co-evolutionary adaptations in the origin and development of creative spinoffs and start-ups, with a general orientation towards sustainability at universities. The results show that successful collaboration among academics, businesses, and the government is required to promote such endeavors. This research contributes to the existing knowledge on technology transfer management through the integration of concepts from the literature on organizational co-evolution and the Triple Helix innovation model. The paper adds some theoretical insights and practical consequences concerning the management of technology transfer procedures and opens further settings for establishing research in this area (Paniccia & Baiocco, 2018).

The extant literature focused on the transfer of technology with the objective of achieving sustainable development. It attempts to identify common themes, areas of consensus, or social repercussions from these transfers. The review points to the neglect of the social dimension in technological research. The most important issues are ideas, resources and technology, clean construction and policy, management and action. The social impacts of greatest concern are those affecting health, quality of life and poverty reduction, particularly in affected areas and on highways. The results are consistent with the sustainable development goals because they show that different approaches can bring social benefits. On the other hand, however, this research also finds that a more holistic assessment of the social implications is required in the technology transfer literature to successfully address the challenges of sustainable development.

3. RESEARCH GAPS, RESEARCH QUESTIONS AND HYPOTHESIS

The literature identifies several themes and gaps in the current research body on Technology Transfer (TT) and its implications for sustainable development. Although the existing literature projects TT have the potential to enhance environmentally friendly practices, there is a telling lack of in-depth analysis of the factors that influence TT adaptation within this context. In addition, the complexity of TT processes, which involve multiple players and elements, has not been adequately explored. While some studies allude to feasibility studies and global TT frameworks, there is a limited understanding of these complexities and their influences on the adaptation of TT. Third, empirical research on the effects of identified factors on the adaptation is also limited. Although some studies provide theoretical insights, a thin body of empirical research systematically investigates these effects, thus limiting the likelihood of uncovering broader patterns and trends that could inform adaptation.

Another gap in research concerns the social consequences of TT for sustainable development. Available studies do acknowledge this, but more is required to have this argument clearly presented in the literature. Much of the current research neglects the broader social impacts of TT—for example, health improvements or poverty reduction—and often merely focuses on technical issues. By addressing these gaps, it may be possible to develop effective strategies for the promotion of sustainable development through TT. Hence, future research can shed some important light onto the intricacies of the TT processes that, in turn, inform efforts of designing impactful sustainability policies through systemic identification, analysis of factors influencing TT adaptation, and conducting empirical investigations.

Therefore, the following study seeks to address the following research questions:

i. What are the primary factors influencing the adaptation of sustainable technology transfer?

ii. How do policy and regulatory mechanisms impact technology transfer adaptation?

iii. What role does stakeholder engagement play in facilitating or hindering sustainable technology transfer?

iv. To what extent do environmental considerations influence the adoption of sustainable technology transfer?

v. How do monitoring and evaluation efforts affect the success of technology transfer initiatives?

Based on the above literature review and research questions the study proposed following null hypothesis for testing:

H_{01}: Environmental considerations do not positively influence technology transfer adaptation.

H_{02}: Effective monitoring and evaluation frameworks do not significantly contribute to technology transfer adaptation.

H_{03}: Policy and regulatory mechanisms do not have a significant positive impact on the adaptation of technology transfer.

H_{04}: Stakeholder engagement does not have a positive effect on sustainable technology transfer adaptation.

4. RESEARCH OBJECTIVES

The study aims to explore factors influencing sustainable technology transfer adaptation by:

i. Identifying key enablers and barriers within sustainability frameworks.

ii. Assessing the role of policy and regulations in promoting technology transfer.

iii. Evaluating stakeholder engagement in successful implementation.

iv. Investigating environmental considerations in adaptation.

v. Analyzing the effectiveness of monitoring and evaluation frameworks.

5. CONCEPTUAL FRAMEWORK

The conceptual model of the study is guided by the way that policy and regulation, stakeholder engagement, environmental considerations, and monitoring and evaluation impact the adoption of Sustainable Technology Transfer, drawing on large literature representing their complex interrelations. Jeffries (1977) demonstrates how policies that require or encourage sustainable development deter investment in many sectors, stressing the importance of strong policy frameworks in shaping the available financial aid. Equally, while stakeholder participation improves project acceptability, as noted by Li et al. (2018) and Davis (2005), this also underlines secured financial support through strengthened partnerships. Environmental dimensions, emphasized by Ferreira et al. (2020) and Salvador et al. (2021), outline the ecological consequences of transferred technologies and, therefore, instruct funding decisions to move towards projects that are viable on an environmental basis. In addition, the establishment mechanisms for monitoring and evaluation, highlighted by Millstone et al. (2010) and Van der Gaast et al. (2009), provide proof of project impact and effectiveness in convincing potential financiers. Pandey et al. (2022) highlight the need to demonstrate positive outcomes

as one way of attracting the adaption of technology transfer from philanthropic foundations and impact investors. Such findings highlight how policy, stakeholder engagement, environment, and monitoring and evaluation all intersect in their influence on the adoption of sustainable technology transfer. It is in recognizing and capitalizing on these relationships that the conceptual model provides a comprehensive framework to guide effective resource allocation and project implementation within the realm of sustainable technology transfer.

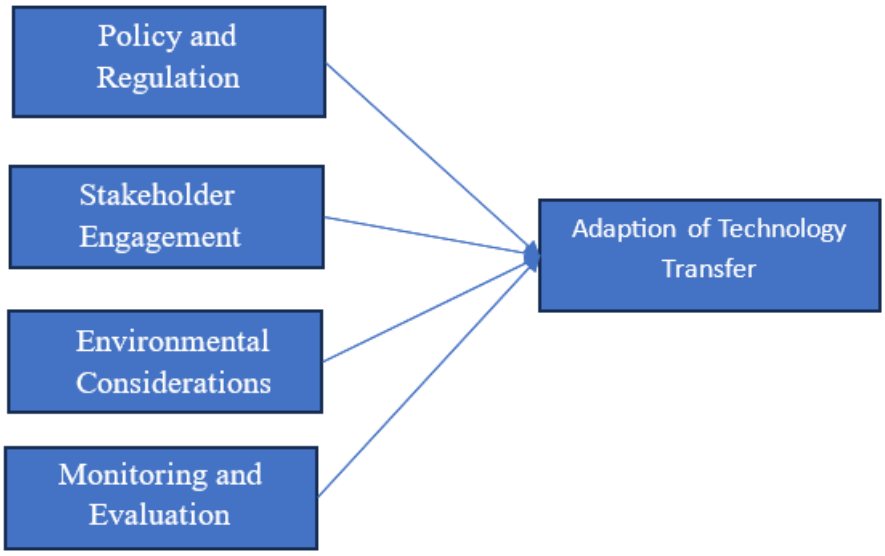

Figure: 1. Conceptual framework

Source: Literature review

6. RESEARCH METHODOLOGY

6.1. Research Design

This study employs a mixed-methods approach, combining quantitative and qualitative techniques to provide a comprehensive analysis of sustainable technology transfer adaptation. This study uses quantitative research as the main methodology for investigating sustainability practices in technology transfer among industry practitioners and professionals. The data used in the research were derived from primary sources and were generated using a well-structured survey questionnaire. Factor analysis within the AMOS program was used to unveil the primary underlying drivers of technology transfer sustainability.

6.2. Participants

The study surveyed industry professionals, technology transfer managers, policymakers, and sustainability experts who actively participate in technology transfer initiatives across several industries. The sample size targeted was 135, selected using a mixed-method approach to ensure fair representation across sectors and organizational hierarchies. Participants were selected using purposive sampling to ensure a diverse representation across relevant sectors in India.

6.3. Data Collection Methods

A structured questionnaire was used, incorporating Likert scale items to measure perceptions regarding policy frameworks, stakeholder engagement, environmental factors, and monitoring mechanisms. The questionnaire was specifically designed to elicit information on practices that enhance the long-term sustainability of technology transfer initiatives. With the application of Likert scale questions in this questionnaire, an attempt was made to elicit the opinions and attitudes of the respondents concerning various parameters related to sustainable technology

transfer. To make the gathering of data more efficient, the survey will be conducted online using digital platforms or email distribution channels.

6.4. Data Analysis Techniques

Structural Equation Modeling (SEM) was applied using AMOS to conduct confirmatory factor analysis and validate the research model. Factor analysis is a robust statistical technique that determines the core components or factors that significantly affect sustainability measures of technology transfer created by industry actors and professionals. With the use of CFA, the latent constructs are validated, and therefore, the relationships between the variables checked may have. Cronbach's Alpha was used to assess reliability, ensuring internal consistency among constructs. The R-square value was calculated to measure the model's explanatory power in predicting technology transfer adaptation. Therefore, the findings of the study are reliable and valid; hence, they ensure the assurance of insight into key drivers fostering the adoption of sustainable technology transfer initiatives.

7. DATA ANALYSIS AND RESULT

7.1. Demographic statistics

Demographic statistics are useful for describing the attributes of the participants involved in the data analysis. Table 1 presents the demographic characteristics of the respondents who answered the survey, providing insights into gender, age, education level, job title, years of experience, company size, and employment status.

The data show that 59.25 percent of the respondents were male, while 40.74 percent were female. The age distribution shows that 29.62 percent of the respondents were within the 36-45-year age group, which is the highest, followed by 23.70 percent in the 26-35 years age group. With respect to educational attainment, a significant proportion of respondents (45.92 percent) possessed a bachelor's degree. This was succeeded by individuals with a master's degree (29.62 percent). Occupational roles among participants were diverse, with technology transfer managers emerging as the predominant category (40.74 percent), followed by engineers (25.92 percent).

In terms of experience, nearly half of the respondents have 6-10 years of experience (49.62 percent). The company size distribution indicates that medium-sized companies, with 51-500 employees, constitute the largest group at 49.62 percent. Finally, regarding employment status, the data show that 73.33 percent are full-time employees, while 26.66 percent are contractual workers. Overall, these demographic statistics provide valuable insights into the profiles of the survey respondents, facilitating a deeper understanding of the sample population.

Table 1 Demographic Statistics

Variables	**Frequency**	**Percent**
Gender:		
Male	80	59.25
Female	55	40.74
Age:		
18-25	30	22.22
26-35	32	23.70
36-45	40	29.62

46-55	25	18.51
56 and above	8	5.92
Education Level:		
Diploma	25	18.51
Graduation	62	45.92
Post graduation	40	29.62
Doctorate or Professional courses	8	5.92
Position/Job Title:		
Technology Transfer Manager	55	40.74
Research and Development (R&D) Personnel	21	15.55
Executive/Manager	23	17.03
Engineer	35	25.92
Years of Experience:		
1 - 5 years	46	34.07
6 - 10 years	67	49.62
11 - 15 years	22	16.29
Company Size:		
Small (1-50 employees)	12	8.88
Medium (51-500 employees)	67	49.62
Large (501+ employees)	56	41.48
Employment Status:		
Full-time	99	73.33
Contractual	36	26.66

Source: Author's calculations.

7.2. Reliability Statistics

A Cronbach's alpha score of over 0.70 suggests a strong correlation between the items and a reliable measurement of the same underlying concept. The entire collection of statements had a Cronbach's alpha value of 0.874, indicating highly reliable data (Table 2). Cronbach's alpha values greater than 0.70 are acceptable (Nunnally, 1994).

Table 2 Internal consistency

Cronbach's Alpha	N of Items
.874	25

Source: SPSS Output. Author's calculations

7.3. Confirmatory Factor Analysis (CFA)

The CFA confirmed the factor structure of the dataset. The measurement model was evaluated by examining the Reliability, Validity statistics, and model-fit indices.

7.3.1. Reliability and Validity statistics

Statistics on data reliability and validity can provide insights into the quality and homogeneity of the measuring scales used in the investigation. These are the requisite statistics for ascertaining data accuracy and credibility to ensure the strength of the results and conclusions derived from the research.

Table 3 Reliability and Validity statistics

Constructs	**Reliability statistics**					**Validity measure –** Fornell and Larker, 1981				
	CR	**Cronbach alpha**	**AVE**	**MSV**	**MaxR(H)**	**ATT**	**PR**	**ME**	**SE**	**EC**
ATT	0.864	.858	0.567	0.523	0.901	0.753				
PR	0.872	.868	0.696	0.833	0.888	0.723***	0.834			
ME	0.930	.926	0.816	0.061	0.958	0.248*	0.158†	0.803		
SE	0.897	.895	0.686	0.833	0.917	0.492***	0.813***	0.119	0.828	
EC	0.890	.887	0.731	0.290	0.899	0.375**	0.535***	-0.064	0.538***	0.755

Source: Author's Calculations.

Cronbach's alpha values greater than 0.60 are acceptable (Nunnally, 1994). A composite reliability greater than 0.7 is desirable (Hair et al., 2019). AVE for each constructs should be greater than 0.50 (Fornell & Larcker, 1981). The reliability and validity statistics are presented in Table 3. Therefore, the questionnaire items showed acceptable model fit measures, reliability, and validity. The results of this research instill trust in the accuracy of the data gathered and validate the study's findings and conclusions on sustainable practices in technology transfer.

7.3.2. Model Fit Measures

Model fit indices were measured using normed chi-square $\chi 2/df$, goodness of fit index (GFI), standardized root mean square residual SRMR and Comparative fit index CFI.

Table 4 Model Fit Measures

Measure	Estimate	Threshold as per Gaskin and Lim, (2016)
CMIN	453.600	--
DF	120	--
CMIN/DF	3.780	Between 1 and 3
CFI	0.843	>0.95
SRMR	0.0793	<0.08
RMSEA	0.048	<0.06
PClose	0.060	>0.05

Source: Author's Calculation

The model fit indices were $\chi 2$ (df) = 453.600 (120), p = 0.000, normed $\chi 2$ = 3.780, CFI = 0.843, PCLOSE = 0.060, RMSEA = 0.0793, and SRMR = 0.0793. As shown in Table 5, this is an acceptable model according to Hair et al. (2006). Removals were made on account of lower, less than .40 standard estimates and for establishing reliability and validity for SE1, ME1, ME2, EC4, EC5, PR4, and PR5. The R-square value of 0.969 means that 96.90 percent of the total variation in the FS scores was explained by the four constructs considered in this study, thus indicating a very high explanatory power for the model. Figure 2 shows the modified model.

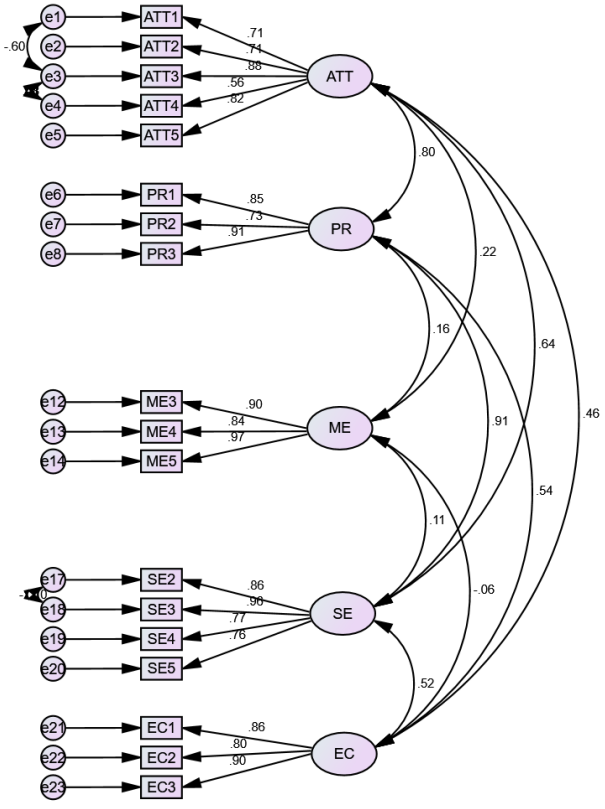

Fig. 2. CFA for Sustainable Technology Transfer, Source: AMOS output. Author's calculations.

7.4. Path analysis as Structural model

Curve estimation in SPSS confirmed that all the relationships of the model were acceptably linear for analysis using a covariance-based SEM algorithm like AMOS. Imputed scores of the latent constructs were used for path analysis in AMOS so as to evaluate the impact of each construct on its dependent construct. The standardized regression weights, correlations between latent constructs, and the squared multiple correlation value for FS are presented in Figure 3.

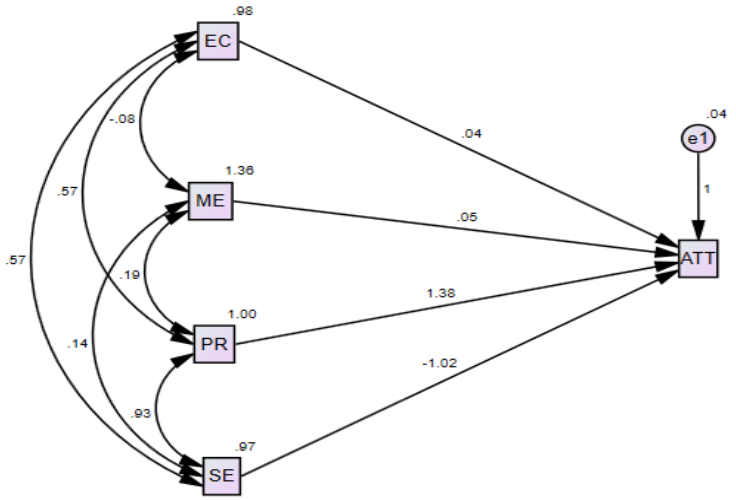

Fig. 3. SEM of Adaption of Sustainable Technology Transfer.

Source: AMOS Output. Author's calculations

Table 5 provides a comprehensive overview of relationship estimates, standard errors (S.E.), critical ratios (C.R.), and p-values (P), offering insights into the strength, significance, and reliability of the examined relationships. Each row corresponds to a specific relationship denoted by labels such as ATT, PR, SE, EC, and ME. The estimates signify direction and magnitude, with higher values indicating stronger positive associations. Smaller standard errors suggest more reliable estimates, whereas higher critical ratios indicate greater significance. Notably, all relationships exhibit extremely low p-values (***) indicating high statistical significance, bolstering confidence in the findings' validity.

Table 5 Path analysis

Relationships	Estimate	S.E.	C.R.	P-values	Interpretation @ 5% significance level
H1: ATT : <--- EC	.041	.023	1.789	.074	Positive and insignificant
H2: ATT <--- ME	.052	.016	3.231	.001	Positive and significant
H3: ATT <--- PR	1.383	.056	24.731	***	Positive and significant
H4: ATT <--- SE	-1.018	.056	-18.104	***	Negative and significant

Source: AMOS Output. Author's calculations.

Table 6 briefly shows the results as follows:

H_1: Environmental Considerations (EC) and Adaptation of Technology Transfer (ATT)

The coefficient estimate for EC is 0.041, with a standard error of 0.023 and a critical ratio (C.R.) of 1.789. The p-value is 0.074, which is greater than the 5% significance level. Hence, the relationship between environmental considerations and the adaptation of technology transfer is positive but insignificant at the 5% level. In other words, there is insufficient evidence to reject the null hypothesis (H_{01}), meaning environmental considerations do not significantly influence technology transfer adaptation. Rather than assuming that this warrants further research, the study discusses potential reasons, including regulatory inconsistencies and industry-specific barriers.

H_2: Monitoring and Evaluation (ME) and ATT

The coefficient estimate for ME is 0.052, with a standard error of 0.016 and a C.R. of 3.231. The p-value is 0.001, which is less than 0.05, indicating a positive and significant relationship between monitoring, evaluation, and adaptation of technology transfer at the 5% significance level, highlighting the need for robust assessment frameworks to ensure long-term sustainability. Since the null hypothesis (H_{02}: Effective monitoring and evaluation frameworks do not significantly contribute to technology transfer adaptation) is rejected, this finding suggests that as monitoring and evaluation improve, the adoption of technology transfer also increases significantly.

H_3: Policy and Regulation (PR) and ATT

The coefficient estimate for PR is 1.383, with a standard error of 0.056 and a highly significant C.R. of 24.731. The p-value is less than 0.001, which strongly supports a positive and significant relationship between policy, regulation, and adaptation of technology transfer. Since the null hypothesis (H_{03}: Policy and regulatory mechanisms do not have a significant positive impact on the adaptation of technology transfer) is rejected, this confirms that improved policy and regulation contribute significantly to the adoption of technology transfer. However, the strength of this relationship varies across industries and regions, requiring context-specific policy interventions.

H_4: Stakeholder Engagement (SE) and ATT

The coefficient estimate for SE is -1.018, with a standard error of 0.056 and a C.R. of -18.104, indicating a highly significant relationship. The p-value is below 0.001, showing that stakeholder engagement has a significant but negative impact on the adaptation of technology transfer. As stakeholder engagement increases, the adaptation of technology transfer decreases. Since the null hypothesis (H_{04}: Stakeholder engagement does not have a positive effect on sustainable technology transfer adaptation) is not rejected but rather reinforced, this suggests that excessive or mismanaged engagement efforts may create inefficiencies, emphasizing the need for a balanced approach.

8. DISCUSSION

The findings provide insights into the complex interplay of different factors in technology transfer adoption, which is based on a strong body of literature on initiatives in the areas of sustainable technology transfer. Environmental factors are found to be positive but insignificantly associated with the adoption of technology transfer, supporting prior research that emphasizes the need to consider environmental factors in the process of technology transfer if it is to be sustainable in the long run (Ferreira et al., 2020; Salvador et al., 2021). While these factors are included in funding decisions, the lack of statistical significance leads to the need

for further examination of their precise effects on the adaptation of technology transfer. Further, the various significance of different variables used in this research question underlines that the path to attaining environmental sustainability through technology transfer is very complex. Understanding which components of the variables bear more weight could be valuable for the development of targeted and effective interventions.

Conversely, Monitoring and Evaluation have a significant positive relationship with the adaptation of technology transfer. This resonates with the literature that calls for systematic monitoring and evaluation mechanisms, as noted by Millstone et al. (2010) and Van der Gaast et al. (2009). This proves the importance of demonstrating positive outcomes and return on investment to instill confidence among potential financiers, in tandem with the insights obtained from Pandey et al. (2022).

PR is a strong predictor of adaptation, which agrees with the literature pointing to the effect of an enabling regulatory environment that attracts investment. This relationship clearly stipulates that transparent and sound policy frameworks are important for facilitating financial assistance for the execution of sustainable technology transfer initiatives.

The high negative correlation of stakeholder engagement with the adaption of technology transfer is, however, surprising and stands in contrast to previous literature that highlights the role of stakeholders in securing financial support for the project. There is a delicate balance between stakeholder engagement and adoption of technology transfer because, according to Aerts et al. (2022), collaborative engagement is important for the acceptability and legitimacy of the project. The negative association between financial aid and stakeholder engagement raises some critical questions regarding this uneasy balance of resource distribution and inclusive decision-making processes within technology transfer initiatives. This calls for methods that give due consideration to financial assistance and meaningful stakeholder participation if both the success and sustainability of such initiatives are to be achieved.

In general, these findings underline the complex interplay of policy frameworks, stakeholder engagement, environmental considerations, and monitoring and evaluation mechanisms influencing the adoption of technology transfer for sustainable technology transfer initiatives. This influence can therefore be harnessed through the utilization of available literature to ensure effective strategic consideration of resources by organizations and policymakers to enhance the adaption of technology transfer for fostering environmentally and socioeconomically development-oriented initiatives. There is such a correlation in financial assistance, legislation and regulation, stakeholder participation, environmental concerns, and monitoring and evaluation that underscores the complexity that characterizes sustainable technology transfer projects. However, the insignificant correlations and inconclusive findings indicate the need for a greater understanding of the systems involved.

9. CONCLUSIONS

The complex interplay of factors culminates in the adaptation of technology transfer to sustainable initiatives, which is otherwise not easily understood in shallow waters. This study highlights a nuanced relationship between environmental considerations, monitoring and evaluation mechanisms in place for the same policy and regulatory frameworks, and stakeholder involvement regarding technology transfer adaptation, based on an exhaustive review of the literature. From a scientific contribution perspective, the study advances knowledge on sustainable technology transfer by integrating policy analysis, stakeholder dynamics, and environmental factors within an empirical framework. Although strongly influential in determining funding, environmental concerns exhibit a statistically non-significant influence on the adaptation to technology transfer. The point worth noting here is the statistical significance of the monitoring and evaluation bodies/mechanisms if the

technological transfer adaptation goes, the indication being that the key lies in the relatively high impact of the authority to show positive performance. Again, the robustness of the positive link shown for the policy and regulation frameworks and technology transfer adaptation reflects the requirement of transparent regulatory conditions to encourage fresh investments in clean activities. However, the unanticipated negative relationship between stakeholder engagement and technology transfer adaptation calls for a detailed analysis of the fine balance between the degree of stakeholder involvement and the commitment of resources. Further research into stakeholder engagement strategies is needed to determine the optimal balance between involvement and efficiency in technology transfer projects. These results underline that holistic and context-specific tactics that focus on financial support and meaningful stakeholder involvement allow TT programs to be successful and ensure long-term survival.

This study reveals the complex interplay of factors that influence technology transfer adaptation. Environmental considerations have a positive yet statistically insignificant relationship, highlighting the need for more in-depth research. Monitoring and evaluation are important determinants of success, emphasizing the significance of strong mechanisms of evaluation. Policy and regulation have a significant positive relationship, underlining regulatory frameworks as key drivers of sustainable innovation. On the negative side, the relationship with stakeholder engagement draws attention to some traps in over-emphasizing engagement endeavors during reorientation. From a practical relevance perspective, policymakers and industry practitioners can use these findings to design targeted interventions, ensuring that technology transfer mechanisms align with sustainability goals. Strengthening monitoring and assessment provisions in technology transfer activities, creating an enabling policy environment that encourages sustainable innovation, and carefully engaging with stakeholders—without unintentionally causing negative repercussions—are crucial strategies moving forward.

Because previous studies have mostly been conducted theoretically, empirical insights into which factors influence technology transfer adaptation are missing. Therefore, this paper provides directions and useful guidelines to policymakers, practitioners, and researchers on the role of monitoring and evaluation, policy and regulation, stakeholder engagement, and environmental considerations. To refine the understanding of these linkages, sector-specific analysis should be explored, as variations in technology transfer adaptation may differ across industries such as energy, manufacturing, and healthcare. Additionally, longitudinal studies could assess how policy changes and technological advancements influence adaptation over time, while comparative studies between developed and developing economies could shed light on differing regulatory and financial constraints. Enriching the discourse on sustainable innovations with evidence-based decision-making in technology transfer initiatives will be instrumental in achieving sustainable development goals.

The results clearly reveal the interplay between financial aid, stakeholder engagement, policy and regulation, environmental considerations, and the monitoring and evaluation of sustainable technology transfer. Addressing environmental issues properly and designing strategies that effectively involve stakeholders while emphasizing a strong monitoring and evaluation system can fulfill the objective. Further interdisciplinary research on stakeholder involvement and policy discussions is critical for advancing knowledge on the sustainability of technology transfer and its application to positive engineering change for a more sustainable future.

Additional information

Ethical Compliance

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Author's contributions

All the authors contributed to the conception and design of the study.

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Data availability statement

The data for the study are available upon request.

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REFERENCES

Aerts, G., Cauwelier, K., de Pape, S., Jacobs, S., & Vanhondeghem, S. (2022). An inside-out perspective on stakeholder management in university technology transfer offices. *Technological Forecasting and Social Change*, 175, 121291.

Badu-Apraku, B., Fakorede, M. A. B., Menkir, A., Marfo, K. A., & Akanvou, L. (2005). Enhancing the capacity of national scientists to generate and transfer maize technology in West and Central Africa: research implementation, monitoring and evaluation. *Experimental agriculture,* 41(2), 137-160.

Besharati, N., & Rios, O. G. (2017). A monitoring and evaluation framework for South-South cooperation. South African Institute of International Affairs.

Blohmke, J. (2014). Technology complexity, technology transfer mechanisms and sustainable development. *Energy for Sustainable Development*, 23, 237-246.

Bozeman, B. (2000). Technology transfer and public policy: a review of research and theory. *Research policy*, 29(4-5), 627-655.

Corsi, A., Pagani, R. N., & Kovaleski, J. L. (2020). Technology transfer for sustainable development: Social impacts depicted and some other answers to a few questions. *Journal of Cleaner Production*, 245, 118522.

Craiut, L., Bungau, C., Bungau, T., Grava, C., Otrisal, P., & Radu, A. F. (2022). Technology Transfer, Sustainability, and Development, Worldwide and in Romania. *Sustainability*, 14(23), 15728.

Davis, K. E. (2005). Regulation of technology transfer to developing countries: the relevance of institutional capacity. *Law & Policy*, 27(1), 6-32.

Feng, X. Z., & Li, M. (2014). Literature Review on Suitability Monitoring of Emerging Technology Transfer for Sustainable Development. *Applied Mechanics and Materials*, 513, 867-870.

Fernandes, C. I., Veiga, P. M., Ferreira, J. J., & Hughes, M. (2021). Green growth versus economic growth: do sustainable technology transfer and innovations lead to an imperfect choice? *Business Strategy and the Environment*, 30(4), 2021-2037.

Ferreira, J. J., Fernandes, C. I., & Ferreira, F. A. (2020). Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: A comparison of European countries. *Technological Forecasting and Social Change*, 150, 119770.

Fitiu, A. (2017). Building sustainable development through technology transfer in a Romanian university. *Sustainability*, 9(11), 2042.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, *18*(1), 39-50.

Gandenberger, C., Bodenheimer, M., Schleich, J., Orzanna, R., & Macht, L. (2016). Factors driving international technology transfer: Empirical insights from a CDM project survey. *Climate Policy*, 16(8), 1065-1084.

Gaskin, J. and Lim, J. (2016). Model Fit Measures. AMOS Plugin. Gaskination's StatWiki.

Gumbi, S. (2010). A review of performance standards to monitor, evaluate and assess the impact of technology transfer offices. *South African Journal of Science*, 106(7), 1-9.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European business review*, *31*(1), 2-24.

Hoekman, B. M., Maskus, K. E., & Saggi, K. (2005). Transfer of technology to developing countries: Unilateral and multilateral policy options. *World development*, 33(10), 1587-1602.

Hyman, E. L., & Corl, T. C. (1984). A System for the Monitoring and Evaluation of Appropriate Technology Projects. Appropriate Technology International.

Jeffries, C. P. (1977). Regulation of Transfer of Technology an Evaluation of the UNCTAD Code of Conduct. Harv. Int'l. LJ, 18, 309.

Karakosta, C., Doukas, H., & Psarras, J. (2010). Technology transfer through climate change: Setting a sustainable energy pattern. *Renewable and sustainable energy reviews*, 14(6), 1546-1557.

Kreiling, L., Serval, S., Peres, R., & Bounfour, A. (2020). University technology transfer organizations: Roles adopted in response to their regional innovation system stakeholders. *Journal of Business Research*, 119, 218-229.

Lee, W. J., & Mwebaza, R. (2022). New strategy for innovative RD&D in view of stakeholder interaction during climate technology transfer. *Sustainability*, 14(14), 8363.

Li, F., Zhang, S., & Jin, Y. (2018). Sustainability of university technology transfer: Mediating effect of inventor's technology service. *Sustainability*, 10(6), 2085.

McAdam, M., Miller, K., & McAdam, R. (2021). A micro level investigation of stakeholder motives on university technology transfer business models. *Studies in Higher Education*, 46(5), 951-964.

McCulloch, R. (1981). Technology transfer to developing countries: implications of international regulation. *The Annals of the American Academy of Political and Social Science*, 458(1), 110-122.

Millstone, E., Van Zwanenberg, P., & Marshall, F. (2010). Monitoring and evaluating agricultural science and technology projects: theories, practices and problems. *IDS Bulletin*, 41(6), 75-87.

Nunnally, J. C. (1994). Psychometric theory 3E. Tata McGraw-hill education, New York, NY.

Pandey, N., de Coninck, H., & Sagar, A. D. (2022). Beyond technology transfer: Innovation cooperation to advance sustainable development in developing countries. *Wiley Interdisciplinary Reviews: Energy and Environment*, 11(2), e422.

Paniccia, P. M., & Baiocco, S. (2018). Co-evolution of the university technology transfer: Towards a sustainability-oriented industry: Evidence from Italy. *Sustainability*, 10(12), 4675.

Salvador, R., Barros, M. V., do Prado, G. F., Pagani, R. N., Piekarski, C. M., & de Francisco, A. C. (2021). Knowledge and technology transfer in sustainability reports: fomenting stakeholder engagement for sustainable development. *Corporate Social Responsibility and Environmental Management*, 28(1), 251-264.

Sam, K., Coulon, F., & Prpich, G. (2017). Use of stakeholder engagement to support policy transfer: A case of contaminated land management in Nigeria. *Environmental Development*, 24, 50-62.

Schneider, M., Holzer, A., & Hoffmann, V. H. (2008). Understanding the CDM's contribution to technology transfer. *Energy policy*, 36(8), 2930-2938.

Van der Gaast, W., Begg, K., & Flamos, A. (2009). Promoting sustainable energy technology transfers to developing countries through the CDM. *Applied Energy*, 86(2), 230-236.

van Drooge, L., & Spaapen, J. (2022). Evaluation and monitoring of transdisciplinary collaborations. *The Journal of Technology Transfer*, 47(3), 747-761.

Wu, A., & Li, T. (2020). Gaining sustainable development by green supply chain innovation: Perspectives of specific investments and stakeholder engagement. *Business Strategy and the Environment*, 29(3), 962-975.