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The role of university–industry linkages in promoting technology transfer: implementation of triple helix model relations

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Abstract

This study recognized the importance of linking higher education institutions with various industries in a given country to promote technology transfer and sustainable development. However, in one or another way, the linkage was not well-practiced in Ethiopia. The study aims to assess the role of university–industry linkages in technology transfer and identify the barriers and opportunities of the linkage. Universities have institutionalized intermediary organizations such as technology transfer offices, collaborative research centers, incubators, and science parks to enhance university–industry collaboration. The collaboration between academia and industry is understood as the transactions between universities and firms that involve the exchange of knowledge, skills, resources, and capabilities. The study uses the concept of the triple helix model and proposes the establishment of the Higher Education Institutions–Industry Resource Integration Center as a way forward to solving the problems that Ethiopian industries are facing. A triple helix of university–industry–government relations is emerging as a common format that transcends national boundaries. The integration of these functions is changing the nature of the university and its role in society. The potential for national development in Ethiopia and elsewhere resides in entrepreneurial universities taking the lead in infusing knowledge, innovation, technology, and enterprise into the entire society.

Keywords: Technology transfer, University–industry linkages, Collaboration, Triple helix, Government, Innovation

Introduction

Technology is at the heart of development (Walsh et al., 2020). In the economy, there are not enough businesses to use their knowledge (Park et al., 2021). Technology is a system of knowledge, skills, experiences and organization. It is also the combination of equipment and knowledge (Co-operation and Development, 1998). Technological development is the overall process of invention, innovation and diffusion of technology or processes. It is the systematic use of economic, scientific, technical, and commercial knowledge to meet business requirements. The application of scientific knowledge to the practical aims of human life is also referred to as technology. Technology transfer (TT) is the process of conveying scientific and technological research results to the market place

and to wider society, along with associated skills and procedures. It is the movement of data, designs, inventions, materials, software, technical knowledge or trade secrets from one organization to another or from one purpose to another. The technology transfer process is guided by the policies, procedures and values of each organization involved in the process. Research on University Technology Transfer (UTT) has focused on emphasizing the importance of intellectual property (IP) licensing to technological commercialization strategies. Universities are under more and more pressure to make contributions to socioeconomic growth (Amry et al., 2021). In addition to the traditional roles, which were mainly teaching and basic research activities, universities have been taking on additional roles such as knowledge and technology transfer to industry and commercialization of knowledge (Alexandre et al., 2022). University–industry linkages play a crucial role in technology transfer. Effective and efficient University–Industry Linkage is a necessary condition for knowledge and technology transfer from university to the industry (Alexandre et al., 2022).

University graduates and research outputs have to be absorbed by the industry. University–industry linkage is aimed at supporting the creation of Science and Technology Innovation System in the country. This is meant to build collaborative research initiatives that would be industry driven, with the goal of technology invention, adoption or adaptation by regional industry. The government between academia and industry is understood as the transactions between university researchers and industry researchers or managers that lead to the creation of new knowledge or technology. In nations like Ethiopia, where the culture of developing and utilizing indigenous technology is low and the majority of companies are reliant on traditional trade, formal university–industry linkage and knowledge transfer channels must be aggressively pursued. The university can start and manage the linkage through official channels for efficient knowledge and technology transfer.

Some of the advantages of technology transfer are technology transfer leads to competitive advantage for a company to edge out its rivals; technology transfer helps in research and development of a particular product which helps to take into account public and private need; new technological innovations can lead to creation of new markets and birth of new consumers; it has cost-saving factors, when new equipment and machinery are used in place of old ones and new technology is being applied for making process running in the industries becomes less costly. Money can be saved in many ways which is beneficial for the business owners. University–industry linkage can have various benefits for both parties, such as enhancing productivity, competitiveness, innovation, and social welfare. Some of the challenges of university–industry linkages are different goals and objectives between universities and industries; different cultures and values between universities and industries (cultural barriers); intellectual property rights issues; legal constraint; infrastructure barriers; attitudinal barriers; lack of trust between universities and industries; lack of communication between universities and industries. These challenges interact in complex and dynamic ways to shape the outcomes and impacts of UILs. Therefore, it is important to adopt a holistic and systemic perspective when studying and managing university–industry linkages (UILs).

University–industry linkages play a crucial role in facilitating the transfer of technological knowledge from universities to firms. These linkages involve collaborations and

partnerships between academic institutions and industry, where both parties work together to solve challenges and promote innovation in a knowledge-based economy. The university system, with its essential training for scientists, is responsible for transferring technological knowledge to firms. This transfer of knowledge is essential for fostering innovation, entrepreneurship, and economic growth. Furthermore, publicly funded research is often used to stimulate knowledge transfer and promote economic growth (Chen & Esangbedo, 2018).

Importance of University–industry linkages are of utmost importance for several reasons. First, these linkages enable universities to align their research and educational programs with the needs of the industry. By actively engaging with industry partners, universities can ensure that their curriculum and research projects are relevant and up-to-date. This alignment not only enhances the quality of education and research at universities but also increases graduates' employability by equipping them with the skills and knowledge valued by the industry.

Second, university–industry linkages foster technological innovation by collaborating with industry, universities can access resources, expertise, and funding that are essential for conducting research and developing new technologies (AbebeAssefa, 2016; Priya et al., 2021; Teressa, 2022). This collaborative approach enables universities to contribute to the advancement of technology and scientific infrastructure, which in turn supports economic growth. Moreover, university–industry linkages serve as a catalyst for economic growth. By working together, universities and industry can drive the development and commercialization of new technologies, leading to the creation of innovative products and services. This collaboration helps to stimulate entrepreneurship and create new job opportunities, contributing to the overall growth of the economy. In addition, university–industry linkages play a crucial role in knowledge transfer from academia to society (Ssebuwufu et al., 2012). Through collaborations and partnerships, universities can effectively transfer their research findings, expertise, and knowledge to industry partners. This knowledge transfers enables industry players to stay updated with the latest advancements in their respective fields and utilize this knowledge to drive innovation within their organizations. The role of university–industry linkages in technology transfer is crucial as it aligns research and educational programs with industry needs, fosters technological innovation, drives economic growth, and facilitates knowledge transfer. Moreover, university–industry linkages play an important role in talent development (Teressa, 2022). Through collaborations with universities, industry players have access to a pool of talented individuals who are equipped with the necessary skills and knowledge. These individuals can contribute to research and innovation projects, driving technological advancements and supporting industry growth. Overall, university–industry linkages are essential for enhancing technological and scientific infrastructure, promoting innovation and entrepreneurship, driving economic growth, and facilitating knowledge transfer (Rossoni et al., 2023).

To the best of my knowledge, there have been no potential studies undertaken on the role of university–industry linkages in technology transfer in Ethiopia. Studying the function of university–industry links in Ethiopia is crucial if we accept that they aid in knowledge transfer and national growth. The relationship between technology transfer in Ethiopia and university–industry ties has not been extensively studied. Aside from

this, gap analysis, institutional capacity, and factors influencing university–industry links constituted the majority of the research publications. The implication is that university–industry linkages in promoting technology transfer were not given attention in Ethiopia. Identifying the challenges and impacts of university–industry linkages in technology transfer and economic growth becomes sound enough to put an agenda for further research and the targeting of policymakers in intervening in that particular study area.

University–industry linkage contributes to technology transfer and determines the firm products of the country. It is important to study the role of the University–industry linkages in Ethiopia which are instrumental in technology transfer (Bekana, 2017; Plewa et al., 2013). I found a systematic review on university–industry linkages in Ethiopia. The report presents the findings of a scoping study on university–industry linkages in Africa to determine what interface structures, policies, positions, incentives, and funding avenues are needed to promote effective university–industry linkages in Africa (Anato & Marisennayya, 2021; Zavale & Langa, 2018). This study has identified the major challenges hindering the growth of university–industry linkage (UIL) in Ethiopia, which include the presence of limited budget to research universities; mismatch between graduates' knowledge and skills and industries' needs; lack of trust between universities and industries; lack of awareness about the importance of UIL among stakeholders; and lack of government support (Anato & Marisennayya, 2021).

Another study has identified three categories of articles based on their theme of strengthening the UIL to effectively implement field-based learning (FBL) in Higher Education Institutions in Ethiopia (Gashaahun, 2020). Scholars, particularly in emerging nations, have long overlooked universities' role as the cradle for the development of skills and knowledge. Heterogeneity can be seen in the impacts of entrepreneurship and links between universities and industry on economic growth before and after the 2008 financial crisis (Hou et al., 2021). The role of university–industry linkages in technology transfer in Ethiopia is to strengthen the linkage of the university with the industry for mutual knowledge sharing and technology transfer. This is done through cultivating an innovation culture by organizing innovation consultative meetings with partners in the industry and its innovation hub. The Ethiopian educational system has placed a premium on university–industry linkages and technology transfer, resulting in the establishment of offices in all public universities (Gashaahun, 2020; Gobena et al., 2021).

The present study focuses on investigating the role of university–industry linkages in promoting technology transfer through the implementation of the triple helix method. The study aims to enhance technology transfer, multidisciplinary programs, teaching, research, prototyping, and industry experience for university personnel and students.

Methodology

Methods for technology transfer

Technology transfer is the process of sharing skills, knowledge, technologies, methods of manufacturing, samples of manufacturing and facilities among governments or other institutions to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials or services. The technology transfer process

is guided by the policies, procedures and values of each organization involved in the process. There are several methods for technology transfer such as exporting direct goods with technology incorporated, subsidiaries, licensing and joint ventures. The methods for technology transfer can be divided into two categories: domestic and international. Domestic technology transfer refers to the transfer of technology within a country or region. This can be done through licensing agreements, joint ventures, spin-offs or other means. International technology transfer refers to the transfer of technology across national borders. This can be done through licensing agreements, joint ventures, franchising or other means.

Methods (models) in university industry linkages

These are some of the main methodologies for university–industry linkage that can be used to guide and improve the collaboration process. A methodology for university–industry linkage is a systematic way of establishing and managing the collaboration between academic institutions and industrial firms for the purpose of mutual benefit, such as knowledge transfer, innovation, and economic development. There are different methodologies for university–industry linkage, depending on the context, objectives, and nature of the collaboration. Some of the common methodologies are as follows:

The Network model This is a model that emphasizes the importance of networks and relationships in facilitating university–industry linkage. The model suggests that the collaboration is based on trust, communication, mutual understanding, and shared goals. The model also highlights the role of intermediaries, such as technology transfer offices, industry associations, or research centers, in bridging the gap between university and industry (Ankrah & Al-Tabbaa, 2015; O'Dwyer et al., 2023).

The Evolutionary model This is a model that focuses on the dynamic and complex nature of university–industry linkage. The model suggests that the collaboration evolves over time through different phases, such as embryonic, initiation, engagement, and established. The model also identifies the barriers and enablers of each phase, such as trust, intellectual property, and cohesiveness (O'Dwyer et al., 2023; Plewa et al., 2013).

The Triple Helix model It is a "model of 'trilateral networks and hybrid organizations' of 'university–industry–government relations". This model describes the interaction of three institutional spheres: the university, the industry, and the government. The model suggests that the university can play an active role in innovation and economic development by collaborating with industry and government, and by taking on entrepreneurial functions. The model also implies that the boundaries between the three spheres are blurred and flexible, allowing for cross-sectional partnerships and exchanges (Etzkowitz, 2003).

Triple helix model as an important remedy

The triple helix model of innovation is a framework that describes the interactions between the university, industry, and government to foster economic and social development. The model is based on the idea that innovation arises with in each of the three spheres, such as interactions increase with in this framework, each component evolves to adapt some characteristics of the other institution, which then gives rise to hybrid institutions. The model was first theorized by Henry Etzkowitz and

Loet Leidesdorff in the 1990s (Etzkowitz, 2003; Okonofua et al., 2021). Triple-Helix is the most cited model in the discourse of university–industry linkage. The triple helix model is represented by three circles (helices) with overlapping showing interactions. University Industry Linkage can take various forms and involve different intensities of engagement. The three components of the model are universities engaging in research and development, Training, curriculum development, consultancy, education, incubators, and spinoff's; industries can be engaged in producing goods, Entrepreneurial venturing, product and service development; the government have given rise to new intermediary institutions, such as technology transfer offices, industry parks, and science parks. In addition, the government has given financing, policy formulation, innovation support, and advisory services. Writers in the field like Etzkowitz (2002) state that with the establishment of the Triple Helix model of university, industry and government interactions, universities are expected to play a leading role in strengthening the relationship. This institutional configuration stimulates innovation and technology transfer among the spheres. Hence, universities assumed to take the prime initiative in forging the triadic relationship.

The triple helix model has been widely adopted and as applied by policy-makers has participated in the transformation of each sector. There is a global competition and economic development between the university, government and industries (Kimatu, 2016). Figure 1 shows the links between the university, industry, and the government for their mutual benefit. Figure 2 depicts the conceptual framework for the study. Universities accept students with specific environmental qualities as input, as Fig. 2 illustrates. In addition, they hire and prepare faculty members and supply the necessary funds, materials, and knowledge to ensure their smooth operation. The inputs undergo some sort of processing as well, leading to the production of research results and skilled labor (graduates) for the economy. The labor market absorbs the knowledge produced as well as the qualified manpower produced by the universities. They also provide feedback for the improvement of each of the parts and keep the system cyclical. The government maintains university and industry balance by setting rules,

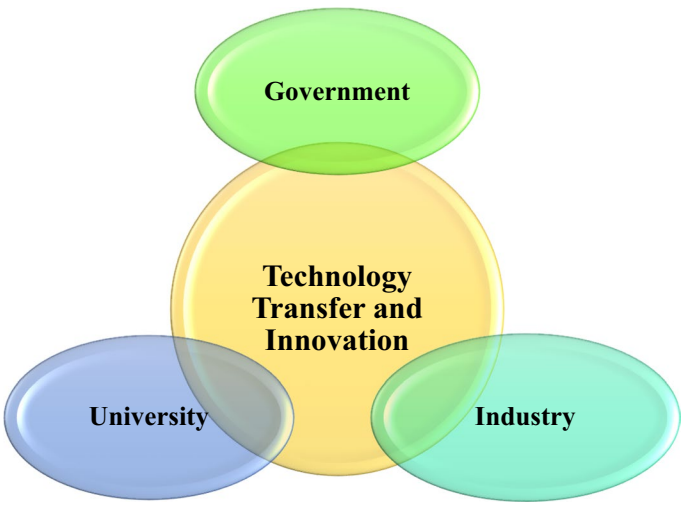

Fig. 1 The triple helix model university–industry–government relations

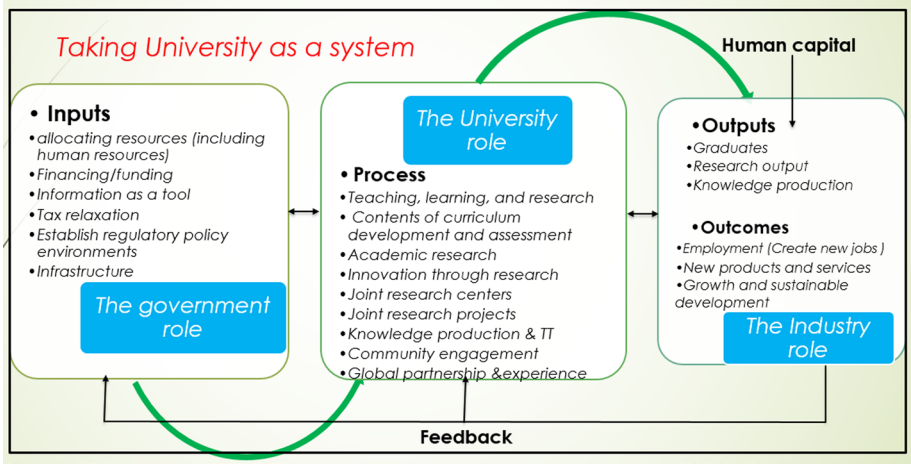

Fig. 2 Conceptual framework for the study

providing safeguards, and allocating resources, particularly in developing countries, while universities are responsible for research output quality and knowledge production.

Triple helix and policy making

The triple helix model has been used as a lens through which evolving relationships between university, industry and government can be analyzed (Galvao et al., 2019; Rodrigues & Melo, 2013). However, according to Etzkowitz (1994), it can also be a policy-making tool. It has been applied for both purposes by government organizations, such as the United States Department of Energy (Etzkowitz & Leydesdorff, 1995). Etzkowitz argues that after the end of the Soviet Era, triple helix inspired policies were implemented in Eastern Europe to promote their growth. In Sweden, the triple helix policy aimed at tying together innovation initiatives at different scales to increase their overall efficiency (Etzkowitz, 2007, 2008).

Public policy problems are socially complex due to a range of stakeholders who involve in the coordinated action. Not only promoting systems modeling as a methodology in policy development, but the workshops also provided evidence on the importance of having a holistic or systemic approach in formulating policies to address a complex national problem that requires interactions among stakeholders (Sunitiyoso et al., 2012). The triple helix model has also been applied to developing countries and regions (Cai & Amaral, 2021; Ferdinands et al., 2023; Fidanoski et al., 2022; Saad & Zawdie, 2011). The breakdown of the inefficiency score for different inputs reveals that countries have the largest potential for reducing CO_2 emissions and the least room to reduce the Education Index and Civil Society Participation (Fidanoski et al., 2022). A series of activities in the knowledge, innovation, and consensus areas achieve the Triple Helix systems' overall function, which is the generation, distribution, and use of knowledge and innovation. This viewpoint offers a more detailed understanding of the movement of resources and knowledge inside and across the spaces, which aids in identifying any gaps or obstructions. It also gives an explicit framework for the systemic interaction between Triple Helix players that was previously absent. The articulation and non-linear interactions

between the spaces, seen through the lens of Triple Helix Systems, can produce novel combinations of information and resources that can further innovation theory and practice, particularly at the regional level (Ranga & Etzkowitz, 2013, 2015; Sunitiyoso et al., 2012).

The quadruple Helix Model: It is built on the innovation economics triple helix model; the quadruple helix model adds civil society and the media as a fourth element to the framework of interactions between university, industry, and government (Cai & Lattu, 2022; Shin et al., 2023). Elias G. Carayannis and David F. J. Campbell co-developed the quadruple helix and the quintuple innovation helix framework; the quadruple helix was detailed in a 2009 study (Carayannis et al., 2012; König et al., 2021; Shin et al., 2023). With the introduction of civil society and the environment as pillars and focal areas of policy and practice, the framework significantly broadens and extends the triple helix model of innovation economics. The environment stresses the sustainability priorities and exigencies that need to inform and moderate both top-down policies and practices as well as bottom-up initiatives. In particular, civil society emphasizes the role of bottom-up initiatives complementing top-down government, university, and industry policies and practices (Cai & Lattu, 2022; König et al., 2021). Simultaneously, a number of authors were investigating the idea of an extension of the triple helix model of innovation to a user-oriented quadruple helix (Cai & Etzkowitz, 2020; Cai & Lattu, 2022; Leydesdorff & Smith, 2022). The goal is to close the gaps that exist between innovators and consumers, or civil society. In fact, this paradigm argues that the triple helix model limits the potential influence of developing technologies because they do not necessarily align with societal wants and requirements. This approach places equal emphasis on universities' civic responsibilities as well as their roles in teaching and research. The idea of a "media-based democracy" is also included in the quadruple helix model. Carayannis and Campbell, quoting Plasser, define this as "media reality overlaps with political and social reality; perception of politics primarily through the media; and the laws of the media system determining political actions and strategies" (Awasthy et al., 2020; Carayannis et al., 2012; González-Martinez et al., 2021). According to Carayannis and Campbell, this fourth helix encompasses both civil society and innovation users, recognizing that knowledge and innovation policies and strategies need to involve the "public" in order to effectively accomplish goals and objectives (Carayannis & Campbell, 2010, 2021; Steenkamp, 2019).

The quintuple helix model: The quintuple helix model is based on the triple and quadruple helix models and adds as the fifth helix the natural environment, "where the environment or the natural environments represent the fifth helix." The quintuple helix views the natural environments of society and the economy as drivers for knowledge production and innovation, thus defining opportunities for the knowledge society and knowledge economy. "The Quintuple Helix can be proposed as a framework for transdisciplinary and interdisciplinary analysis of sustainable development" (Campbell & Carayannis, 2013; Carayannis et al., 2012). It relates knowledge, innovation and the environment (natural environments) to each other. The quadruple and quintuple innovation helix framework describes university–industry–government–public-environment interactions within a knowledge economy (Carayannis et al., 2012). The most important constituent element of the quintuple helix is knowledge,

which, through a circulation between societal subsystems, changes innovation and know-how in a society and for the economy (Carayannis et al., 2012). As indicated in Fig. 3,The quintuple helix visualizes the collective interaction and exchange of this knowledge in a state by means of the following five subsystems (i.e., helices): (1) education system, (2) economic system, (3) natural environment, (4) media-based and culture-based public (also 'civil society'), (5) and the political system (Carayannis et al., 2012). Each of the five helices has an asset at its disposal, with a societal and scientific relevance (see Fig. 3).

1) The education system defines itself in reference to academia, universities, higher education systems, and schools. In this helix, the necessary 'human capital' (e.g., students, teachers, scientists/researchers, academic entrepreneurs, etc.) of a state is being formed by diffusion and research of knowledge.
2) The economic system consists of industry/industries, firms, services and banks. This helix concentrates and focuses the economic capital (e.g., entrepreneurship, machines, products, technology, money, etc.) of a state.
3) The natural environment subsystem is decisive for sustainable development and provides people with natural capital (e.g., resources, plants, variety of animals, etc.).
4) The media-based and culture-based public subsystem integrates and combines two forms of capital. This helix has, through the culture-based public (e.g., traditions, values, etc.), a social capital. In addition, the helix of media-based public (e.g., television, internet, newspapers, etc.) contains capital of information (e.g., news, communication, social networks).
5) The political system formulates the will, i.e., where the state is heading, thereby also defining, organizing, and administering the general conditions of the state. Therefore, this helix has political and legal capital (e.g., ideas, laws, plans, politicians, etc.).

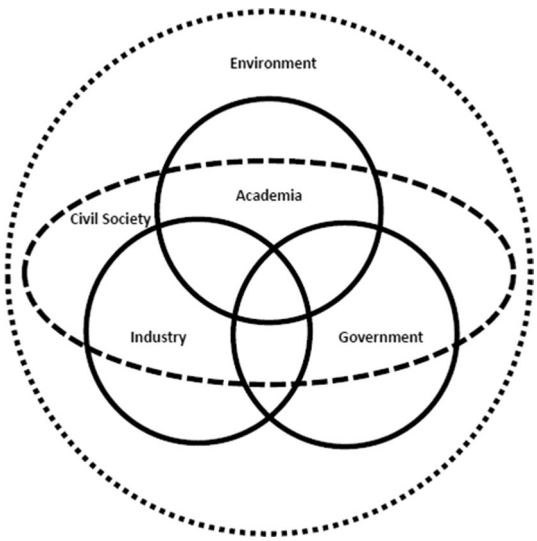

Fig. 3 The five helices of quintuple helix (Carayannis et al., 2012)

Circulation of knowledge for sustainable development

The resource of knowledge is the most important 'commodity' in the quintuple helix, and the circulation of knowledge continually stimulates new knowledge. As a result, each helix in the quintuple helix imparts knowledge to the others in order to advance and pioneer novel technologies that increase sustainability. The example of how education is injected into sustainable development and circulates throughout the economy in five steps helps to easily understand the circle of knowledge (see Fig. 4) (Carayannis & Campbell, 2010; Carayannis et al., 2012; König et al., 2021).

Step 1: When investments flow into the education helix to promote sustainable development, they create new impulses and suggestions for knowledge creation in the education system. Therefore, a larger output of innovations from science and research can be obtained. Simultaneously, teaching and training improve their effectiveness. The output that arises from human capital for sustainable development is then an input into the economic system helix.

Step 2: Through the input of new knowledge via human capital into the economic system helix, the value of the knowledge economy consequently increases. Through the enhancement of knowledge, important further production facilitates and develops opportunities for a sustainable, future-sensitive green economy, based on knowledge creation. This knowledge creation realizes in the economic system new types of jobs, new green products and new green services, together with new and decisive impulses for greener economic growth. In this subsystem, new values, like corporate social responsibility, are demanded, enabling and supporting a new output of know-how and innovations by the economic system into the natural environment helix.

Step 3: This new sustainability as an output of the economic system is a new input of knowledge in the natural environment helix. This new knowledge 'communicates' to nature and results in less exploitation, destruction, contamination, and wastefulness. The natural environment can, thus, regenerate itself and strengthen its natural capital, and humanity can also learn from nature via new knowledge creation. The goal of this helix is to live in balance with nature, to develop regenerative technologies, and

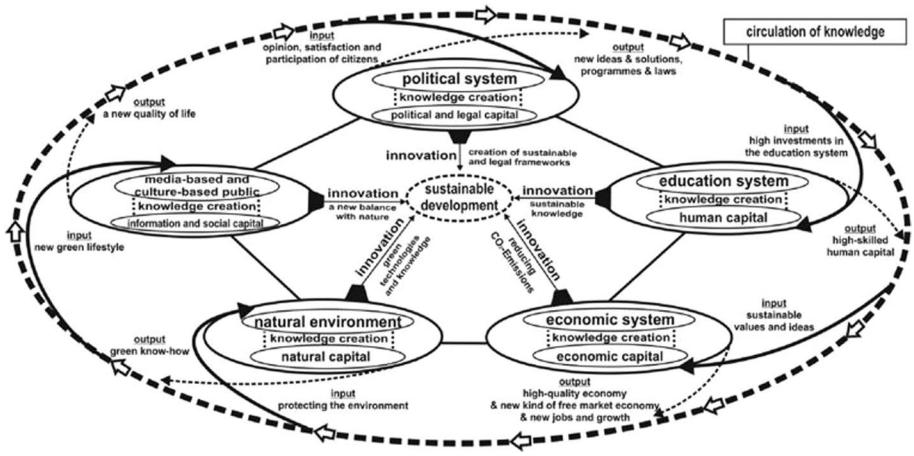

Fig. 4 Effects of investments in education for sustainable development (Carayannis et al., 2012)

to use available, finite resources sustainably. Here, natural science disciplines come into play, forming new green know-how. This know-how is then an output of the natural environment subsystem into the public helix.

Step 4: The output of the natural environment results in an input of new knowledge about nature and a greener lifestyle for the media-based and culture-based public helix. Here, the media-based public receives information capital, which spreads through the media information about a new green consciousness. This capital should provide incentives on how a green lifestyle can be implemented in a simple, affordable, and conscious way, i.e., knowledge creation. This knowledge creation promotes the social capital of the culture-based public, on which a society depends for sustainable development. This know-how output then serves as new input, about the wishes, needs, problems, or satisfaction of citizens, for the political system helix.

Step 5: The input of knowledge into the political system is the know-how from the media-based and culture-based public together with the collective knowledge from the three other subsystems of society. Important discussions on this new knowledge in the political systems are necessary impulses for knowledge creation. The goal of this knowledge creation is political and legal capital, making the quintuple helix model more effective and more sustainable. Consequently, there is an output of suggestions, sustainable investments, and objectives. This leads to the circulation of knowledge back into the education system.

Results and discussion

Challenges of university–industry linkage in technology transfer

Several researchers and practitioners have identified various factors that can facilitate or hinder the process of transferring knowledge and technology from academia to industry (Panagopoulos & Carayannis, 2013; Sideri & Panagopoulos, 2018). Some of the main challenges that hinder the development and performance of university–industry linkages are

a) Knowledge differences: Universities and industries often have different types of knowledge, such as tacit vs explicit, basic vs applied, general vs specific. These differences can make it difficult to communicate, understand, and integrate the knowledge across the two sectors.
b) Goal differences: Universities and industries also have different goals and incentives, such as academic freedom vs commercialization, curiosity-driven vs problem-oriented, long term vs short term. These differences can create conflicts of interest, misalignment of expectations, and difficulties in evaluating the outcomes of the collaboration.
c) Cultural differences: Universities and industries have different organizational cultures, norms, values, and practices, such as openness vs secrecy, collaboration vs competition, peer-review vs market feedback. These differences can affect the trust, commitment, and satisfaction of the partners involved in the collaboration.
d) The lack of trust and communication between the partners.
e) The cognitive and cultural barriers that prevent the effective transfer and absorption of knowledge.

f) The cost and risk involved in the collaboration process.
g) The legal and ethical issues related to the ownership and protection of intellectual property.

Strategies for strengthening university–industry linkage

To overcome these challenges and enhance university–industry linkages, various possible strategies and frameworks have been proposed. Some of the common strategies include

- establishing clear goals, roles, and responsibilities for each partner; it can help to prepare clear and transparent policies and guidelines for collaboration and technology transfer.
- fostering a culture of collaboration and trust among the partners: Trust is essential for building and maintaining a successful university–industry linkage. Trust can reduce uncertainty, increase information sharing, enhance cooperation, and foster mutual learning among the partners.
- developing effective communication and feedback mechanisms: Communication is crucial for facilitating knowledge transfer in university–industry linkage. Communication can improve understanding, reduce ambiguity, resolve conflicts, and coordinate actions among the partners.
- creating and supporting intermediary organizations that can facilitate the identification, matchmaking, negotiation, and management of linkages. Intermediaries are actors or entities that can bridge the gap between universities and industries. Intermediaries can provide services such as matchmaking, brokering, advising, training, and funding.
- mutual understanding, and respect among partners,
- providing incentives and rewards for UIL participants; both academics and firms to engage in linkages
- promoting networking and learning opportunities among the partners.
- evaluating the outcomes and impacts of university industry linkage.
- Experience: Experience is a valuable asset for enhancing university–industry collaboration. Experience can increase familiarity, confidence, competence, and reputation among the partners. Experience can also help to identify and overcome potential challenges and leverage existing opportunities. UIL is a complex and dynamic phenomenon that requires continuous learning and adaptation. By following the above strategies and frameworks, universities and industries can enhance their collaboration and achieve mutual benefits.

Impact of university–industry linkage on economic growth

University–industry linkage (UIL) is the interaction between universities and industries to exchange knowledge, skills, and resources for mutual benefit. UIL can have various forms, such as joint research projects, technology transfer, consultancy services, training programs, student internships, etc. UIL can have a positive impact on economic growth

by enhancing innovation, productivity, competitiveness, and entrepreneurship in both sectors. According to some studies, UIL can affect economic growth through capital formation and human capital, which are variables of the endogenous growth model (Soegiarto et al., 2022). Capital formation refers to the accumulation of physical and financial assets that can be used for production. Human capital refers to the stock of skills and knowledge that can increase the efficiency and creativity of workers. UIL can contribute to capital formation by facilitating the transfer and commercialization of new technologies and innovations from universities to industries. UIL can also contribute to human capital by improving the quality and relevance of education and training for students and workers. However, the impact of UIL on economic growth may vary depending on the context and characteristics of each country. For example, a study by Togoontumur and Cooray (2023) found that UIL significantly and positively affects economic growth through capital formation for a panel of 124 countries. However, there was no such indirect effect in high and upper–middle–income countries separately. Another study by Arenas and González (2018), and Terán-Bustamante et. al. (2021) examined the effect of university technology transfer (UTT) and university–industry collaboration (UIC) on economic growth for a panel of 53 African countries (Bareke 2018). They found that UTT is negatively associated with economic growth in fixed effect and ordinary least squares (OLS) models, whereas UIC shows no significant impact in fixed-effect but a significant positive effect in OLS models (Puerta-Sierra & Jasso, 2020; Terán-Bustamante et al., 2021). These results suggest that UIL is not a panacea for economic growth, but rather a complex and context-specific phenomenon that requires careful analysis and policy intervention. Some factors that may influence the effectiveness of UIL include the quality and quantity of research output from universities, the absorptive capacity and innovation demand from industries, the institutional and legal framework for intellectual property rights and contracts, the availability and accessibility of funding and infrastructure, and the cultural and social norms and values of collaboration.

Conclusion and recommendations

Conclusion: the way forward for university–industry linkages

University–industry linkages (UILs) are important mechanisms for fostering innovation and economic development in emerging and developed economies. However, they are not easy to establish or sustain. University–industry linkages require careful planning and management from both universities and industries. They also require supportive policies and institutions from the government and other stakeholders. University–Industry Linkages can provide benefits for both universities and industries, such as access to knowledge, skills, resources, innovation, competitiveness, enhancing productivity, markets, and networks. Though, UILs also face challenges and barriers, such as institutional differences, cultural gaps, trust issues, intellectual property rights, and regulatory frameworks. Therefore, it is essential to understand the factors that influence the evolution and success of UILs, and to design policies and strategies that can enhance their effectiveness and impact. Effective and efficient University–Industry Linkage is a necessary condition for knowledge and technology transfer from university to the industry. University graduates and research outputs have to be absorbed by the industry. University–industry linkages play an important role in technology transfer. They help to

bridge the gap between academia and industry by facilitating the transfer of knowledge and technology from universities to industry. This can lead to the development of new products and services, as well as the creation of new businesses and jobs. The following conclusions were drawn from the study:

a) University–industry linkages can help to promote innovation and economic growth by facilitating the transfer of knowledge and technology from universities to industry.
b) The success of university–industry linkages depends on a number of factors, including the availability of funding, the quality of research being conducted, and the level of collaboration between universities and industry.
c) University–industry linkages can help to address societal challenges by promoting the development of new technologies and products that can improve people's lives.
d) Intermediaries play a key role in facilitating technology transfer from universities to industry by overcoming relational barriers and are better suited to help small firms than large.
e) Research on academic engagement and technology transfer or commercialization offers important insights into the relationship between characteristics, activities and abilities of individual academic researchers, with outcomes such as successful technology transfer and commercialization.

Recommendations

Some of the possible implications and recommendations for policy-makers and practitioners are

a) To increase collaboration between businesses and academic institutions. This promotes the sharing of knowledge, advances technology, and reduces the need for human labor.
b) To provide incentives and support for both universities and industries to engage in UILs, such as funding schemes, tax breaks, awards, recognition, training, mentoring, and networking.
c) To foster a culture of collaboration and trust between universities and industries, and to promote mutual understanding and respect for each other's missions and values.
d) To facilitate the creation and maintenance of UILs, such as by providing intermediaries, platforms, brokers, matchmakers, etc., that can help identify potential partners, coordinate activities, monitor progress, and resolve conflicts.
e) To ensure a conducive legal and regulatory framework for UILs, such as by protecting intellectual property rights, ensuring ethical standards, and reducing bureaucratic hurdles.
f) To foster circumstances and creating awareness of technology transfer for both higher education institutions and industries.
g) To evaluate the performance and impact of UILs, such as by developing indicators, metrics, methods, and tools, that can capture the outputs, outcomes, and impacts of

UILs at different levels (individuals, organizations, sectors, regions), and over different time horizons (short term vs long term).

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Author contributions
The author contributed to the study's conception, data analysis, data collection, draft writing, editing and final review of the manuscript. The author read and approved the final submitted manuscript.

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Data availability
The dataset generated during and/or analyzed during the current study is available from the corresponding author based on a reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the study reported in this article.

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