Strengthening the absorptive capacity of the national innovation system through university-industry research collaboration: A Theory of Inventive Problem Solving approach

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Abstract

There has been a universal recognition that university-industry research collaboration (UIRC) is vital to strengthen the national innovation system (NIS) and economic growth. Despite a series of research studies on the significance of UIRC, present baseline models to enhance the capabilities of NIS through URIC are still scarce, specifically in developing countries. This research has highlighted that absorptive capacity has a vital influence on the NIS as well as on the research and innovative activities of an individual. Moreover, this research highlights how education and training (E&T) can enrich the absorptive capacity of NIS and UIRC using the Theory of Inventive Problem Solving (TRIZ) approach. The methodology involves applying TRIZ tools, such as function modeling, contradiction analysis, and inventive principles to identify effective strategies for improving the absorptive capacities of universities and industries and consequently of NIS. Thus, proposed solutions include enhancing the education, training systems and programs, promoting collaboration between universities and industries, and decreasing aids, such as foreign-educated and skilled workforce, which can strengthen the absorptive capacity of NIS. Analysis of this research suggests that a strong E&T system and upgrading the standard of education are crucial factors for improving the absorptive capacity of NIS. Recommendations include developing policies that foster a culture of knowledge, promoting interdisciplinary research, and incentivizing innovation. Future research directions include exploring comparative analysis with other developed and developing countries' strategies in customizing the education and research system to enhance the outcomes of research and innovations.

Keywords: Absorptive Capacity, Education and Training, National Innovation System, Theory of Inventive Problem Solving, University-Industry Research Collaboration

1. Introduction

Innovations and new technologies heavily rely on our capacity to assimilate and apply novel concepts and ideas, which is termed as absorptive capacity (Kale et al., 2019). This role is analogous to the robust foundation of a house that sustains its structure. Nations worldwide are increasingly recognizing the factors to enhance their capability to learn and apply emerging technologies, viewing it not just as a beneficial pursuit but as an absolute necessity (Albort-Morant et al., 2016). This realization stems from confronting challenging economic issues that can be effectively addressed and securing a promising future through the development of new and advanced technologies. Both industry and academia play pivotal roles in the domain of inventions and technology. The central component of a vast machine facilitates the exchange of ideas and advances technology (Iqbal et al., 2015; Khan, 2022; Ye & Wang, 2019; Yu et al., 2022), and its absorptive capacity plays a crucial role in the realm of innovation. Despite our awareness of universities and industries and their collaboration significance, producing new technology is always challenging, particularly in developing nations (Iqbal et al., 2021). In industrialized nations, absorptive capacity is widely acknowledged as a fundamental factor in promoting technological innovation and transformation within university-industry research collaboration (UIRC) and contributing significantly to long-term economic progress (Terstriep & Lüthje, 2018). Given the present state of the international economy and the imperative of ensuring future prosperity, countries worldwide recognize the need to strengthen their national innovation systems (NISs) by enhancing their absorptive capacity (Ahn, 2016). Numerous research studies have consistently emphasized the critical significance of both UIRC and absorptive capacity, recognizing their profound influence on the NIS. Despite the recognized importance of absorptive capacity, the rate of technical innovation resulting from UIRC remains relatively low, particularly in developing nations (Iqbal et al., 2022). Various research endeavors have sought to identify the constraints on producing a number of research and innovations in UIRC and explore ways to address them. Unfortunately, many of these initiatives have focused on superficial solutions, such as hosting workshops and seminars or employing knowledgeable staff who provide only short-term remedies for underlying issues (Iqbal, 2018; Iqbal et al., 2022). Recognizing the pivotal roles of universities and industries as integral components of the NIS, actively contributing to technological innovation, it becomes imperative to examine the impact of absorptive capacities of universities and industries and their research collaborations on the broader innovation landscape (Chryssou, 2020).

This study aims to enhance the absorptive capacities of universities and enterprises to address the aforementioned challenge. A notable limitation identified in existing research is the absence of a visual thinking strategy, leading to a constrained level of predictability in outcomes (Czinki & Henntschel, 2015; Kasravi, 2010). Given the intricate interdependencies between the two key constituents of the NIS, universities and industry, a comprehensive evaluation necessitates the adoption of a visual thinking strategy (Ersin, 2009; Terninko et al., 1998). To address this, the study advocates the implementation of the Theory of Inventive Problem Solving (TRIZ) paradigm and associated resources. Utilizing the concepts of TRIZ in a non-technical domain is not new; much research has already contributed to such a domain (Hammer & Kiesel, 2019; Lin & Chen, 2021; Navas et al., 2015; Walter, 2015; Wang et al., 2015). TRIZ, traditionally associated with technical problem-solving, has shown significant potential in social, management, and humanities domains, particularly in business and management. Mann and Spain (2000) emphasize that TRIZ can effectively address social, management, and humanities issues by providing a structured approach to decision-making and strategic planning in organizations. Furthermore, Ruchti et al. (2001) highlight that TRIZ can enhance business decision-making processes, demonstrating its versatility beyond engineering applications. The methodology's 12 principles serve as valuable tools for navigating complex business challenges, fostering innovative solutions, and improving management practices (Ruchti et al., 2001). Despite its technical origins, the integration of TRIZ into non-technical domains remains underexplored, indicating a need for further research to fully leverage its capabilities in business contexts. Ishrat et al. (2023) conducted an extensive and exhaustive discussion on TRIZ in social, management, and humanities domains, particularly in business and management.

In contrast to conventional strategies involving concessions or trade-offs, TRIZ excels at resolving contradictions, rendering it a potent tool for generating innovative solutions to challenges (Hammer & Kiesel, 2019). Utilizing a two-stage process of "cause and effect analysis and inventive principles," TRIZ furnishes a visual thinking tool that enables the systematic resolution of problems (Kasravi, 2010). Typically, the initial phase of the TRIZ methodology involves pinpointing the core problem by eliminating peripheral concerns and assumptions. This necessitates breaking down the issue into its fundamental components, comprehending each facet, expressing the elements in the most fundamental or elementary manner, and ultimately liberating oneself from the constraints of the language used to articulate the problem (Ersin, 2009). During this phase, the TRIZ approach relies on the problem solvers' capacity to contemplate the fundamentals of the issue and recognize its pivotal elements. To delve into the complexities of modeling relationships, we employed key TRIZ tools in this study, such as function modeling and cause-effect chain analysis (Ersin, 2009). Beyond providing comprehensive problem-solving techniques, TRIZ also illuminates the exploration of inconsistencies between parameters that are deteriorating and those that are improving. Furthermore, it furnishes a comprehensive roadmap that addresses all parameters (Su and Lin, 2008; Ekmekci, 2019). Consequently, we present an enriched perspective to enhance the absorptive capacities of the NIS through the application of TRIZ tools and solutions.

There are five primary contributions from this research. First, it enriches the discourse of absorptive capacity and its implications for research institutions, particularly universities and industries, by presenting a practical solution using the TRIZ theory to enhance their potential for technological innovation. In addition, it stands as the pioneering application of TRIZ theory to UIRC investigations, substantiating its effectiveness in this context. Third, it supplements the existing body of literature on the NIS by showcasing how TRIZ theory can be harnessed to illuminate the critical elements of UIRC. Fourth, it identifies supportive factors that can enhance UIRC's capacity for innovation and, consequently, fortify the NIS. In conclusion, this study underscores the significance of education and training (E&T), standards of education (SE), on absorptive capacity. By unlocking the latent potential of businesses and universities to contribute invaluable research and innovations to their respective countries, the study provides policymakers with practical insights and relevance.

The rest of this article is organized as follows: in Section 2, conceptual design and hypothesis development are presented, while research design and methodology are presented in Section 3. Results and analysis are covered in Section 4, followed by a conclusion and future direction in Section 5.

2. Conceptual Design and Hypothesis Development

Absorptive capacity holds a prominent role in NISs and is integral to the theory of economic growth, facilitating faster development in innovation-driven economies (Spreafico, 2022). It denotes the ability to assimilate, process, adapt, and apply new information for business purposes, aiding both innovation and industrial processes (Miguélez & Moreno, 2015). Various definitions exist; one perspective, as proposed by Müller et al. (2020), defines absorptive capacity as the capability to absorb, process, and utilize new information effectively. Another definition, by Naqshbandi & Tabche (2018), views it as the power to transform knowledge into a productive form, while Ishrat et al. (2023) characterize it as the capability to identify the importance of new external knowledge, integrate and employ it to attain economic objectives. In essence, absorptive capacity is the technological competence rooted in a firm's internal technical capabilities, playing a pivotal role in fostering innovation (Murovec & Prodan, 2009). One of the primary challenges hindering collaboration between university and industry personnel during the establishment of UIRC is the deficiency in technological competency or absorptive capacity (Carrasco-Carvajal, 2023). In lower-income nations, the relatively subdued educational systems have resulted in a less conspicuous presence of absorptive capacity, which is a pivotal element in research and innovations (Chryssou, 2020). The quality of E&T is emphasized as a determining factor for research breakthroughs (Zahra & George, 2002). Particularly in developing nations, industries often rely on external technical support, such as collaborations with universities or the recruitment of highly qualified foreign expertise (Iqbal, 2018).

Universities, recognized as centers of learning and education, play a pivotal role in the advancement of research-oriented systems (Iqbal et al., 2012; 2015; Kim & Park, 2023). Similarly, the presence of a well-structured education system, institutions for training management, and a robust technology infrastructure contributing to the production of highly educated and skilled professionals has a profound impact on the success of research and development endeavors (Iqbal et al., 2015). The quality of E&T, as highlighted by Müller et al. (2020), significantly influences research and innovation capabilities. Similarly, several studies (Heiden et al., 2015; Iqbal et al., 2010; 2013) elaborate that high-tech nations consistently achieve breakthroughs and enhance their market position by elevating competitiveness among their citizens through high-quality training and education. Moreover, numerous studies have identified a direct correlation between the volume of innovations and E&T, emphasizing that highly educated and trained individuals play a crucial role in driving progress in research and innovation (Kobarg et al., 2018). In line with this observation, the hypothesis of the study is: E&T have a positive influence on the absorptive capacity of universities and industries and on NIS (H1a).

However, it is observed that universities, especially in lower-income nations, persist in training and educating their staff using outdated methods (Akram, 2020). Additionally, there is a lack of flexibility in the curriculum to meet industry requirements due to various operational constraints, such as adherence to traditional teaching syllabi, theory-centric curricula, mindset-oriented curricula, and adherence to self-produced curricula (Topkaya, 2015). Consequently, graduates from such programs may face challenges in transforming knowledge into practical applications (Gu, 2021). Li et al. (2023) suggest that institutions of higher learning and training should modernize their curricula, advocating for a research-focused curriculum as it would yield greater benefits in terms of research and innovation compared to a theory-based one. Theoretically-based curricula lead to graduates who lack practical experience and are ill-prepared for engaging in research and innovation or enhancing their absorptive capacities. Overall, the E&T systems in developing nations remain of low quality and are in urgent need of the introduction of research-based teaching and training methodologies (Alexander & Yuriy, 2018; Chen et al., 2019; Iqbal et al., 2010; Mallana et al., 2013). The standard of E&T has been shown to be a significant determinant of information absorption and is closely linked to absorptive capacity, as indicated by Iqbal et al. (2013). Thus, this study posited the following hypothesis: standard of education as a reinforcing factor of E&T has a positive influence on the absorptive capacity of universities and industries and on NIS (H1b).

Furthermore, several studies have demonstrated that developing nations rely on foreign-educated and skilled workers (FESW) to enhance their research and innovations due to their lower educational standards (Dooley & Gubbins, 2019). FESW constitutes a critical resource that businesses can leverage to improve production (Patston et al, 2018). Similarly, a substantial body of research has found that FESW has a significant impact on national research and innovation. This impact includes promoting technological spillovers, facilitating the integration of international trade, fostering a more competitive business climate, and stimulating enterprise development.

Despite these contributions, FESW may not significantly contribute to the growth of a nation's intellectual capital (Knudsen et al., 2001). Davies et al. (2014) define intellectual capital as the collective knowledge, experience, learning, and teamwork skills possessed by a workforce, enabling them to solve problems and add value to a company. Similarly, Crown et al. (2020) characterize intellectual capital as the application of individual intelligence to generate novel ideas and information. Intellectual capital, considered a nation's internal competitive advantage, plays a fundamental role in fostering innovation, essential for the nation's development (Truong & Nguyen, 2023). A dynamic environment and high intellectual standards in education are imperative for sustaining and enhancing research and innovation. Countries should prioritize developing intellectual capital and fostering innovative capabilities rather than relying on the employment of FESW (Farzaneh et al., 2022). Industrialized nations have become significant players in global competition, research, and innovation by consistently generating intellectual capital and enhancing their innovation systems, gradually reducing dependence on FESW (Rehman et al., 2011). According to Arshad et al. (2023), intellectual capital has gained prominence in recent years, contributing to creative ideas and technological advancements in research and innovation firms. As a result, the economy has advanced to a higher stage, intensifying competition through these technological developments. Nations strive to become market leaders or maintain their positions in the global economy by enhancing the number of inventors from the supply side of the economy. Many countries have enhanced their E&T systems to produce highly educated, skilled workers and inventors. In summary, it is extensively documented that an organization's innovation capacity is directly associated with its intellectual capital rather than relying on FESW (Ahmed et al., 2020). Intellectual capital is rapidly becoming a critical factor at the top of the value chain for institutions and organizations. Thus, this study posited the following hypothesis: FESW does not have a significant influence on the absorptive capacity of universities and industries and on NIS (H2).

3. Research Design and Methodology

This study employed an open-ended questionnaire to collect data through a survey approach based on the positivist paradigm. In this paradigm, knowledge is initially derived from facts, evidence, and reasoned thinking. Subsequently, assertions are formulated, and hypotheses are tested using statistical methods. This approach proves valuable in uncovering important discoveries and insights while describing norms and correlations between variables (Ozgun et al., 2022). When the target population is geographically dispersed, the survey method becomes an appropriate strategy for data collection. Surveys serve as an effective means of gathering information from participants, aiding in accurately documenting norms, defining variable correlations, and understanding generalized interactions across constructs, thereby yielding crucial insights and discoveries (Alrowwad et al., 2020). Survey research possesses the capability to characterize the relationships between variables (Groeneveld et al., 2015). The primary focus of the survey approach in this study is quantitative, involving the collection of a substantial amount of participant data through an open-ended questionnaire. To authenticate the instruments, a panel of knowledgeable adjudicators was employed, as recommended by Dong et al. (2023). A pilot test of the questionnaire was conducted to ensure that its wording and structure were suitable for the survey, allowing the researcher to verify the appropriateness of the data needed from the target group. Following the confirmation of the instruments' validity, an online questionnaire was distributed to the respondents, with an anticipated total of about 500 participants.

To achieve a 95% confidence level within a population of 500, Krejcie and Morgan's table suggests a sample size of 210 respondents; however, for increased precision, this study gathered data from 214 respondents. The study instrument included absorptive capacity as the dependent variable and E&T, FESW, and SE as independent and reinforcing variables, accordingly. Relevant variables were selected and measured based on the parameters within the scope of the present study. Table 1 provides a comprehensive overview of the main variables and constructs within the study, detailing the number of items associated with each.

Table 1. Variables, constructs, and items of research instruments

Variables	Constructs	N	Items
Dependent variable	Absorptive capacity	1	Competencies of understanding and learning capabilities.
		2	Ability to transform new knowledge into commercial ends.
Independent variable	Education and training	1	Number of educational organizations.
		2	Number of training management institutions.
		3	Number of educated people for research and innovation.
	Foreign-educated and skilled workers	1	Talent and intelligence in the national innovation system.
		2	knowledge and expertise in the national innovation system.
		3	Number of research and innovations in the national innovation system.
Reinforcing factor	Standards of education	1	Research based on teaching and training curriculum.
		2	Introducing a new syllabus according to new challenges.

The study centered around the dependent variable of absorptive capacity, encompassing competencies related to comprehension and learning (Item 1) and the application of newly acquired knowledge for commercial purposes (Item 2). E&T served as the independent variable, with components such as the quantity of educational organizations (Item 1), training management institutions (Item 2), and educated individuals for research and innovation (Item 3). Another independent variable was FESW, covering the number of research and innovations in the NIS (Item 3), knowledge and expertise in the NIS (Item 2), and skills and intelligence in the NIS (Item 1). The reinforcing factor was the SE, incorporating a curriculum for teaching and training based on research (Item 1) and the introduction of a new syllabus in response to emerging challenges (Item 2). These constructs and items were thoughtfully selected and measured to explore their interconnections and contributions to the absorptive capacity of UIRC.

The methodology followed a structured TRIZ problem-solving process to systematically address the challenges within UIRC. To ensure logical consistency, the application of TRIZ encompasses four key stages: problem identification, cause analysis, contradiction analysis, and application of inventive principles. To assess the practical implications of the solutions developed through TRIZ, this study additionally incorporated partial least squares (PLS) analysis. PLS serves as a complementary tool that validates the effectiveness of the strategies identified through the TRIZ framework, thus ensuring that the proposed solutions for enhancing absorptive capacity are grounded in empirical data. The process began with function analysis to identify and outline the functions of the system, followed by cause-and-effect chain analysis (CECA), which was used to trace the root causes of weak absorptive capacity within UIRC. Following this, a contradiction analysis was conducted to identify conflicting factors, such as the dependence on foreign expertise versus the need to develop local talent. Once contradictions were identified, appropriate TRIZ inventive principles, such as prior action, dynamicity, and phase transition, were applied to propose structured solutions. Finally, the effectiveness of these proposed solutions was validated through PLS analysis, which served as a quantitative measure to determine the impact of TRIZ-based strategies on absorptive capacity. By following this structured paradigm, the study ensured that TRIZ was applied in a methodological and systematic manner, avoiding any logical confusion. The detailed methodology can be visualized in Fig. 1.

Moreover, the TRIZ theory, along with the validated statistical programs Statistical Package for the Social Sciences and Smart PLS, was employed to develop and validate our hypothesis. TRIZ models and tools were used to determine the most effective method for improving the absorptive capacity of UIRC. The TRIZ method encourages critical thinking for creative problem-solving. In this context, a function model (Fig. 1) was created to illustrate the seamless process of strengthening the NIS. On the other hand, the CECA (Fig. 2), which is the second feature of TRIZ, revealed

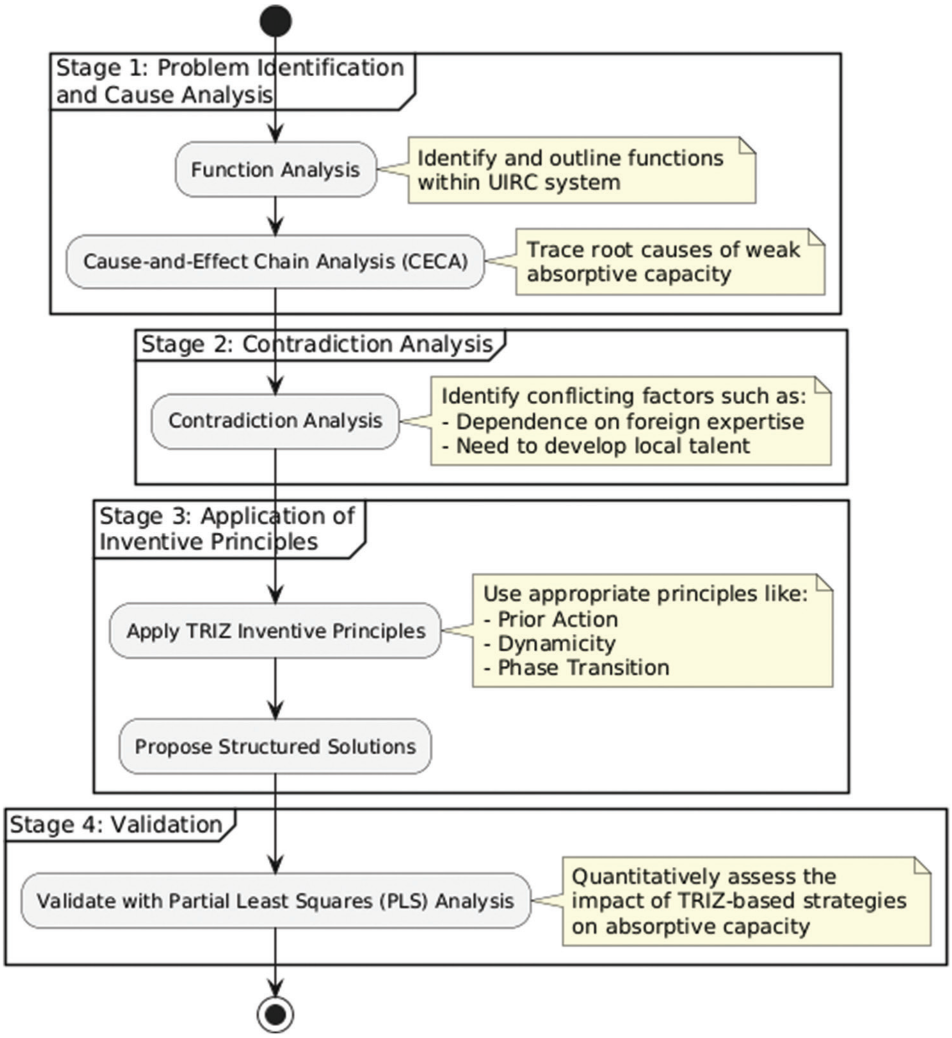

Fig. 1. The Theory of Inventive Problem Solving-based methodology with partial least squares validation for university-industry research collaboration

potential root causes with the function model that can be systematically addressed.

To achieve this, a TRIZ matrix was utilized to identify parameters that were worsening and improving, followed by the identification of proposed creative principles. Table 2 presents one possible approach to resolving the issue. Concurrently, the TRIZ-based framework (Fig. 3) illustrates a tangible, concise, accurate, and systematic solution to the problem.

3.1. Function Model

A function model, also referred to as an activity model or process model, is a systematic representation of the functions, actions, activities, procedures, and operations within a specific field of study. It serves as an organized depiction of the various components that contribute to the functioning of a system, aiding in the identification of ongoing situations, opportunities, information needs, and the description of functions and processes (Valjak & Bojcetic 2022). A function model represents the key processes in UIRC and their impact on strengthening the NIS. Initially, the function "providing real problems" was included, but further analysis revealed that its effectiveness depends on how well industries can absorb and apply academic insights. Simply presenting real-world challenges does not automatically lead to innovation unless structured mechanisms are in place to facilitate knowledge application. The revised function model, therefore, shifts the focus from merely identifying problems to enhancing problem-solving capabilities within collaborations. Similarly, the function "provide knowledge" was reconsidered because knowledge alone does not guarantee innovation. Industries often face difficulties integrating theoretical research into practical solutions. If knowledge transfer occurs without proper application pathways, research outputs may remain underutilized. To address this, the

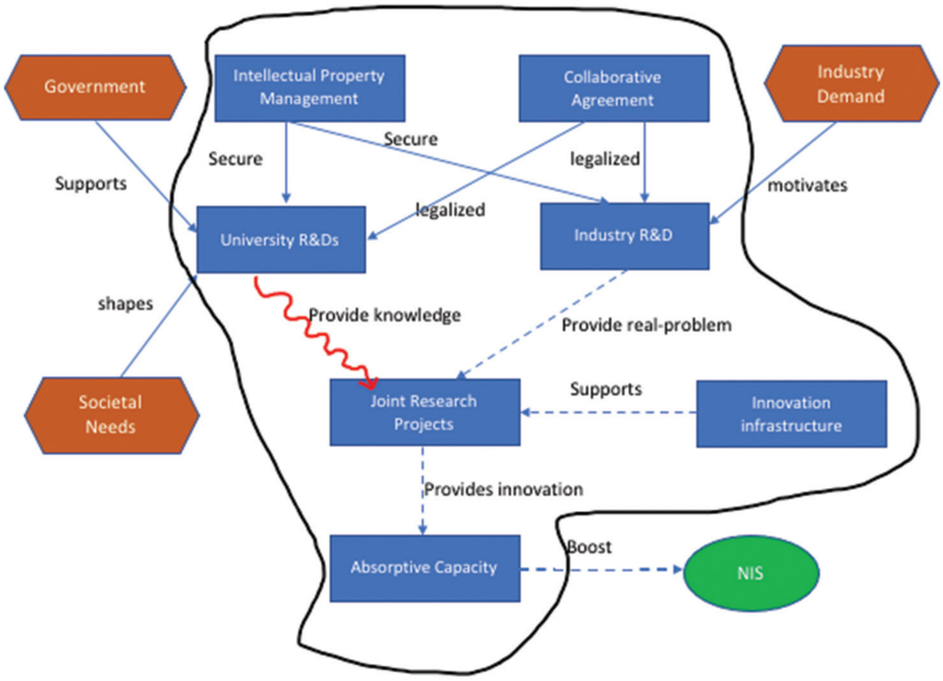

Fig. 2. University-industry research collaboration function model

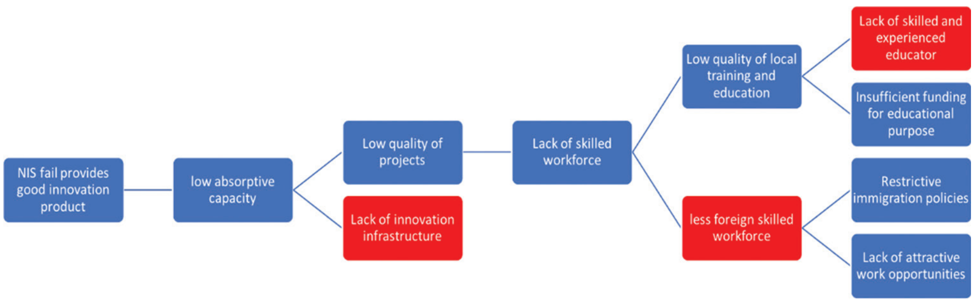

Fig. 3. Cause and effect analysis for the national innovation solution's failure to provide a good innovation product

Table 2. Inventive principles

Inventive principles	
# 10 Prior action # 28 Replacement of mechanical system	# 15 Dynamicity # 36 Phase transition

revised function model now emphasizes co-creation of knowledge, where universities and industries collaborate actively to ensure that research is directly applicable to industrial needs.

Fig. 1 in this context illustrates the key components playing a significant role in research and discoveries. For instance, programs for instruction and training are depicted, showcasing their role in supporting basic research, which in turn, forms the foundational knowledge and comprehension base for the NIS. E&T programs play a crucial role in equipping individuals with the necessary knowledge and skills for research and development initiatives. On the other hand, absorptive capacity is responsible for the recognition, absorption, and utilization of external information, enabling industries to identify and leverage insights from external sources, fostering innovation and growth. This function is intricately connected to UIRC, as the successful transfer and exchange of knowledge depend on effective collaboration between universities and industries. The shared role of collaboration is evident in the intertwined dynamics of absorptive capacity, UIRC, and E&T programs. It underscores the critical importance of collaborative efforts and absorptive capacity in achieving positive outcomes and advancing the national innovation system. Moreover, the functional model depicted in Fig. 2 offers a comprehensive overview of the interactions among various components that contribute to the goal of enhancing the absorptive capacity of NIS through knowledge transfer and effective UIRC. Within the framework of UIRC and NIS, it underscores the significance of E&T, collaborative efforts, and the utilization of knowledge in driving innovation and fostering growth.

3.2. Cause and Effect Chain Analysis

CECA highlights that while real-world problems exist in many industries, the challenge lies in their ability to absorb and implement academic research into practical solutions. The issue is not the absence of real problems but the lack of structured mechanisms to bridge academic research and industrial application. Similarly, knowledge provision alone is not sufficient—without clear implementation strategies, industries may struggle to translate academic insights into innovation. The revised function model thus emphasizes solution-driven collaboration and industry-academia co-creation, ensuring that research findings are effectively utilized.

Additionally, TRIZ analytical thinking employs CECA to identify conflicts related to goals. CECA involves investigating the underlying causes and their relationships to an observed effect, with the primary aim of graphically representing the outcome (Davies et al., 2014). This effect is usually a negative outcome, drawback, or issue that the project aims to address. CECA is utilized to delve into the fundamental reasons behind a specific occurrence (Crown et al., 2020). For instance, in the context of the NIS, the primary issue is its limited absorptive capacity. Incorporating FES can potentially enhance the volume of research and innovation projects. However, CECA studies and previous research indicate that FESW may have a negative impact on the unemployment rate.

Table 3 highlights the problems and their underlying causes in the hiring of FESW.

In the context of the research, the table delineates specific challenges along with their respective underlying causes. The first challenge pertains to insufficient absorptive capacity, and it is discerned that a workforce lacking in education and competence is the primary driver of this issue. Challenge 2, centering on the presence of a skilled and educated immigrant labor force, is traced back to the inadequacy of a competent and educated local workforce. Moreover, Challenge 3 underscores the problem of unemployment, attributing it to low educational standards and the recruitment of foreign workers as the main contributing factors. This table succinctly summarizes the central issues related to employment and absorptive capacity, providing clarity by establishing a direct link between each challenge and its underlying causes. Table 4 and Fig. 3 indicate that the country's lack of educated and trained workers is the primary reason for low absorptive capacity. Therefore, while FESW can increase the workforce in research companies, it may also contribute to a decline in the employability rate.

Table 3. Challenges and root causes

Challenges	**Root causes**
Low absorptive capacity	Lack of a local educated and skilled workforce
Foreign-educated and skilled workforce	Lack of an educated and skilled workforce
Unemployment	Number of hiring foreign workforce Low standard of education

Table 4. If then contradiction analysis

If-than-but	**Statements**
If	Hired foreign-educated and skilled workforce
Then	Enhanced number of research and innovation
But	Unemployment of the local workforce increased
Improving parameter	Productivity
Worsening parameter	Force (Intensity)
Recommended inventive principle	Prior action, dynamicity, replacement of mechanical system, and phase transition

Based on Fig. 3, we formulated an engineering contradiction model as shown in Table 4. Table 4 provides problem modeling using engineering contradiction. This model analyzed the basic challenge to enhance the research collaboration between universities and industries and NIS, specifically hiring the FESW to improve the number of research and innovations. However, hiring FESW will increase unemployment among the local educated workforce. The detailed solutions of this model are discussed in the following section.

From the contradiction analysis, it has been analyzed that the basic challenge to enhance the research collaboration between universities and industries and NIS is the lack of an educated and skilled workforce. To resolve the matter, it is mandatory to refurbish the absorptive capacities of the researchers by improving the SE. In this regard, Table 3 provides a comprehensive overview of the issues along with their underlying causes.

3.2.1. Applying inventive principle

The application of inventive principles is geared toward stimulating creative thinking to address technical challenges (Krejcie & Morgan, 1970). The objective of research on innovative principles is to refine principal definitions by providing a comprehensive list of analogous examples and customizing definitions for specific domains, such as manufacturing, business, informatics, and chemistry (Valjak & Bojectic, 2023). In this context, TRIZ recommends inventive principles (Table 2) as potential solutions for the challenges. Table 2 delineates specific innovative principles designed to address challenges, with each principle offering a distinct perspective on problem resolution. The first principle, "prior action," underscores the importance of establishing robust policies and strategies in advance to navigate through challenging situations effectively. The second concept, "dynamicity," highlights the significance of adaptability in plans and programs to address shifting conditions. The third principle, "replacement of mechanical systems," suggests that better outcomes may result from modernizing or replacing antiquated systems. The fourth and final premise, "phase transition," proposes a modification or overhaul of the educational system to achieve constructive outcomes. Each tenet presents a unique strategy for overcoming obstacles, all contributing to the shared objective of enhancing employment rates and absorptive capacity. The inventive principles were developed through a thorough examination of creative solutions from previous patents.

The TRIZ toolkit outlines four potential solutions to address the issues of unemployment and insufficient absorptive capacity. For instance, the innovative principles suggest implementing phase transition, dynamicity, prior action, and mechanical system replacement to enhance the nation's employability and increase its absorption capacity. To delve into specifics, the principle of previous activity advocates for robust policies and plans for each affair, while dynamicity encourages flexibility in these areas. Similarly, phase transitions and mechanical system replacements amplify the notion of action shifts. The innovative ideas presented in the TRIZ toolkit offer insights into potential strategies that can be applied to enhance absorptive capacity and increase the employment rate. Table 5 provides a detailed explanation of the recommended creative principles, offering a comprehensive guide for implementing strategies to address the challenges of absorptive capacity and unemployment.

Table 5 provides a comprehensive overview of specific creative principles, their associated imaginative triggers, and the potential solutions that can be derived from their application. The inventive trigger in focus is the imperative need for a change in the national curriculum, index, and standard of education. The first principle, "prior action," advocates taking the necessary steps proactively and in advance. The second principle, "dynamicity," underscores the importance of a dynamic environment for optimal performance, with potential solutions centered around enhancing flexibility and adaptability. These solutions

Table 5. Inventive principles descriptions

Invention principle	**Inventive trigger as a guideline**	**Potential solutions from the suggested inventive principles**
# 10 Prior action	Perform the required change in advance	The standard of education/index of education/and curriculum of education must be changed at the national level.
# 15 Dynamicity	The environment must be dynamic to provide optimal performance/ enhancing flexibility and adaptability	Increase the dynamicity of education and training programs to better align with industry needs/ SHuman capital must be transferred into intellectual capital, so the absorptive capacity can be enhanced.
# 28 Replacement of mechanical systems	Replace the system that is fixed with changes over time	The number of local employment opportunities must be increased by providing up-to-date education and training.
#36 Phase transition	Using the phenomenon of phase change	Increase the innovative capabilities of the nation by changing the old prospectus to a new one.

involve making E&T programs more dynamic to meet industry demands and transforming human capital into intellectual capital to enhance absorptive capacity. The third principle, "replacement of mechanical system," suggests replacing outdated E&T with more modern approaches to increase local employment, replacing fixed systems that are unable to adapt to changing times. The fourth principle, "phase transition," utilizes the phenomenon of phase shift to propose practical ways to enhance the country's innovation capacity by repurposing outdated prospectuses. This approach suggests not only replacing old frameworks with new ones but also adapting and improving existing structures to meet modern demands.

Table 6 offers a systematic overview of the challenges at hand, their root causes, and recommended solutions for effective problem resolution. The primary challenge involves the low absorptive capacity within universities and industries, primarily attributed to an

Table 6. Challenges, root causes, and solutions

Challenge	Root cause	Solution
Challenge 1: Low absorptive capacity in universities and industries	Lack of an educated and skilled workforce	Solution 1: Prioritize hiring foreign-educated and skilled workforce to improve absorptive capacity
		Solution 2: Increase dynamicity in education and training programs to better align with industry needs.
Challenge 2: High unemployment rate	Low standard of education	Solution 3: Replace outdated mechanical systems with modern ones to improve productivity and competitiveness
		Solution 4: Implement phase transition in education by increasing the index of education to better prepare graduates for industry demands

inadequately educated and skilled workforce. The table delineates two principal approaches to tackle this issue: prioritizing the hiring of foreign-educated and skilled workers to enhance absorptive capacity and enhancing the dynamism of E&T programs to align more effectively with the evolving needs of industry. The secondary challenge pertains to a high unemployment rate, rooted in the inadequacies of the education system. In response, the table proposes two strategic measures: first, integrating contemporary mechanical systems to enhance competitiveness and productivity, and second, implementing a phase transition in education by elevating the educational index to better prepare graduates for industry expectations. These collective strategies aim to address the underlying issues, fostering an environment that supports improved absorptive capacity and reduced unemployment rates through strategic interventions in education, workforce dynamics, and systemic changes.

Following a comprehensive explanation of the innovative principles, they were practically applied to address real-time problems. Table 6 outlines the identified challenges along with the root cause and solutions. Solution 1, prioritizing the employment of foreign-educated and talented labor, and Solution 2, enhancing dynamicity in E&T programs, offer effective measures to overcome Challenge 1, characterized by low absorptive capacity in universities and industries. On the other hand, Solution 3, replacing outdated mechanical systems, and Solution 4, implementing phase transition in education through improving the index of education, are proposed to tackle Challenge 2, which involves the high unemployment rate resulting from the hiring of skilled workers with foreign education. These solutions reflect a strategic approach to address the identified challenges and promote positive outcomes.

Fig. 4 serves as a visual aid to enhance understanding of the relationship between each solution and the identified challenges. These visuals facilitate the decision-making process by providing a clear representation of how well each solution addresses the specific contradictions and underlying issues outlined in the problem statement. They contribute to a comprehensive and organized approach to evaluating and ranking solutions based on their effectiveness in resolving the identified challenges related to absorptive capacity and unemployment. Furthermore, Fig. 4 clearly demonstrates that employing creative ideas can effectively tackle issues related to low absorptive capacity in academic institutions and businesses, as well as address national unemployment. For instance, leveraging past practices and introducing dynamism can serve as proactive measures for a workforce with foreign education and expertise. Similarly, addressing the second problem can involve implementing creative ideas, such as replacing outdated mechanical systems and introducing phase transitions. For example, revamping the obsolete educational system requires the adoption of new teaching and training methodologies. Instead of a curriculum based on theory, educational institutions must transition to one grounded in research. The advancement of research and innovations, as well as researchers' capacity to absorb information, is insufficiently bolstered by theoretical knowledge alone. Thus, the quality of education plays a significant role in enhancing the capacity of universities, industries, and the NIS. TRIZ's approach provides a means to alleviate the challenges by emphasizing the significance of E&T for UIRC and the NIS. A detailed and comprehensive description is presented in Fig. 4. Fig. 4 outlines the parameters of the "index of education and educated and skilled workforce," illustrating the proposed solutions to mitigate the challenges related to absorptive capacity. Proposed solutions encompass improving the absorptive capacities of universities and industries, the number of research and innovations, and fortifying the NIS. According to the TRIZ-based framework to enhance the absorptive capacity of the NIS requires a modification in the education index or standard. The inventive principles, such as phase transitions, mechanical system replacements, prior action, and dynamicity, contribute to enhancing the

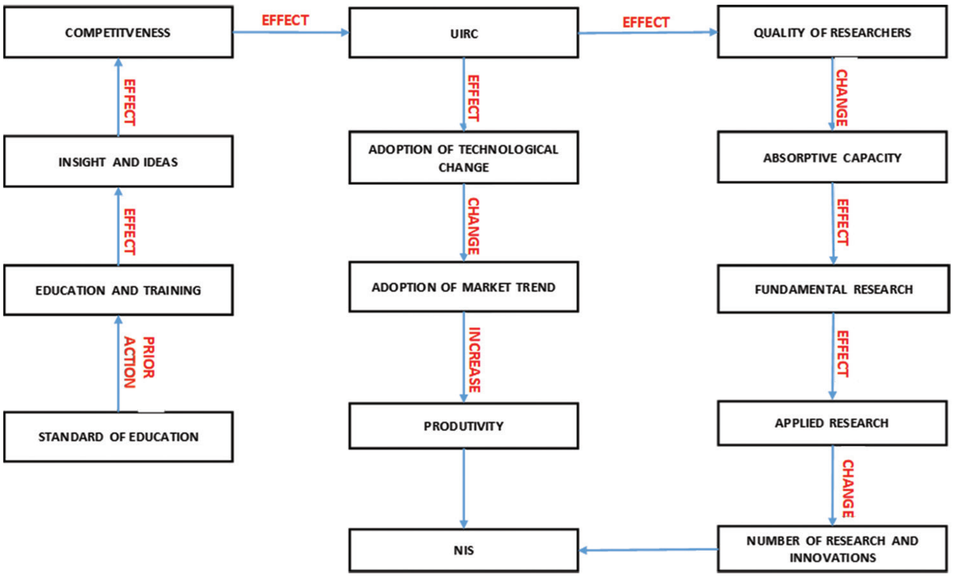

Fig. 4. Theoretical framework using the Theory of Inventive Problem Solving approach
Abbreviations: NIS: National innovative solutions; UIRC: University-industry research collaboration

perception of action shifts. They provide insights into potential strategies that can be employed to improve the absorptive capacity of NIS.

4. Results and Analysis

In this study, both PLS analysis and the Statistical Package for Social Sciences software were utilized for data analysis. It is important to highlight that each variable in this study was employed in a formative manner. Consequently, the evaluation of the formative path model necessitates completing both the measurement and structural model assessments (Labuda, 2015). This approach ensured a comprehensive understanding of the relationships and interactions between the variables, allowing for a thorough analysis of the formative nature of the path model in the study.

To strengthen the connection between TRIZ and PLS, it is essential to clarify the role of PLS as a validation tool rather than an independent analytical framework. While TRIZ provides theoretical solutions based on systematic problem-solving heuristics, PLS analysis empirically tests whether these solutions align with real-world data. If PLS results support TRIZ solutions, it provides quantitative validation that the proposed strategies effectively enhance absorptive capacity within UIRC. However, if PLS results contradict TRIZ, several explanations must be considered. First, a mismatch between theoretical solutions and practical implementation may indicate that while TRIZ suggests effective strategies, they may require additional contextual adaptation before being applicable in specific industry settings. Second, measurement issues within the PLS model could lead to discrepancies if certain constructs do not fully capture the intended aspects of TRIZ-based solutions, requiring adjustments to the model design. Third, a contradiction between TRIZ and PLS could highlight limitations in industry absorptive capacity, where industries may lack the necessary readiness, infrastructure, or policy support to implement TRIZ-based solutions effectively.

By integrating TRIZ with PLS in this manner, a strong correlation is established between theoretical problem-solving and empirical validation, ensuring a logically consistent approach. The study acknowledges that while TRIZ serves as a structured innovation methodology, PLS provides an evidence-based verification mechanism to assess whether proposed strategies yield tangible improvements in absorptive capacity. If discrepancies arise, rather than dismissing TRIZ or PLS findings, further analysis should be conducted to determine the underlying cause of the inconsistency. This approach ensures that TRIZ applications remain logically sound while maintaining a rigorous empirical foundation for validating proposed solutions.

4.1. Assessment of the Measurement Model

The measurement model in this study was designed to elucidate the process of measuring latent constructs. It focuses on assessing the validity of the constructs and their indicators to ensure the accuracy and reliability of the measurements. The goal is to thoroughly evaluate the measurement qualities, ensuring that the indicators effectively capture the intended latent constructs and contribute to the overall robustness of the model. This meticulous examination is crucial for establishing the credibility and effectiveness of the measurement model employed in the study.

4.2. Assessment of Construct Validity

The importance of avoiding redundancy among constructs at the construct level was emphasized to prevent multicollinearity, which is inferred for each construct in this study. Multicollinearity occurs when two or more variables in the model exhibit a significant correlation, leading to potential issues. In the presence of multicollinearity, regression coefficient estimates become unreliable. The study made sufficient efforts to operationalize the five variables effectively, aiming to capture their distinct contributions without introducing redundant or overlapping elements. The goal is to ensure the reliability and accuracy of the regression analysis and subsequent interpretations of the model.

Table 7 encompasses crucial information on constructs, their corresponding indicators, and collinearity statistics, specifically focusing on tolerance and variance inflation factor (VIF). These metrics are fundamental for the meticulous evaluation of the measurement model's quality. The objective of this model is to elucidate the measurement process of latent constructs, aiming to assess the reliability of both the constructs and their associated indicators. The primary emphasis is placed on four key constructs: SE, FESW, E&T, and absorptive capacity. Regarding absorptive capacity, AC_1 and AC_2 exhibited tolerances of 0.332 and 0.410, and VIF values of 3.012 and 1.260, respectively. In the E&T construct, indicators ET_1, ET_2, ET_3, and FW_1 displayed varied tolerance and VIF values, indicating potential collinearity concerns.

Table 7. Assessment of construct validity

Constructs	Indicators	Collinearity statistics	
		Tolerance	Variance inflation factor
Absorptive capacity	AC_1	0.332	3.012
	AC_2	0.410	1.260
Education and training	ET_1	0.831	1.203
	ET_2	0.757	1.320
	ET_3	0.925	3.171
	FW_1	0.811	2.233
Foreign-educated and skilled–workforce	FW_2	0.317	1.162
	FW_3	0.202	1.214
Standard of education	SE_1	0.844	1.125
	SE_2	0.922	1.037

The FESW indicators, FW_2 and FW_3, showed signs of collinearity based on their tolerance and VIF values. The SE construct, represented by SE_1 and SE_2, demonstrated acceptable tolerance and VIF values. Values exceeding five for VIF or falling below 0.2 for tolerance may signify problematic collinearity. These statistics play a pivotal role in evaluating the dependability of the measurement model and guide researchers in addressing potential issues with the indicators of the constructs for a comprehensive assessment of the structural model.

As stated by Cong and Tong (2008), a tolerance level higher than 0.20 and a VIF value not exceeding five are considered acceptable to avoid multicollinearity issues. The VIF test results are presented in Table 3, following the completion of the stepwise regression analysis for each construct. The findings indicate no evidence of multicollinearity, as all tolerance values surpass 0.20, and all VIFs remain below the thresholds. This suggests that the variables within each construct maintain sufficient independence and do not exhibit problematic correlations, meeting the recommended criteria for reliable regression analysis.

4.3. Assessment of Indicators' Validity

The indicator-level analysis addresses the question of whether each indicator effectively contributes to its respective construct by conveying the intended meaning. Strong relationships between constructs and indicators are recommended. In this regard, the weight of each indicator is determined to assess its relevance to the construct (Kim & Park, 2023; Russo & Spreafico, 2015). PLS calculates indicator weights, with a recommended threshold of $p < 1/\sqrt{n}$ to evaluate their contributions. In this research, each construct has a minimum of two and a maximum of three indicators, resulting in *p*-values of 0.709 and 0.578 for constructs with two and three indicators, respectively, as outlined in Table 4. These *p*-values indicate the significance of each indicator's contribution to its corresponding construct. The table illuminates the loadings and weights of the indicators for each construct in the model. These values are crucial for assessing the significance of each indicator's contribution to its corresponding construct. In the absorptive capacity construct, the weights of 0.3450 and 0.2895 for AC_1 and AC_2, respectively, indicate their relative importance. The indicator loadings, represented by 0.6118 and 0.9966, further elucidate the direction and degree of the association between the construct and the indicators. For the E&T construct, ET_1 and ET_2 exhibit weights of 0.4054 and 0.3272, while their loadings of 0.7208 and 0.8116 highlight their contributions. ET_3, with a loading of 0.9906 and a weight of 0.3319, similarly has a considerable impact on the construct. Similarly, FW_1, FW_3, FESW, SE, and SE_1 construct weights emphasize their contributions. Overall, the table facilitates understanding of the relative contributions of each indicator to its particular construct with respect to loading and weight.

The indicators' weights for each connected component are presented in Table 8, showcasing their substantial contribution to the variance in their respective constructs, as indicated by the significant item weights. However, the occurrence of two indicators, specifically "FW (FW_2)" and "SE (SE_2)," varies due to their formulaic values. In this context, when indicator weights are not significant at ($p< 1/\sqrt{n}$), item loadings become essential, as suggested by Hair et al. (2014). Remarkably, all of the constructs' item loadings were deemed significant (p>0.50), underscoring the profound significance and relevance of each construct with its corresponding indicators. Following the establishment of a valid measurement model, PLS analysis was conducted to assess the structural model in the subsequent phase of the study.

4.4. Assessment of the Structural Model

The study investigated three main relationships (H1a, H2) and one reinforcing effect (H1b) proposed for the structural model. The examination of the structural model involved the assessment of R^2 values and pathway coefficients. The findings of the hypotheses are illustrated using the research model, which is presented in two stages in this study. Figs. 5 and 6 provide a visual representation of how FESW impacts UIRC and absorptive capacity, and how E&T influences UIRC and absorptive capacity, respectively. These visualizations offer a clear understanding of the relationships between the inventive principle and the key variables in the study.

Table 8. Assessment of indicators' validity

Constructs	Indicators	Indicators weight (t−V)	Indicators loading (t−V)
Absorptive capacity	AC_1	0.3450	0.9966
	AC_2	0.2895	0.6118
	ET_1	0.4054	0.7208
	ET_2	0.3272	0.8116
Education and training	ET_3	0.3319	0.9906
	FW_1	0.1445	0.6726
Foreign-educated and skilled workforce	FW_2	−0.0476	0.8234
	FW_3	0.0393	0.9667
Standard of education	SE_1	0.6093	0.5882
	SE_2	−0.3969	0.7512

In terms of the structural model, the R^2 values and path coefficients (β) are crucial for explaining the variances in absorptive capacity attributed to the impacts of FESW and UIRC. For instance, the β value of FESW and UIRC, represented as 0.497 and 0.542, respectively, highlights their significant impact on absorptive capacity. Correspondingly, the R^2 values of absorptive capacity, amounting to 11.6%, underscore the substantial contribution of FESW to the variance in absorptive capacity. Thus, Fig. 5 establishes that FESW plays a critical role in enhancing both UIRC and their collaborative absorptive capacity.

Furthermore, Fig. 6 illustrates the impact of E&T on UIRC and absorptive capacity, portraying their significant role on both variables. Path coefficient values of E&T (1.985 and 1.236) indicate a significant influence on absorptive capacity. This depiction in Fig. 6 emphasizes the importance of E&T in fostering UIRC and contributing to their joint impact on absorptive capacity.

The R^2 values for absorptive capacity in the context of E&T stand at 21.3%, indicating a substantial contribution of E&T to the variance in absorptive capacity. Moreover, the path coefficients of E&T (1.985) and UIRC (1.236) were elevated by introducing the reinforcing component SE from 1.985 to 2.708 and UIRC from 1.236 to 2.103, respectively. This reinforcement resulted in an increase in the variations R^2 from E&T to absorptive capacity, escalating from 21.3% to 31.8%. Consequently, Fig. 6 illustrates the significant reinforcing role of SE in enhancing E&T and UIRC efficiency, subsequently improving absorptive capacity.

The analysis conducted in this study underscores the significance of the E&T factor in enhancing the absorptive capabilities of the NIS. While it is widely recognized that the presence of FESW contributes to the development of research and innovations, the study's results reveal an interesting finding. Contrary to the initial hypothesis that FESW would have a more substantial positive impact on NIS's absorptive capacity, the research indicates that E&T, with an R^2 value of 21.3%, has a greater and more significant influence on NIS's absorptive capacity compared to FESW, which has an R^2 value of 11.6%.

The research findings challenge initial assumptions about the perceived significance of FESW in relation to absorptive capacity. Contrary to expectations, the study indicates that E&T emerges as a more influential and desirable element for enhancing the absorptive capacity of NIS compared to FESW. Moreover, the study contributes to existing literature by identifying SE as a reinforcing element. The analysis suggests that while E&T at the national

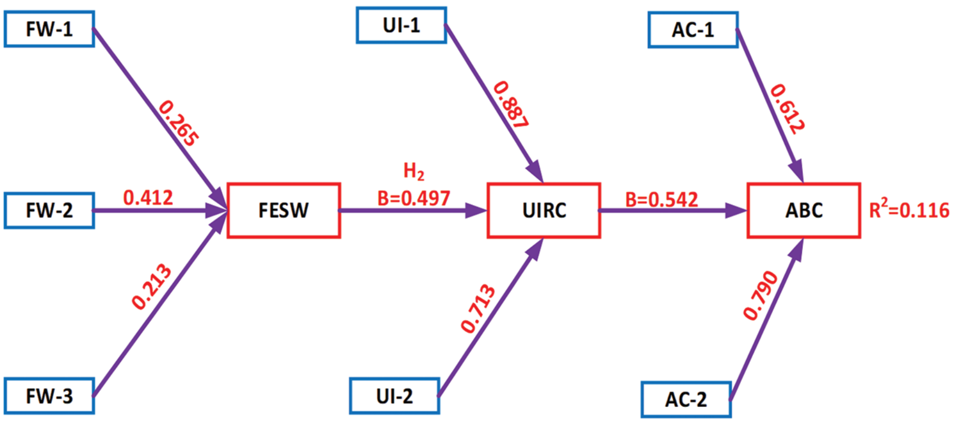

Fig. 5. Effect of FESW on UIRC and ABC
Abbreviations: FESW: Foreign-educated and skilled workforce; UIRC: University-industry research collaboration, ABC: Absorptive capacity

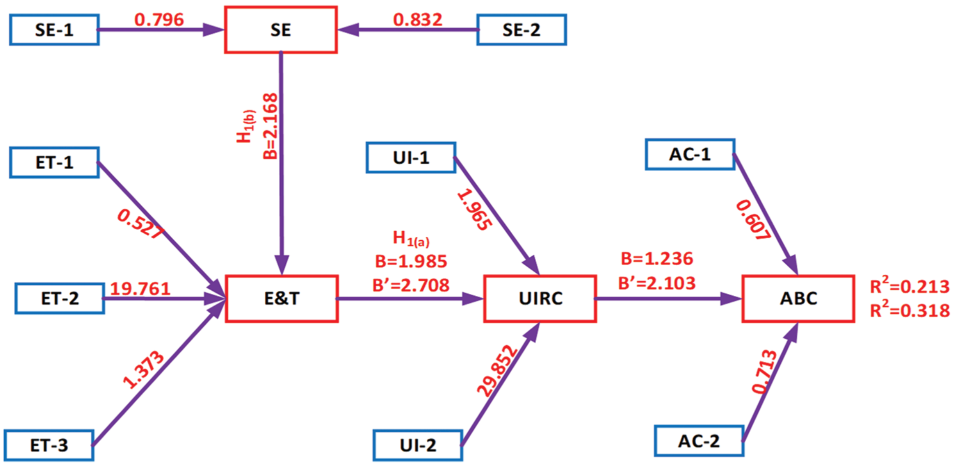

Fig. 6. Effect of E&T on UIRC and ABC
Abbreviations: E&T: Education and training; UIRC: University-industry research collaboration; ABC: Absorptive capacity

level can enhance the competence of UIRC, SE plays a crucial reinforcing role, providing an additional advantage in improving NIS's absorptive capacity. This nuanced understanding contributes valuable insights toward the inventive principles (prior action, dynamicity, replacement of mechanical system and phase transition) that provide a valuable solution to not only mitigate the FESW and employability disorders from the country but also provide a considerable pathway to enhance the absorptive capacities of the researchers and consequently the number of research and innovations in NIS.

5. Conclusion and Future Direction

In conclusion, this research offers enduring pathways for enhancing the absorptive capacity of UIRC and provides profound insights into the realm of NIS. Despite numerous studies focusing on UIRC assessment, the present research stands out as theory-based, filling a critical gap in existing literature. By underscoring the substantial influence of UIRC on the NIS, this article endeavors to bridge the divide between research and innovation organizations and policymakers. The findings aim to inform strategic decisions, fostering a more synergistic relationship between academia, industry, and policymakers in the pursuit of innovation and technological advancement.

The study makes several noteworthy contributions to the ongoing discourse on research and innovation projects involving collaborations between academic institutions and business sectors. First, it provides practical solutions within the framework of TRIZ, shedding light on the limitations and opportunities inherent in such studies. TRIZ introduces a fresh perspective by pinpointing absorptive capacity as a vital factor influencing the inventive performance of UIRC, thus strengthening the NIS.

Second, the research delves into the significant constraints faced by UIRC, with specific emphasis on the role of E&T. This focus underscores the importance of intellectual capital development and the learning processes within UIRC, contributing valuable insights into the challenges and opportunities associated with educational initiatives in the context of collaborative research and innovation, rather than hiring FESW. The study, therefore, extends the understanding of the multifaceted dynamics involved in UIRC, providing a foundation for informed decision-making and strategic planning in this domain. The versatility of the TRIZ framework positions it as an invaluable tool for policymakers seeking practical solutions across various scenarios. The study underscores the effectiveness of TRIZ by generating creative ideas (prior action, dynamicity, replacement of mechanical system, phase transition), emerging as a potent strategy to address limitations in absorptive capacity. This finding adds depth to the existing literature by highlighting the important role of E&T initiatives in enhancing UIRC's capacity for innovation.

Moreover, the research contributes to the scholarly landscape by introducing a reinforcing factor, SE, as a crucial component that fortifies UIRC's E&T capacity. These supportive elements are encompassed in intellectual capital development, fostering robust collaborations between academia and industry, diminishing the dependencies on FESW, and cultivating an independent innovation ecosystem. Recognizing and nurturing these factors becomes paramount for maximizing UIRC's potential to drive innovation. This insight provides policymakers and stakeholders with a nuanced understanding of the intricate elements that contribute to a thriving collaborative research and innovation landscape.

In practical terms, policymakers stand to gain significant insights from the TRIZ approach, as it furnishes them with a comprehensive understanding of how UIRC dynamics influence the NIS. This study aspires to offer a robust framework that enhances UIRC's innovation capacity, providing policymakers with clarity on the intricate interconnections among academia, industry, and the broader innovation ecosystem. By leveraging the TRIZ methodology, legislators can make informed decisions and formulate effective policies that foster a conducive environment for collaborative research, innovation, and the overall advancement of the NIS.

Furthermore, this study suggests intriguing avenues for future research aimed at overcoming the challenges encountered in this study. By expanding the scope beyond Malaysia, conducting comparative analyses among various developed and emerging nations can unveil significant disparities in the enhancement of the NIS's creative potential. Such cross-national analyses have the potential to enhance our understanding of the intricate dynamics propelling innovation within UIRC and its broader implications for NISs. This comparative approach offers the opportunity to glean valuable insights from different contexts, contributing to a more comprehensive and nuanced understanding of the factors influencing innovation on a global scale.

This study essentially functions as a lighthouse, illuminating the path toward a more comprehensive UIRC that integrates the NIS. The insights gained from this research provide a roadmap for policymakers to optimize UIRC, offering guidance to nations in fostering a more innovative and promising technological future. By emphasizing the interconnectedness of UIRC with broader innovation systems and educational standards, this study provides valuable signposts for policymakers seeking to navigate the complexities of enhancing innovation and technological advancement on a national scale.

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