

**UNIVERSITY- INDUSTRY LINKAGE FOR TECHNOLOGY
TRANSFER IN CASE OF SOME SELECTED PUBLIC UNIVERSITIES
IN ETHIOPIA.**



Segni Adugna Tamune

A Thesis Submitted to the Department of Technology and Innovation Management,

College of Humanity and Social Science.

Presented in Partial Fulfillment of the Requirement for the Degree of Master's of Science in
Technology and Innovation Management

School of Postgraduate Studies

Adama Science and Technology University

September, 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled “**University- Industry Linkage for Technology Transfer in Case of Some Selected Public Universities in Ethiopia**” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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Date

RECOMMENDATION

I, the advisor(s) of this thesis, hereby certify that I have read the revised version of the thesis entitled “**University- Industry Linkage for Technology Transfer in Case of Some Selected Public Universities in Ethiopia**” prepared under my/our guidance by Segni Adugna Tamune submitted in partial fulfillment of the requirements for the degree of Master’s of Science in Technology and Innovation Management. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

		
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APPROVAL PAGE

Thesis I, the advisors of the thesis entitled “**University- Industry Linkage for Technology Transfer in Case of Some Selected Public Universities in Ethiopia**” and developed by Segni Adugna Tamune, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Segni Adugna Tamune have read and evaluated the thesis entitled “**University- Industry Linkage for Technology Transfer in Case of Some Selected Public Universities in Ethiopia**” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Technology and Innovation Management.

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TABLE OF CONTENTS

LIST OF TABLES	vii
LIST OF FIGURES	viii
ABSTRACT	x
CHAPTER ONE.....	1
INTRODUCTION	1
1.1. Background and Rationale.....	1
1.2. Statements of the Problem	2
1.3. Research Questions.....	3
1.4. Research objective	3
1.4.1. General objective.....	3
1.4.2. Specific Objective.....	3
1.5. Significance of the study.....	4
1.6. Delimitation (Scope).....	4
1.7. Basic Terminologies	5
CHAPTER TWO.....	8
LITERATURE REVIEW	8
2.1. Historical Overview of University-Industry Collaboration and Technology transfer ..	8
2.2. Milestones in Technology Transfer Practices.....	9
2.3. Forms of University-Industry Linkage	11
2.4. Motivations and Benefits of University-Industry Collaboration	12
2.4.1. Motivations for Universities.....	12
2.4.2. Motivations for Industries	14
2.4.3. Mutual Benefits and Synergies.....	15
2.5. Theoretical perspective	17
2.5.1. Triple Helix model	17
2.5.2. The Quadruple Helix model	20
2.5.3. Knowledge Spillover Theory	20
2.5.4. Models and Theories of Technology Transfer	21
2.6. Empirical perspective	21
2.6.1. Quantitative Outcomes of University-Industry Linkages (UIL)	22
2.6.2. Qualitative Outcomes of University-Industry Linkages (UIL)	25
2.6.3. Barriers and Challenges of University-Industry Linkage.....	26
2.6.4. Best Practices and Strategies for University-Industry collaboration.....	27

2.6.5. Case Studies and Examples of Successful University-Industry Collaborations and Technology Transfer.....	28
2.7. Conceptual Framework.....	30
CHAPTER THREE	33
RESEARCH METHODOLOGY	33
3.1. Research Design	33
3.2. Sampling Method and Sample Size determination.....	33
3.3. Data Collection Methods	35
3.4. Data analysis method	36
3.4.1. Analysis procedures.....	36
3.4.2. Computation of Technology Transfer Index (TTI) and UIL Index.....	37
3.4.3. Model specification	40
3.5. Reliability.....	42
3.6. Ethical Considerations and Confidentiality	43
CHAPTER FOUR	44
RESULTS AND DISCUSSIONS	44
4.1. Introduction.....	44
4.2. Analysis of International Best Practices in University-Industry Linkages and Technology Transfer.....	45
4.3. Results of Qualitative and Descriptive Data.....	57
4.3.1. Current Institutional Framework of University-Industry Linkages in Ethiopia..	59
4.3.2. Analysis of Structure and Function of Technology Transfer Offices in Facilitating University-Industry Linkages in the selected Universities.....	71
4.3.3. Challenges Affecting University-Industry Linkages.....	74
4.4. Empirical Results	77
4.4.1. Influences of University-Industry Linkages on Technology Transfer	77
CHAPTER FIVE	92
CONCLUSION AND RECOMMENDATIONS	92
5.1. Conclusion	92
5.2. Recommendations.....	94
REFERENCES	95
APPENDIX	103

LIST OF TABLES

Table 1. Analysis of variance (ANOVA) of the relationship between Education and gender of the respondents	79
Table 2: ANOVA of the relationship between Education and University type (AU or ASTU or AASTU or AMU).....	79
Table 3: ANOVA of the relationship between Education and University generation type	80
Table 4: ANOVA of the relationship between Researchers' experience and university type ..	80
Table 5: UIL-Technology Transfer, whole sample	86
Table 6: UIL-Technology Transfer, by university	89

LIST OF FIGURES

<i>Figure 2.1 Potential benefits of university-industry linkage</i>	<i>17</i>
<i>Figure 2.2: Evolution of Triple Helix Model.....</i>	<i>20</i>
<i>Figure 2.3: Conceptual framework</i>	<i>32</i>

LIST OF ABBREVIATIONS

AAU	Addis Ababa University
ASTU	Adama Science and Technology University
AASTU	Addis Ababa Science and Technology University
AU	Ambo University
ADEA	Association for the Development of Education in Africa
ANOVA	Analysis of Variance
CSA	Central Statistical Agency
ESDPs	Education Sector Development Programmes
ETP	Education and Training Policy
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Product
HEI	Higher Education Institutions
IPR	Intellectual Property Rights
MoE	Ministry of Education
MoST	Ministry of Science and Technology
MoU	Memorandum of Understanding
TTO	Technology Transfer Offices
TT	Technology Transfer
TVET	Technical and Vocational Education and Training
U & I	University and Industry
UIC	University-Industry Collaboration
UIL	University-Industry Linkage
UN	United Nations
UNDESA	United Nations Department of Economics and Social Affairs
UNDP	United Nations Development Programmes
UNESCO	United Nations Education Scientific and Cultural Organization

ABSTRACT

This study offers a comprehensive evaluation of university-industry (U-I) linkages and technology transfer (TT) by integrating international best practices with an in-depth analysis of selected Ethiopian public universities. By synthesizing literature from countries such as the U.S., Germany, Japan, South Korea, China, Brazil, Thailand, and Africa, the research was identified that effective U-I linkages are supported by strong institutional frameworks like the U.S. Bayh-Dole Act and Germany's Fraunhofer Society. The study was further examined Ethiopia's institutional framework through reviewing policies such as the Ethiopian Science and Technology Policy (1993) and the Ethiopian Innovation and Technology Transfer Policy (2018), and assessed what actually practiced at Addis Ababa University (AAU), Adama Science and Technology University (ASTU), Addis Ababa Science and Technology University (AASTU), and Ambo University (AU). Using a mixed-methods design, including interviews with key informants and surveys of 240 academic staff, the research was identified significant barriers to effective UIL and TT, such as inconsistent policy implementation, fragmented organizational structures, and limited industry engagement. Analysis employing ANOVA and multiple regression reveals that education levels, university types, and proximity to the center notably affect UIL and TT outcomes. Joint research projects and infrastructural development are positively associated with successful technology transfer, whereas academic collaboration alone does not significantly impact TT. The findings highlight the need for improved policy enforcement, better alignment with national strategies, enhanced industry partnerships, and more effective technology transfer frameworks. Addressing these challenges is crucial for strengthening Ethiopian universities' institutional frameworks and advancing technological innovation and economic growth.

Keywords: University-Industry linkage, Technology, Technology Transfer.

CHAPTER ONE

INTRODUCTION

1.1. Background and Rationale

The collaboration between universities and industries is not entirely new since such practices have been in place for over a century in informal ways. However, the emergence of a global knowledge economy has enhanced the need for strategic partnerships that exceed the traditional funding of discrete research projects by industries (Edmondson et al., 2012).

Guimon (2013) affirms that a functional collaboration between universities and industries plays a pivotal role in skills development (education and training), the generation, acquisition, and adoption of knowledge (innovation and technology transfer), and the promotion of entrepreneurship (start-ups and spin-offs).

The literature indicates that in developed and newly industrializing countries there are sufficient evidence of interaction between universities and industries, but developing countries have universities that function, for the most part, independent of industries and industries that depend on foreign sources of knowledge to sustain production and possibly meet competitive challenges (Eniola-Arigbe et al., 2022).

Furthermore, the rise in graduate unemployment experienced in most African countries shows weak linkages of universities with the productive sector at every level, from big industry to agricultural producers, to medium-and-small scale enterprises (Adepoju & Adediji, 2016).

In Ethiopia, UIL is a relatively new concept. However, there is a growing recognition of the importance of UIL, and a number of initiatives have been taken to promote collaboration between universities and industries. One of the main initiatives is analyzing of national science, technology and innovation policy and revising the policy. Accordingly the STIP of the FDRE was issued in 2012 replacing the national Science and Technology Policy that was adopted in 1993. In the newly issued policy eleven critical issues were identified and universities, research institutes, TVET institutions and industries linkage is one of the critical issues. Not only this but also universities, research institutes, TVET institutions and industries are considered as core actors in the national innovation system. The other initiatives include the establishment of the

office that dedicated to university-industry linkages (UILs), preparing procedural directives for the linkage of universities and industries, the provision of training and support for university-industry collaboration. Addition to this the Science, Technology and Innovation Policy of Ethiopia that was issued in 2012 confirms that universities are not taking leading role and are lagging behind the industries in strengthening the linkage.

Despite some efforts to strengthen the interaction between the two parties, the current status of UIL in Ethiopia is found to be weak and even nonexistent in extreme cases (Hiwote, 2014; Abraham, 2016). UIL in Ethiopia still faces a number of challenges (Adepoju & Adediji, 2017). These include, lack of awareness among both universities and industries of the benefits of UIL. This is due to a number of factors, including the fact that UIL is a relatively new concept in Ethiopia, and the fact that there is limited information available on the benefits of UIL. Cultural barriers that can hinder UIL. For example, there is a traditional divide between academia and industry in Ethiopia, and this can make it difficult for universities and industries to work together. Lack of resources available to support UIL. This includes funding, infrastructure, and human resources.

1.2. Statements of the Problem

According to Adepoju & Adediji (2016) university-industry linkage (UIL) is a process through which universities and industries collaborate to achieve common goals. This can include research and development (R&D), education and training, the transfer of technology, knowledge, and skills between the two sectors. UIL can be beneficial for both universities and industries, as it can help to improve the competitiveness of both parties and to improve the quality of research and education, and create new opportunities for innovation and economic growth.

Abraham(2016) states the interactions between academia and industry are rapidly moving towards science and technology policymaking, planning and management owing to this, in recent years, there has been growing interest among scholars, the private sector and policymakers on the importance of the University and Industry and government relationship in fostering national growth.

Even though there is an increasing concern about the issues, there is a significant gap in the literature on UIL in Ethiopian context related to university-industry linkage for technology

transfer. There is a lack of research on the factors that contribute to successful UIL, the challenges that are faced by universities and industries in collaborating, and the impact of UIL on the competitiveness of both parties. This gap in the literature is a significant problem, as it prevents policymakers and practitioners from developing effective policies and strategies to promote UIL.

Thus, the purpose of this study is to examine what is actually happening in the Universities regarding the links between university and industry and analysis the influence of U-I linkage for technology transfer. The result of the study expected to provide policymakers and practitioners with the information they need to develop effective policies and strategies to promote UIL in Ethiopia.

1.3. Research Questions

This paper was addressed the following major questions.

- What are the international best practices of U-I linkages?
- What does the current institutional framework of U-I linkages in Ethiopia look like?
- How are Transfer offices organized to facilitate U-I linkages?
- How does university-industry linkage (UIL) influence technology transfer in the selected universities?
- What major challenges exist in the U-I linkage which could limit its functions?

1.4. Research objective

1.4.1. General objective

The general objective of this study is to understand the status of university- industry linkages and their roles towards technology transfer in case of selected public universities in Ethiopia.

1.4.2. Specific Objective

Specifically, this study aimed to

- Explore the international best practices for university-industry linkage.
- Explore the current institutional frameworks of University- Industry in Ethiopia in case of the selected public universities in comparison with international experience.

- Analyses the structural function of technology transfer offices to facilitate university-industry collaboration in the selected universities.
- Analyses the influence of UIL on technology transfer in case of those selected universities.
- Explore the exists major challenges that could limit the function of UIL in the selected universities

1.5. Significance of the study

- The research will unpack useful information on the current status of university industry linkages and hence contribute to the similar works done by researchers.
- The research findings can also be used by university leaders, industry owners and policy makers in designing the necessary measures.
- Finally, new insights for further study may also be obtained from the research.

1.6. Delimitation (Scope)

The study was focus on the status of university-industry linkage for technology transfer in the selected four government universities in Ethiopia. Purposively the study was focused only on four (4) public universities, namely Addis Ababa University (AU), Ambo University (AMU), Addis Ababa Science and Technology University (AASTU) and Adama Science and Technology University (ASTU). Since 2011, the two science and technology universities have taken a special mission from government to become a center of excellence in science and technology. To attain their mission, they are expected to collaborate with industries and to have more practices than the other universities. Addis Ababa University is the first-generation public university of the nation that ranked in 1st place in every aspect. It has consistently maintained a strong position among Ethiopian universities over several years.

Whereas Ambo University is the second-generation public universities, its proximity to the center as compared to the other second generations and then it was selected as one of a sample of the study. Therefore, these four universities were purposively selected to explore the status of university-industry linkage in Ethiopia in view of their potential contributions towards innovation and technology transfer.

1.7. Basic Terminologies

University

A higher education and research institution that grants academic degrees in various fields of study. It typically encompasses faculties, schools, or departments offering undergraduate, graduate, and postgraduate programs. Universities also engage in research, knowledge creation, and dissemination activities (University - New World Encyclopedia, n.d.)

This definition stands only for public universities in this study.

Industry

Industry refers to the productive sector that involves economic activities related to the creation, production, manufacturing, or provision of goods and services. It encompasses sectors such as manufacturing, agriculture, mining, construction, services (like healthcare, finance, education), and more. Industries are characterized by processes that convert raw materials, labor, and capital into finished products or services that can be sold or exchanged in the market United Nations Statistics Division (2008) and World Trade Organization (2020).

University-Industry Collaboration

University-Industry collaboration defined in various ways by different scholars in different literatures, but the following definition was used for this study purpose.

University-industry collaboration refers to partnerships, interactions, and joint initiatives between universities or research institutions and industry organizations. These collaborations aim to leverage the complementary expertise, resources, and capabilities of academia and industry to achieve common goals, such as research, innovation, technology development, and economic growth (Perkmann & Walsh, 2007).

Technology

Technology refers to the application of scientific knowledge, tools, techniques, and processes to create products, services, or systems that address human needs or solve practical problems. It encompasses a wide range of domains, including information technology, biotechnology, engineering, healthcare, and manufacturing (Bunge, 1974).

Technology Transfer

Technology transfer is the process of transferring scientific findings, research outcomes, or technological innovations from one entity, such as a university or research institution, to another entity, typically industry or the commercial sector. It involves the dissemination, adoption, and commercialization of technology for practical application and societal benefit (Mowery & Sampat, 2004).

Knowledge Exchange

Knowledge exchange refers to the mutual sharing and transfer of knowledge, expertise, and resources between universities and industry through collaborative research projects, technology licensing agreements, and other forms of interaction (Perkmann et al., 2013).

Patent

A patent is a form of intellectual property that grants its holder the exclusive right to make, use, and sell an invention for a limited period, typically 20 years from the filing date of the patent application. In essence, it provides legal protection against others making, using, or selling the patented invention without permission (Miller & Davis, 1990).

License

A license is a legal agreement between two parties where the licensor grants the licensee the right to use certain intellectual property (such as patents, trademarks, copyrights) under specified conditions. It outlines the terms under which the licensee can use the intellectual property, including duration, scope, royalties, and any restrictions (Pisacreta et al., 2005).

Intellectual Property (IP) Management

Intellectual property management involves the identification, protection, and commercialization of intellectual property rights, such as patents, copyrights, trademarks, and trade secrets, arising from collaborative research and innovation activities between universities and industry (Tether & Tajar, 2008).

Commercialization

Commercialization is the process of transforming research outcomes or technological innovations into commercially viable products, services, or processes for market deployment and economic impact. It involves activities such as product development, market analysis, and business model refinement (Gaspar Pacheco et al., 2024).

Spin-off Ventures

Spin-off ventures are start-up companies or entrepreneurial ventures founded by university researchers or students to commercialize technology or intellectual property developed within the university or research institution. They typically aim to bring innovative products or services to market and create economic value (Scott, 2004).

Understanding these key concepts and terminologies is essential for conceptualizing, analyzing, and evaluating university-industry collaboration for technology transfer. They provide the foundational framework for exploring the dynamics, challenges, and opportunities of collaboration between universities and industry in the context of technology transfer.

CHAPTER TWO

LITERATURE REVIEW

2.1. Historical Overview of University-Industry Collaboration and Technology transfer

The evolution of university-industry collaboration has undergone significant transformations, reflecting changes in research, innovation, and economic development. Initially, these collaborations were informal, characterized by apprenticeship systems where students received practical training within industrial workshops. Universities occasionally conducted research projects in response to industry needs on a case-by-case basis, without formalized structures for collaboration (Mowery et al., 2004). However, this dynamic shifted dramatically during World War II and the post-war period when universities became pivotal in defense research and technology development, fostering increased collaboration with government agencies and defense contractors. The Bayh-Dole Act of 1980 in the United States further revolutionized this landscape by allowing universities to retain ownership of federally funded research inventions, thereby facilitating technology transfer to private companies (Mowery et al., 1999).

The establishment of research parks and technology clusters marked another significant milestone in enhancing university-industry collaboration. For example, the Stanford Research Park, established in 1951 adjacent to Stanford University, was one of the earliest examples designed to facilitate such collaboration. The emergence of Silicon Valley in the 1960s and 1970s further catalyzed these efforts, with institutions like Stanford playing a central role in developing the region's technology ecosystem (Saxenian, 1996). Major corporations, such as IBM and Xerox, established research laboratories to conduct fundamental research in collaboration with universities, while joint research agreements funded projects of mutual interest (Thursby, 2002). Industry-led consortia, such as SEMATECH and the Fraunhofer Society, facilitated pre-competitive research and technology development through collaboration with academic and research institutions (Fraunhofer-Gesellschaft - Research in Germany, n.d.). Additionally, the concept of open innovation, popularized by Henry Chesbrough, underscored the importance of external collaboration in driving innovation, leading to the creation of open

innovation platforms, startup accelerators, and incubators that foster closer ties between academia, industry, and the entrepreneurial ecosystem (Chesbrough, 2003).

2.2. Milestones in Technology Transfer Practices

The evolution of technology transfer practices has been marked by several key milestones that highlight the dynamic interplay between university research, industry collaboration, and legislative frameworks. Landmark inventions such as the transistor (1947), integrated circuit (1958), and laser (1960) not only revolutionized telecommunications and electronics but also underscored the critical role of academic research in driving technological advancements. These innovations, emerging from university-industry partnerships, laid the groundwork for significant commercial and societal impacts. Similarly, breakthroughs in biotechnology and pharmaceuticals, including recombinant DNA technology (1973) and the polymerase chain reaction (PCR) technique (1983), catalyzed the development of new drugs, diagnostics, and therapies, demonstrating the potential of academic discoveries to transform entire industries.

The enactment of the Bayh-Dole Act in 1980 marked a pivotal moment in the history of technology transfer in the United States. This legislation empowered universities and other nonprofit institutions to retain ownership of inventions resulting from federally funded research, thereby incentivizing them to pursue commercialization opportunities. The Bayh-Dole Act effectively facilitated the transfer of technology to industry partners, spurring innovation and economic growth. In Europe, the European Patent Convention of 1973 established a unified patent system, enabling inventors to obtain patent protection across multiple countries. This harmonization of patent laws promoted cross-border technology transfer and collaboration between universities and industries. Subsequent revisions to patent laws, such as the America Invents Act (2011), introduced further changes to the patent system, influencing patenting strategies, licensing practices, and intellectual property management in university-industry collaborations.

The establishment of dedicated Technology Transfer Offices (TTOs) at academic institutions has been a crucial development in the commercialization of university research. Stanford University's Office of Technology Licensing (OTL), founded in 1970, was one of the first such offices and set a precedent for other universities to follow. The Association of University

Technology Managers (AUTM), established in 1980, has played a significant role in supporting TTOs worldwide by providing professional development, networking, and advocacy services. These offices have become vital in managing university inventions, facilitating licensing agreements, and fostering entrepreneurial activities.

Over time, technology transfer practices have evolved from a narrow focus on patenting and licensing to a broader emphasis on commercialization and entrepreneurship. Universities are now actively involved in the formation of spin-off companies, startup incubation, and venture capital investment, reflecting a shift towards translating academic research into market-ready products and services. This trend aligns with the principles of open innovation, which encourage knowledge exchange and collaboration with external partners, including industry, startups, and government agencies. By adopting open innovation models, universities can better leverage their research capabilities to address complex societal challenges and drive economic development.

The changing landscape of policies and regulations has also had a profound impact on university-industry collaboration and technology transfer. Governments have developed various innovation policies and programs to foster collaboration, promote entrepreneurship, and stimulate technology-based economic development. These initiatives include research funding schemes, tax incentives, and support for incubation and innovation clusters. Additionally, changes in intellectual property laws and funding mechanisms have encouraged universities to engage more actively with industry partners and pursue technology transfer activities.

Public-private partnerships (PPPs) have emerged as a strategic approach to leveraging private sector resources and expertise for collaborative research and technology development. By facilitating co-investment, risk-sharing, and knowledge exchange, PPPs enhance the capabilities of universities, industries, and government agencies to address complex innovation challenges. Such partnerships have become increasingly important as governments promote applied research and technology commercialization to drive economic growth and competitiveness.

The globalization of innovation has further intensified collaboration between universities and industries across national borders. International agreements and initiatives, such as the European Union's Horizon 2020 program, have promoted cross-border research collaboration, technology

transfer, and knowledge exchange. Efforts to harmonize intellectual property laws and standards, exemplified by the TRIPS Agreement under the World Trade Organization (WTO), have facilitated international technology transfer and collaboration. These developments highlight the interconnectedness of the global innovation ecosystem and the importance of international cooperation in advancing technological progress and addressing global challenges.

2.3. Forms of University-Industry Linkage

University-industry collaboration (UIC) is essential to enhance knowledge transfer, promote technological advancement, innovation and stimulate economic growth, leveraging academic research and industry expertise. Various forms and mechanisms of UIC have been identified in the literature:

These involve collaborative efforts between university researchers and industry partners to solve specific problems or develop new technologies. Joint research projects often receive funding from both public and private sources (Perkmann et al., 2013).

Academics provide expertise to industries through consulting, allowing for the direct application of academic knowledge to practical industry challenges. This form of collaboration is often facilitated through contracts and can lead to long-term partnerships (Bekkers & Freitas, 2008).

Licensing agreements serve as a mechanism for technology transfer; allow universities to license their intellectual property rights to industry partners for commercialization. These agreements enable industries to access and utilize university-developed technologies, inventions, and patents to develop new products, processes, and services. Here is an exploration of licensing agreements as a mechanism for technology transfer (Scott, 2004).

TTOs facilitate the commercialization of university research by managing patents, licenses, and spin-off companies. They act as intermediaries between universities and industries, ensuring that academic innovations reach the market (Markman et al., 2008).

Research centers and institutes are specialized units within universities focused on specific research areas, often established in partnership with industry. They provide a structured environment for sustained collaboration and innovation (Etzkowitz & Leydesdorff, 2000).

Internships and cooperative education programs integrate academic learning with practical industry experience, benefiting both students and companies. They foster talent development and strengthen industry ties with academia (Ankrah & Al-Tabbaa, 2015).

Universities often support the creation of spin-offs and start-ups based on academic research. These new ventures contribute to economic growth and offer a pathway for academic research to enter the market (Rothaermel et al., 2007).

Formal networks such as research consortia and innovation clusters bring together multiple universities and industry partners to work on large-scale projects. These alliances promote knowledge sharing and collective problem-solving (D'Este & Patel, 2007).

Industries fund research projects at universities, providing financial resources and often setting research agendas. This mechanism aligns academic research with industry needs (Geuna & Muscio, 2009).

These mechanisms highlight the diverse ways universities and industries can collaborate, each with unique benefits and challenges. Effective UIC requires mutual trust, clear communication, and alignment of objectives to drive innovation and economic impact.

2.4. Motivations and Benefits of University-Industry Collaboration

2.4.1. Motivations for Universities

Universities are increasingly motivated to engage in collaborative research and technology transfer activities with industries due to a variety of factors that encompass both intrinsic and extrinsic benefits.

Bekkers and Freitas (2009) investigates how different organizational structures of university-industry collaborations impact performance outcomes. The study highlights that universities can generate revenue through licensing patented technologies, copyrights, and other intellectual property assets to industry partners. Royalties from successful commercialization ventures contribute to research funding and institutional sustainability.

Martínez-Ardila et al (2023) conducted a study that examines the impact of university-industry collaborations on spin-off creation by considering joint patents as evidence. This study explores the effects of university-industry collaborations on spin-off creation and highlights UIC has

positive effect on spin-off creation and establishing spin-off companies based on faculty inventions and research discoveries, providing opportunities for equity ownership and financial returns from successful startups.

Jiang et al (2022) study states that collaborating with industries facilitates the transfer of scientific knowledge and technological innovations from academia to the private sector, leading to the development of new products, processes, and services with commercial applications.

According to Kleiner-Schaefer & Schaefer (2022) universities play a critical role in addressing societal challenges and advancing the public good through collaborative research initiatives focused on areas such as healthcare, environmental sustainability, and social justice.

According to the research finding of Jiang by translating research findings into practical solutions and commercial products in collaboration with industry, universities contribute to economic development, job creation, and improvements in quality of life for communities (Jiang et al., 2022).

Dias and Selan (2023) research states that UIC provides for university access to industry-specific expertise, facilities, equipment, and funding resources that complement universities' research capabilities and enable the pursuit of interdisciplinary and translational research.

Industry partnerships offer opportunities for researchers to work on applied research projects with clear practical applications and market relevance, enriching their understanding of industry needs and challenges (Awasthy et al., 2020).

Industry-sponsored research projects provide additional sources of research funding beyond traditional government grants and contracts, diversifying universities' funding portfolios and supporting the sustainability of research programs. Universities that actively engage with industries and establish strong industry partnerships are more competitive in attracting research funding, philanthropic donations, and private investments. Collaborating with reputable industry partners enhances universities' credibility and visibility in the business community, strengthening their reputation as hubs of innovation and fostering a culture of entrepreneurship. Successful technology transfer and industry engagement activities contribute to universities' rankings, accolades, and recognition as leaders in innovation and research excellence (Banal-Estanol et al., 2019).

2.4.2. Motivations for Industries

According to previous studies on UIC, industries are motivated to collaborate with universities for various reasons, ranging from accessing cutting-edge research and talent to seeking opportunities for technology commercialization and enhancing competitiveness.

Industries collaborate with universities to gain access to world-class researchers, academic experts, and interdisciplinary research teams. These collaborations provide industry partners with specialized knowledge and skills in emerging fields and technologies. Universities often provide state-of-the-art research facilities, laboratories, and equipment that go beyond what industries can afford. Collaborating with universities allows industries to access cutting-edge infrastructure for collaborative research and technology development (Bodas & Verspagen, 2017). Collaborating with universities allows industries to identify and recruit top-tier talent. Students, postdoctoral researchers, and faculty members possess relevant skills and innovative thinking that benefit industry partners. Industry-university partnerships support workforce development through experiential learning opportunities, internships, and co-op programs. These initiatives prepare students for careers in industry and enhance their employability (Sun & Turner, 2023).

Industries collaborate with universities to access intellectual property assets, including patents, inventions, and research discoveries. These assets can be commercialized into new products, processes, and services with market potential (Lee, 2000).

Industry partnerships offer opportunities for licensing patented technologies and forming spin-off companies. Joint ventures capitalize on innovative ideas and scientific breakthroughs. Collaborating with universities enhances industries' innovation capabilities, allowing them to differentiate their products, services, and solutions in the marketplace. Industry-university collaborations accelerate innovation, reduce R&D costs, and mitigate risks associated with in-house research efforts. Industries seek partnerships with universities that align with their strategic objectives and research priorities. Long-term collaborations generate mutual value and address shared challenges. Collaborating with universities provides industries with opportunities to explore emerging growth opportunities and expand their product portfolios (Martínez-Ardila et al., 2023).

2.4.3. Mutual Benefits and Synergies

University-industry collaboration offers mutual benefits and synergies that accelerate innovation, mitigate risks, and provide access to diverse expertise and resources for both academia and industry stakeholders. Here's an analysis of these mutual benefits along with relevant references:

Collaboration between academia and industry fosters cross-disciplinary and cross-sectoral exchange of ideas, leading to the co-creation of new knowledge, technologies, and solutions that address complex challenges and drive innovation. Joint research projects and technology transfer initiatives enable universities and industries to leverage complementary strengths, capabilities, and resources to accelerate the development and commercialization of innovative products, processes, and services (Mascarenhas et al., 2024).

Collaborative research partnerships allow academia and industry to share the risks and rewards associated with innovation, with universities providing fundamental research expertise and industries offering market insights, validation, and commercialization pathways (Beck et al., 2022)

Universities diversify their research funding sources by engaging with industry partners, reducing dependence on government grants and enhancing financial stability, while industries mitigate R&D risks by leveraging external expertise and accessing novel technologies developed by academic institutions (Nugent et al., 2022).

As illustrated in Figure 1, Etzkowitz and Dzisah (2008) highlight the multifaceted benefits of university-industry linkages. Their analysis reveals how these collaborations offer unique advantages for universities, industries, and governments alike. For universities, these linkages enhance research capabilities through access to industry funding and resources, guiding academic research towards practical applications. They increase the relevance and impact of academic work, facilitate workforce development by aligning educational programs with market needs, and provide financial support for research projects and infrastructure. Additionally, these collaborations foster innovation and entrepreneurship by supporting the creation of spin-off companies and startups.

Industries benefit from these linkages by gaining access to cutting-edge research and academic expertise, which can drive innovation and solve complex problems. Partnerships with

universities create a direct talent pipeline, ensuring that graduates possess the skills required by the industry. Engaging with universities can also be a cost-effective way for companies to conduct research and development, leading to shared costs and resources. Furthermore, collaborations provide companies with a competitive advantage through early access to new technologies and enhance their corporate social responsibility profiles by addressing societal challenges.

Governments reap significant benefits from promoting university-industry linkages, as these collaborations drive economic growth and development by fostering innovation and creating new industries. Effective policies and frameworks supporting these partnerships enhance the overall innovation ecosystem and national competitiveness. Public-private partnerships exemplified by university-industry linkages can lead to comprehensive solutions for societal challenges and accelerate technological progress. Moreover, government support for these collaborations leads to improvements in higher education and workforce skills, ensuring a highly skilled and adaptable workforce aligned with industry needs. These partnerships ultimately create a dynamic ecosystem fostering continuous improvement, competitiveness, and shared prosperity.

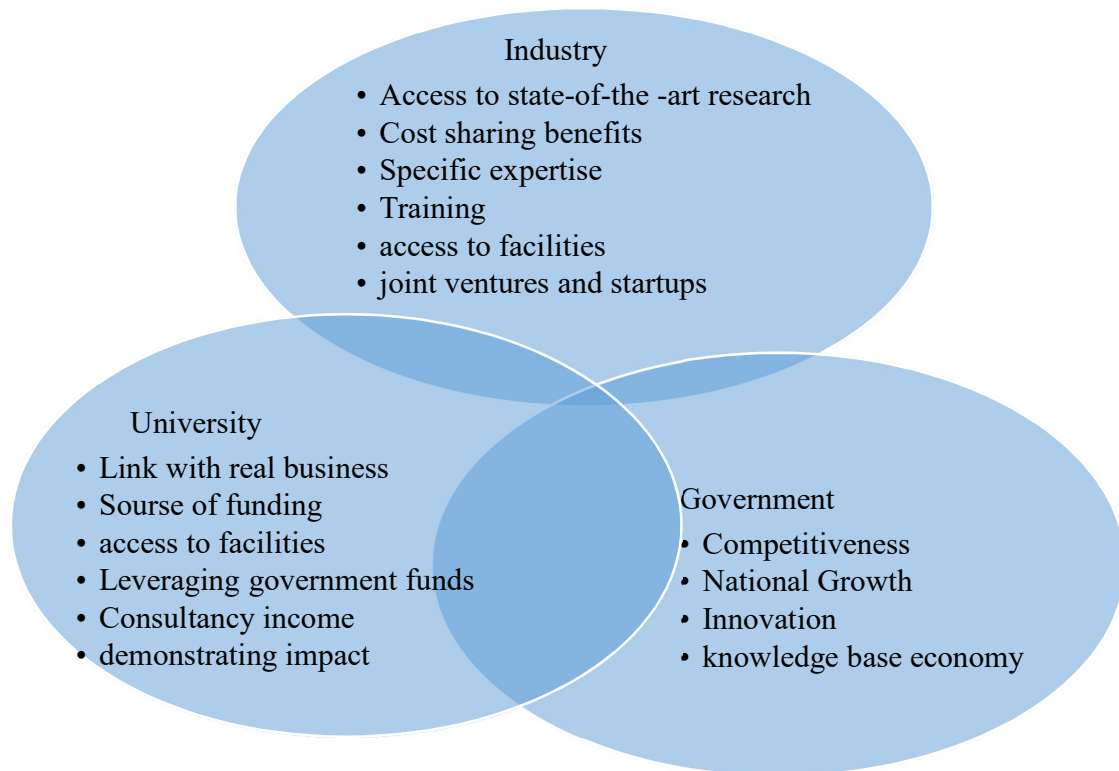


Figure 2.1: Potential benefits of university-industry linkage adapted from (Etzkowitz & Dzisah, 2008)

2.5. Theoretical perspective

2.5.1. Triple Helix model

The Triple Helix model, proposed by Henry Etzkowitz and Loet Leydesdorff in the 1990s, is a conceptual framework that describes the interplay and collaboration among three key actors in the innovation process: universities, industries, and government. This model suggests that innovation and economic development are driven by the dynamic interactions and overlapping roles of these three spheres within what is termed an innovation ecosystem (Cai & Lattu, 2022).

In this model each actors has their own role. University (Academia) represents the knowledge-producing sector, focusing on basic research, education and talent development. Industry represents the market-driven sector, focusing on innovation, commercialization, and economic

growth. Government represents the regulatory and funding sector, providing policies, resources, and infrastructure to support innovation and collaboration.

The model suggests that innovation arises from the dynamic interactions and co-evolution of the three actors. The model recognizes the interconnected nature of academia, industry, and government in driving innovation. It emphasizes the importance of collaborative partnerships and knowledge exchange among the three stakeholders. It facilitates the transfer of knowledge, technology, and expertise between academia, industry, and government and advocates for supportive policies, funding mechanisms, and infrastructure to promote university-industry-government collaboration. It aims to leverage innovation to drive economic growth, job creation, and societal well-being.

The Triple Helix Model facilitates the exchange of knowledge and expertise among academia, industry, and government. Universities contribute scientific discoveries and academic research, while industry provides practical applications and market insights (Etzkowitz & Leydesdorff, 2000). It enhances innovation capacity by integrating different perspectives and resources from academia, industry, and government. It promotes cross-sector collaborations that lead to the development of new technologies, products, and services (Carayannis & Campbell, 2006).

The Triple Helix environment encourages entrepreneurial activities and the creation of startups. Universities often play a pivotal role in supporting spin-off companies based on academic research, with industry providing funding and mentorship (Etzkowitz, 2003).

Collaboration under the Triple Helix Model stimulates regional development by creating innovation clusters and technology parks. These hubs attract businesses, researchers, and investors, driving economic growth and job creation (Leydesdorff & Etzkowitz, 1998).

Governments play a critical role in shaping policies that facilitate UIC within the Triple Helix framework. Effective governance ensures that regulatory environments support innovation, collaboration, and the transfer of knowledge between sectors (Etzkowitz et al., 2000).

Etzkowitz and Leydesdorff (2000) explore the evolution of university-industry-government relations by outlining three distinct models: statist model, laissez-faire model, and triple helix model. Each of these models reflects a unique approach to how these sectors interact and collaborate. A detailed explanation of each model is provided below, with a visual summary depicted in Figure 2, which illustrates how these models differ and evolve over time.

Etzkowitz and Leydesdorff (2000) describe the statist model as one where the government plays a dominant role in driving innovation and economic development. In this model, the government exerts substantial control over research agendas, funding, and technological development, often resulting in centrally planned and managed strategies. Universities and industries have limited autonomy and rely heavily on government directives and funding, operating within a framework of bureaucratic control. This model is exemplified by countries with centrally planned economies, such as the former Soviet Union, where government-directed research and industrial activities were predominant.

The laissez-faire model, in contrast, emphasizes minimal government intervention, with universities and industries functioning independently based on free market principles. Innovation is primarily driven by market demands and competitive dynamics, allowing both sectors high levels of autonomy and flexibility. Collaboration between universities and industries tends to be sporadic and short-term, driven by specific market needs rather than long-term strategic partnerships. This model was evident in the United States during the late 19th and early 20th centuries, where market mechanisms were the main drivers of innovation and economic growth.

The triple helix model represents a balanced and interactive approach where universities, industries, and governments closely collaborate to drive innovation and economic development. This model fosters strong, collaborative networks, creating hybrid organizations such as technology transfer offices and innovation hubs to support joint initiatives and projects. The roles of the three sectors are dynamic and flexible, allowing continuous adaptation to emerging needs and opportunities. Examples of this model can be seen in countries like Sweden and Finland, as well as in innovation clusters like Silicon Valley, where a thriving ecosystem of technological advancement and entrepreneurship is sustained through the collaborative efforts of universities, industries, and government agencies.

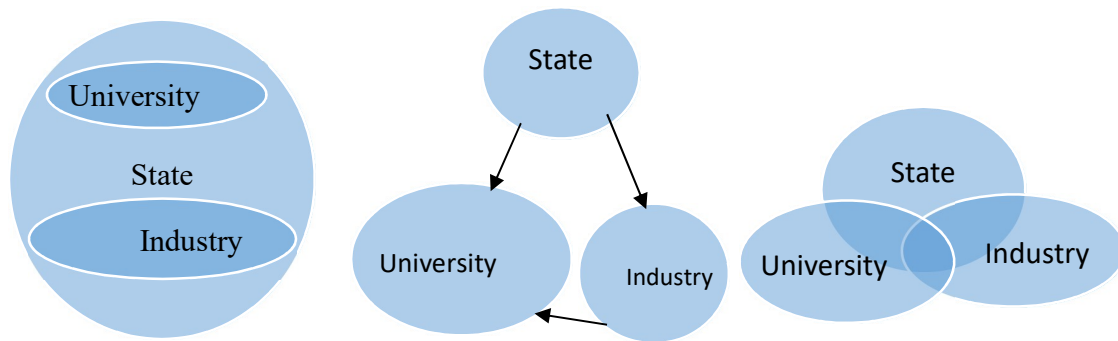


Figure 2.2: From statistic and laissez-faire to triple helix, Adapted from (Etzkowitz&Leydesdorff, 2000)

2.5.2. The Quadruple Helix model

Carayannis and Campbell (2009) proposed another model Quadruple Helix model by considering additional agent, society-based innovation users, to the Triple Helix model. Unlike the Triple Helix model, innovation users are fully integrated into every stage of the innovation process, transferring the ‘innovation push’ of the Triple Helix model to a ‘market-led’ quadruple model that fully captures the evolving trends of U-I collaboration. Furthermore, the Quadruple Helix model proposes that the innovation process is also influenced by the media and not-for-profit organizations, emphasizing the social responsibility for innovation. Hence, the traditional triple Helix model has been extended to encourage interactions among all social sectors for the co-creation of new knowledge and innovation (Roman et al., 2020).

2.5.3. Knowledge Spillover Theory

The knowledge spillover theory suggests that knowledge generated in one context can spill over and benefit other individuals, organizations, or regions, leading to positive externalities. It highlights the importance of knowledge diffusion, collaboration, and networking in driving technology transfer, innovation and economic growth. Knowledge is created through research, experimentation, and learning processes within universities, research institutions, and industry. Spillovers can occur through various channels, including publications, patents, collaborations, workforce mobility, and informal networks. Spillovers create positive externalities by increasing the stock of knowledge, enhancing absorptive capacity, and fostering innovation ecosystems. Policymakers can promote knowledge spillovers through supportive policies,

investments in education and research, and initiatives to facilitate collaboration and knowledge exchange (Feldman & Langford, 2021).

2.5.4. Models and Theories of Technology Transfer

The linear model of technology transfer posits a one-way flow of knowledge from research institutions, such as universities, to industry. It assumes a linear progression from basic research to applied research and then to commercialization, with limited interaction between academia and industry. The interactive model of technology transfer recognizes the dynamic and iterative nature of the innovation process, involving multiple stakeholders and feedback loops. It emphasizes the importance of collaborative interactions between universities, industry, government, and other actors in the innovation ecosystem (Abdul Wahab et al., 2011).

2.6. Empirical perspective

The Empirical Literature Review is a crucial component of study on University-Industry collaboration (UIL) for technology transfer. Empirical evidence serves to validate or challenge the theoretical models of UIL for technology transfer. It provides real-world data that can confirm the applicability of theories in practice and offer insights into how local conditions affect the success of technology transfer.

The review contains a wide range of studies, including case studies, surveys, and quantitative analyses. It was considered both historical and contemporary studies to understand the evolution of UIL for technology transfer. The scope includes diverse methodological approaches to understand the multifaceted nature of UIL.

Therefore, the review examined the outcomes of UIL and empirical evidence from past studies on university-industry collaborations (UIC) highlights the positive impacts on knowledge and technology transfer, human capital development and employment opportunity, innovation and innovation ecosystem, invention and patents filling, spin-off, startups, market impacts, economic policy and economic growth and etc. Summary of the key findings was summarized underneath for each aspect.

2.6.1. Quantitative Outcomes of University-Industry Linkages (UIL)

2.6.1.1. Knowledge and Technology transfer

The quality of research outcomes from university-industry collaborations has a direct positive influence on technology transfer. Empirical results suggest that the size and type of research collaboration can affect technology transfer indirectly through outcome quality. Technology transfer from universities to industries is essential for developing new technologies and driving economic development (Bozeman, 2000). UIL facilitates the transfer of knowledge and technology from universities to industries, leading to innovation and the commercialization of new products and services. This process creates new industries and renews existing ones, contributing to economic diversification (Hailu, 2024). Effective knowledge transfer from universities to enterprises is tangible and measurable, and it requires active facilitation and engagement within the partnerships (Mochly-Rosen et al., 2023). UICs facilitate technology transfer from universities to industry through licensing agreements that allow firms to commercialize academic knowledge and incorporate it into their products or processes. This transfer can enhance firms' innovative capabilities (Mochly-Rosen et al., 2023). UIL activities and incentives to collaborate with industries can enhance smart specialization strategies, leading to higher levels of knowledge transfer and economic growth (Malik et al., 2020).

2.6.1.2. Human capital development and Employment opportunity

Universities play a crucial role in developing skilled human capital. Through UIL, industries can influence curriculum development to ensure that graduates have the skills needed for the modern workforce (Valiente Bermejo et al., 2022). The innovation and technology resulting from UIL can lead to the creation of new companies and the expansion of existing ones, which generates employment opportunities and contributes to a reduction in unemployment rates (Tesfaye, 2024).

2.6.1.3. Innovation and innovation ecosystem

UIL fosters technological innovation critical for economic growth. University-industry collaborations contribute to the innovation ecosystem by providing new ideas, technologies, and facilitating the commercialization of products and services (Terán-Bustamante et al., 2021). The sustainability of university-industry research collaboration is examined by focusing on the actual outcomes, which include innovations that contribute to the nation's innovation

system(Lee, 2000). UIL can stimulate regional development by creating innovation clusters and technology parks that draw in businesses and researchers (Amarathunga, 2024).

Collaborating with universities positively impacts firms' innovation performance(Arenas & Gonzalez, 2019). UICs provide access to new knowledge, research facilities, and interdisciplinary perspectives. Factors such as trust, knowledge complementarity, and prior experience play a crucial roles in shaping the innovation process (Rybníček & Königsgruber, 2019). The relationship between UICs and firms' profitability is multifaceted. While UICs contribute to innovation, their direct impact on profitability may vary. Some studies suggest that UICs initially require investments (e.g., in research collaboration) and may not immediately boost profitability. However, as engagement deepens and successful collaborations evolve, firms can benefit financially. Profitability gains may result from changes in technical efficiency, technology adoption, and network-specific investments (Awasthy et al., 2020).The impact of UICs on firms' innovation indices is not typically measured in direct numbers but is reflected in the increased number of patents, licenses, and start-ups, indicating a higher level of innovation activity (Dempere et al., 2023).

A study titled university-industry technology transfer: empirical findings from Chinese industrial firms investigated Chinese UICs and their effect on innovation output. The researchers collected approximately 6,400 license contracts made between more than 4,000 Chinese firms and 300 Chinese universities from 2009 to 2014. The result of the finding indicates UIC has positive influence on the firm's innovative capacity (Jiang et al., 2022).

2.6.1.4. Market impacts

By collaborating with universities, industries can gain access to cutting-edge research and development, which can enhance their competitiveness in the global market. This can lead to increased exports and economic growth (Filippetti & Savona, 2017). Improving operational capabilities through investments in people, technologies, and processes is key to maximizing business impact, which can potentially be measured and has market implications(Terán-Bustamante et al., 2022). The exact figures on how UICs affect firms' profits and product development are varied and depend on the industry and nature of the collaboration. However, it's widely acknowledged that these collaborations often lead to improved market performance and product innovation (Rybníček & Königsgruber, 2019).

2.6.1.5. Patent Filing and Invention disclosures

The creation of joint patents is a common quantitative outcome, indicating active knowledge transfer and intellectual property development. Studies have shown that UICs can lead to an increase in patent filings, reflecting the innovative output of collaborations (Mascarenhas et al., 2024). Collaborating with universities tends to positively influence patent applications by firms. When firms engage in UIC, they gain access to cutting-edge research and expertise, which can lead to novel inventions and innovations. However, the exact magnitude of this increase may vary based on factors such as the industry, type of collaboration, and the specific research area (H et al., 2023).

The Association of University Technology Managers (AUTM) conducted a survey in 2011 to assess UIC outcomes in Japan and the finding of the survey indicates that university-industry collaboration has positive impact on the number of invention disclosures, number of patent applications, number of licenses, royalty income, number of spin-off companies and the result of the survey shows that number of invention disclosures: 21,865 (6% increase), number of patent applications: 19,905 (6% increase) which means in 2011, the number of patent applications made by national universities in Japan rose to 19,905, which was about a four-fold increase compared to 2008, number of licenses: 6,051 (12.6% increase), total royalty income: 2.5 billion USD (2.6% increase), number of new products: 591 (10% decrease) and number of spin-offs: 671 (3% increase).

UICs have been shown to significantly increase the number of patent applications and licensed patents. For instance, the Association of University Technology Managers (AUTM) reported that in 2019, U.S. universities filed 16,487 new patent applications and were issued 8,516 U.S. patents.

2.6.1.6. Creation of spin-off companies

UICs often contribute to the creation of spin-off companies. These startups emerge from university research and aim to commercialize innovative technologies. Successful UICs can lead to the establishment of spin-offs, which benefit from university-generated IP and expertise. These spin-offs can drive economic growth and foster innovation ecosystems. This suggests that the collaborations between the same university-industry have a positive effect on the creation of spin-offs (Sánchez et al., 2024).

In USA by the year of 2019, universities created 1,080 start-up companies in collaboration with industries (H et al., 2023).

2.6.1.7. Policy and economic growth

Licensing agreements are critical for the commercialization of research. They allow industries to utilize university research outcomes, leading to new products and services. The extent of licensing activities can serve as a measure of the effectiveness of technology transfer initiatives (Sun et al., 2019). The revenue generated from commercialized research is a direct financial outcome of UICs. This includes income from patents, licensing fees, and sales of products developed through collaborative research efforts. The economic impact of these revenues can be substantial, contributing to the growth of both the university and the industry involved (OECD, 2019).

The AUTM noted that university-industry technology transfer activities contributed \$70 billion to the U.S. gross domestic product (GDP) and supported 597,000 jobs in 2019. The overall impact of academic research on the economy is significant, with billions of dollars contributed to the GDP and hundreds of thousands of jobs supported (Da Silva et al., 2022). A longitudinal study by (Siegel et al., 2003) examined the economic impact of UIC. They found that collaborative research projects contribute positively to regional economic growth. A meta-analysis by (Tereshchenko et al., 2024) synthesized findings from various studies. And the study concluded that successful technology transfer resulting from UIC positively affects innovation and economic indicators.

UIL can inform economic policy by providing empirical data and research findings that help policymakers design effective economic strategies and interventions (Ishengoma & Vaaland, 2016).

2.6.2. Qualitative Outcomes of University-Industry Linkages (UIL)

The qualitative outcomes of University-Industry Collaboration (UIC) are crucial for understanding the broader impact beyond measurable metrics. UICs often lead to enhanced research capabilities, as they provide access to additional resources, diverse expertise, and cutting-edge technology (Awasthy et al., 2020). By participating in UICs, universities can integrate more deeply into the innovation ecosystem, contributing to and benefiting from the flow of knowledge and ideas (Tereshchenko et al., 2024). UICs facilitate the development of

specialized knowledge through the sharing of expertise between academic researchers and industry professionals Emerald Insight (2019). The insights gained from industry collaborations can inform the stakeholders about curriculum development, ensuring that education aligns with current industry needs Emerald Insight (2019). Successful collaborations can enhance the brand and reputation of both university and industry partners, attracting top talent and additional funding opportunities (O'Dwyer et al., (2023). Universities that engage in UICs often see an increase in the credibility and applicability of their research, as it is tested and validated in real-world industry settings (Awasthy et al., 2020).

2.6.3. Barriers and Challenges of University-Industry Linkage

University-industry linkages can face several barriers and challenges that impact their effectiveness and sustainability. One major issue is the misalignment of priorities between universities and industries. Universities typically focus on long-term research, education, and knowledge dissemination, while industries prioritize short-term goals such as profitability, innovation, and competitive advantage (Perkmann & Walsh, 2007). These differing objectives can lead to conflicts and misaligned expectations. Effective communication between academic researchers and industry professionals is also challenging due to differences in terminology, jargon, and expectations (Pittaway et al., 2004). Establishing effective communication channels and a common language is essential to bridging these gaps and fostering successful collaborations.

Intellectual property (IP) rights and commercialization disputes present another significant challenge. Negotiating IP agreements can be complex and may discourage collaboration (Waldman & Link, 2003). Disputes over IP ownership and commercialization can hinder partnerships, necessitating strategies for effective IP management. Additionally, limited funding and resources constrain the ability of both universities and industries to engage in collaborative projects. This constraint includes both financial and human resources (Ankrah & Al-Tabbaa, 2015). The availability and allocation of funding significantly affect the scale and success of collaborative projects.

Complex administrative processes and institutional regulations also slow down or hinder collaboration efforts (Bozeman, 2000). Navigating bureaucratic hurdles can obstruct technology transfer processes, adding to the challenges of university-industry partnerships. Furthermore,

differences in research timelines between academia and industry create mismatches. Academic research timelines are often long and uncertain, while industries operate on shorter, more predictable timelines (Gibbons et al., 1995). Aligning these differing time horizons is crucial for successful collaboration.

Other challenges include differing incentives for collaboration, which may result in insufficient motivation for both parties to engage deeply (Link & Scott, 2006). Building trust and establishing strong, long-term relationships is also challenging and requires time and effort (Cowan & Jonard, 2009). Differing risk tolerances between academic researchers and industry partners can impact collaborative ventures, as academics may be more risk-averse due to funding and career implications, while industries might be willing to take on higher risks for potential rewards (Rothaermel, 2001). Navigating different regulatory environments adds complexity to collaborative projects (Mowery & Shane, 2002). Additionally, universities may lack the infrastructure and expertise to transfer technology effectively to industry, and industry partners might not have the capability to adopt and scale new innovations (Etzkowitz & Leydesdorff, 2000). The triple helix model of university-industry-government collaboration can help address these challenges by providing the necessary infrastructure and expertise for successful technology transfer.

2.6.4. Best Practices and Strategies for University-Industry collaboration

Previous empirical studies have identified several best practices and strategies for fostering collaboration between universities and industry. These are:

Establishing clear and shared objectives between university and industry partners is fundamental for successful collaboration (Pertuze, 2010). Developing trust and maintaining open lines of communication are essential for overcoming cultural differences and aligning expectations (Awasthy et al., 2020). Designing IP agreements that are mutually beneficial and flexible can encourage greater collaboration and knowledge sharing (Pertuze, 2010). Collaborative research projects can serve as a platform for both parties to contribute and benefit from shared expertise and resources (Arenas & González, 2018). Empirical studies have identified mechanisms for enhancing technology transfer through university-Industry Collaboration (UIC). The role of intermediary organizations, such as technology transfer offices and collaborative research centers, is crucial in facilitating UIC by bridging gaps between

academia and industry (Alexandre et al., 2022). Establishing programs that focus on the transfer of knowledge, including internships, co-op programs, and executive education, can enhance the technology transfer process (Arenas & Gonzalez, 2019). Implementing innovation management practices, such as needs detection, knowledge creation, and absorption capacity, is vital for successful technology transfer (Sancho-Zamora et al., 2022).

2.6.5. Case Studies and Examples of Successful University-Industry Collaborations and Technology Transfer

Successful university-industry collaborations for technology transfer are crucial for driving innovation, economic growth, and societal development. Some of the case studies along with lessons learned and best practices were explored underneath from the existing literature.

2.6.5.1. Massachusetts Institute of Technology (MIT) and Industry Partnerships

MIT has a long history of successful collaborations with industry partners, leading to numerous technology transfers and commercialization ventures. For example, the collaboration between MIT and Boeing led to the development of advanced aerospace technologies, such as lightweight materials and aviation systems. MIT's emphasis on interdisciplinary research, strong industry ties, and flexible intellectual property policies has facilitated effective technology transfer and commercialization. Establishing dedicated technology transfer offices, fostering a culture of entrepreneurship, and promoting industry engagement through joint research projects and sponsored research agreements (Feldman & Florida, 1994).

The collaboration between IBM and Watson Research Center at MIT resulted in the development of Watson, an artificial intelligence system capable of answering questions posed in natural language. This partnership led to breakthroughs in cognitive computing and machine learning, with applications in healthcare, finance, and other industries (Ferrucci. et al, 2010).

The partnership between the Massachusetts Institute of Technology (MIT) and Samsung Electronics led to the development of flexible display technologies, including OLED (organic light-emitting diode) displays for smart phones and wearable devices. This collaboration demonstrates the convergence of materials science, engineering, and consumer electronics to drive innovation in display technologies (Kim & Moon, 2016).

MIT's close collaboration with the Cambridge Innovation Cluster in Massachusetts has led to the development of groundbreaking technologies in biotechnology, robotics, and renewable energy. Strong industry partnerships, robust technology transfer mechanisms, and supportive government policies (Thompson, 2017).

2.6.5.2. University of Waterloo and industry partnership in Canada

The University of Waterloo's partnership with Communitech, a technology hub in Canada, has facilitated the growth of numerous technology startups and scale-up companies. The best practices are designing industry relevant curriculum, co-op programs, and access to mentorship and funding opportunities (McMurtry & Currie, 2013).

2.6.5.3. Stanford University and Industry partnership

Stanford University's proximity to Silicon Valley has enabled fruitful collaborations between academia and industry, resulting in the birth of numerous technology startups and breakthrough innovations. Companies like Google, Hewlett-Packard, and Cisco have emerged from collaborations with Stanford researchers and students. Stanford's culture of risk-taking, interdisciplinary collaboration, and supportive ecosystem has facilitated rapid technology transfer and commercialization. Encouraging cross-disciplinary research, providing entrepreneurship education and support, and fostering strong ties between academia, venture capital firms, and industry players (Saxenian, 1996).

Stanford University's collaboration with Biogen, a biotechnology company, resulted in the discovery of a novel therapeutic target for the treatment of neurodegenerative diseases, such as Alzheimer's and Parkinson's. This partnership exemplifies the translation of basic research findings into potential drug candidates with clinical implications (Walsh, 2018).

2.6.5.4. European Union Horizon 2020 Program

The Horizon 2020 program funds collaborative research projects involving universities, industries, and other stakeholders across Europe to address societal challenges and foster innovation (Horizon 2020 - European Commission, n.d.).

2.6.5.5. University of Nairobi and Kenyan Tech Startups

The University of Nairobi has established successful partnerships with local tech startups, contributing to the development of innovative solutions in various sectors, including healthcare,

agriculture, and finance. Collaborations have led to the commercialization of mobile payment platforms, agricultural technologies, and health diagnostics tools (Mwangi & Ngugi, 2017).

2.7. Conceptual Framework

From the literature and empirical reviewed this study identified the following independent variables such as linkage on (management, education, research and consultancy, and Technology transfer activities and supportive infrastructures) and dependent variable (i.e., Status of UIL). For these variables a five- point Likert scale is used to measure them.

A comprehensive conceptual framework that indicates the relationship between the status of University-Industry Collaboration (UIC) and various aspects such as Management, Education, Research and Consultancy, and Technology Transfer Activities can be structured as follows in figure 5.

Interrelationships and Synergies

- **Management as an Enabler:** Some past research studies explores how effective management practices contribute to organizational agility in the context of university-industry collaboration. It discusses the role of management in setting strategic directions, fostering innovation, and supporting collaborative efforts between academia and industry. The article examines how supportive leadership and management practices create an enabling environment for education, research, and technology transfer activities, emphasizing their impact on organizational performance and competitiveness. It provides insights into contemporary challenges and opportunities in managing university-industry collaborations effectively. Effective management practices and supportive leadership create an enabling environment for all other aspects. Management sets the tone and provides the necessary support and resources for education, research, and technology transfer activities (Manoharan & Muthhukkannu, 2024).
- **Education as a Foundation:** A Strong education system that incorporates industry needs ensures a steady supply of skilled graduates, fostering a talent pool that is ready to engage in collaborative research and technology transfer. The linkages between higher education, industry needs, and regional innovation dynamics, highlighting strategies for enhancing educational programs to meet industry demands. Integrating education with

industry collaboration to support innovation and economic development(Zhang & Chen, 2023).

- Research and Consultancy as Drivers of Innovation: Collaborative research and consultancy projects drive innovation and generate new knowledge, which can be translated into practical applications through technology transfer activities (Kobylińska & Irimia-Dieguez, 2023).
- Technology Transfer as a Bridge to Market: Technology transfer activities act as a bridge between academic research and industry application, facilitating the commercialization of innovations and contributing to economic development (Hornuf&Thurik, 2021).

Feedback Loops

- Continuous Improvement: Feedback from industry partners can inform curriculum updates and research priorities, ensuring continuous improvement and relevance.
- Sustainable Collaboration: Successful technology transfer and commercialization create a virtuous cycle, attracting more industry partners and funding, further enhancing UIC efforts.

In summary, the status of University-Industry Collaboration is influenced by an interdependent relationship among management, education, research and consultancy, and technology transfer activities. Effective management practices create a supportive environment that enhances educational relevance, drives innovative research, and facilitates the commercialization of technologies, thereby fostering sustainable and impactful UIC.

From the discussed theoretical and empirical literature in this chapter the following conceptual summary was produced in diagram form.

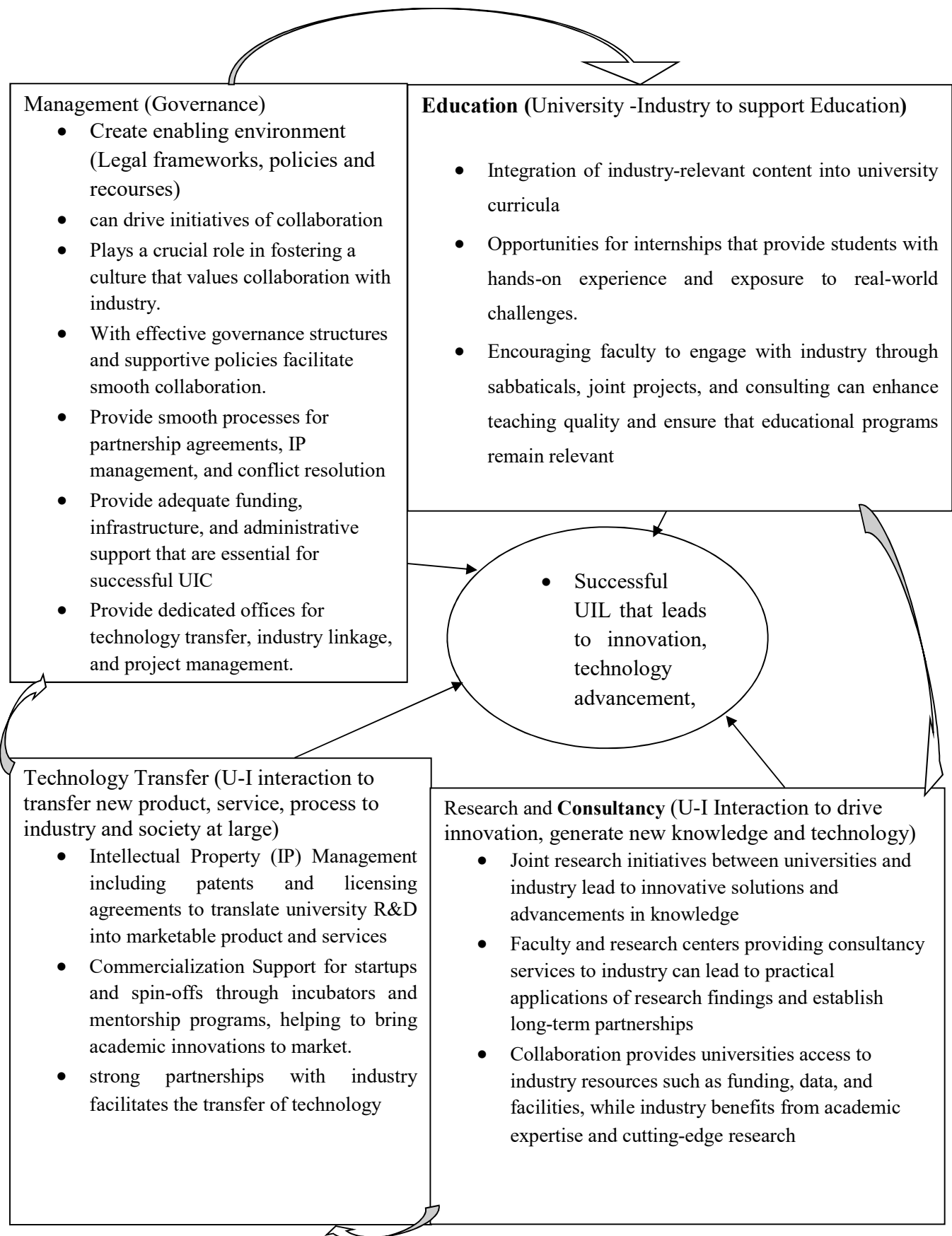


Figure 2.3: Conceptual framework (Source own computation from the reviewed literatures)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Research Design

The research employs a mixed-methods design, combining both qualitative and quantitative approaches to address complex issues and deepen understanding. This design is based on pragmatism, which emphasizes context and objective reality, and aims to integrate various data sources for a comprehensive analysis (Greene & Hall, 2016; Creswell, 2008; Pinto, 2010). The mixed-methods approach resolves the limitations of solely quantitative or qualitative methods by combining their strengths (Cameron, 2011; Creswell, 2015).

3.2. Sampling Method and Sample Size determination

For data collection, the research was adopted distinct sampling methods for different research questions that were described in the first section of this paper. For the first question, some countries were selected based on relevant criterion, (e.g., emerging economies, developed countries). Then a systematic literature review was conducted across multiple academic databases, focusing on best practices in university-industry linkages in those selected countries. The best practices focuses on policy and regulatory environment, organizational structures and capacity, collaborative mechanisms, funding and support mechanisms, programs and initiatives, infrastructure and resources, outputs and outcomes, evaluation and metrics and barriers and challenges in selected countries. This review utilize keywords such as "university-industry collaboration," "technology transfer," "best practices," and "innovation" combined with country-specific terms. In the literature search peer-reviewed journal articles, conference papers, reports published were included.

For the remaining questions, the study purposively selects four public universities in Ethiopia: Addis Ababa University, Ambo University, Addis Ababa Science and Technology University, and Adama Science and Technology University. Since 2011, the two science and technology universities have taken a special mission from government to become a center of excellence in science and technology. To attain their mission, they are expected to collaborate with industries and to have more practices than the other universities. Addis Ababa University is the first-

generation public university of the nation that ranked in 1st place in every aspect. It has consistently maintained a strong position among Ethiopian universities over several years. Whereas Ambo University is the second-generation public universities, its proximity to the center as compared to the other second generations and then it was selected as one of a sample of the study.

Therefore, these four universities were purposively selected to investigate the institutional framework of University-Industry linkage towards technology transfer activities in the two science and technology universities those have special mission from government in technology advancement, in Addis Ababa university the first ranked Ethiopian university as it has long run experience and in Ambo university the second generation.

In terms of participant selection for survey, a random sampling technique was used to ensure each member of the target population had an equal chance of inclusion, thus enhancing the representativeness and validity of the findings. The sample size was determined using the Yamane formula, a standard method for calculating sample sizes from finite populations. The Yamane formula is expressed as $n = \frac{N}{1 + Ne^2}$, where n represents the sample size, N is the population size, and e is the margin of error. For this study, the total target population across the four selected universities was 4,173(source field data), comprised of 1,700 from Addis Ababa University (AAU), 663 from Adama Science and Technology University (ASTU), 607 from Addis Abeba Science and Technology University (AASTU), and 1,203 from Ambo University (AU). With a margin of error set at 6.3% (0.063), the Yamane formula yields:

$$n = \frac{4173}{1 + 4173 * 0.0039} \cong 240$$

Therefore, the final sample size used for the study was 240. To allocate the sample proportionally among the universities, the sample size was distributed according to each university's share of the total population. The proportions were calculated as follows: AAU represented approximately 38.6% of the total population, ASTU 15.1%, AASTU 13.8%, and AU 32.3%. Based on these proportions, the sample sizes were allocated as 93 participants from AAU, 36 from ASTU, 33 from AASTU, and 78 from AU. This proportional allocation ensures

that the sample is representative of the diverse populations across the four universities, thereby maintaining the study's reliability and accuracy (Yamane, 1967).

For the interviews, purposefully the directors of university-industry linkages (UIL) and technology transfer (TT) at each university was selected. This strategic choice ensured that as the key decision-makers who are directly involved in managing and guiding the university's partnerships and commercialization efforts was engaged in the study. Their insights provided valuable perspectives on the dynamics and impact of these collaborations.

From industry side, purposively local private industries that have collaborations with four universities were selected. A list of industries with formal partnerships with four universities was compiled. The analysis revealed that over 95% of these collaborations involved state-owned industries, with minimal involvement from private sectors. Consequently, the focus shifted to private industries. Each private industry was contacted to identify a key informant knowledgeable about the university collaboration. Data were collected through phone and face-to-face interviews with these key informants to gather detailed insights into the nature and scope of the collaborations.

3.3. Data Collection Methods

To assess the current status of university-industry linkages (UIL) for technology transfer in the four selected public universities in Ethiopia, this study addresses five research questions outlined in the initial section. Data collection followed a structured approach using both secondary and primary sources.

For the first research question, secondary data were gathered from academic databases such as Google Scholar, Scopus, and Web of Science. For the remaining questions, policy documents, administrative reports, and bulletins from the four universities were utilized.

Primary data were collected through Likert scale questionnaires and structured open-ended interviews. The Likert scale questionnaires, based on a literature review, addressed variables related to strategic and operational management, educational, research and consultancy activities, technology transfer, infrastructure, and associated challenges. These variables were broken down into a five-point scale for survey purposes, and additional questions were included

to explore differences in perspectives based on respondents' positions, experiences, educational levels, and academic titles.

Structured open-ended interviews were conducted in-depth with the key informants in exploration of thematic areas such as funding, policy, guidelines, leadership, technology infrastructure, and internal governance. Key informants included UIL and Technology Transfer Directors from each university, as well as industry representatives. Interviews were conducted face-to-face to facilitate open discussion, with shorthand notes taken by the interviewer to capture detailed responses.

3.4. Data analysis method

3.4.1. Analysis procedures

To address the first research question, data obtained from literature searches were systematically organized and analyzed using thematic analysis. This analysis focused on identifying common best practices in University-Industry (U-I) linkages across selected countries, examining themes such as institutional frameworks, funding mechanisms, and collaborative approaches.

For the remaining research questions, both quantitative and qualitative data collected through surveys and in-depth interviews were organized and analyzed to triangulate findings from various sources and achieve the study's objectives. Descriptive and inferential statistics were applied to assess and describe the current state of UIL, Technology Transfer Offices (TTOs), and technology transfer activities. One-way Analysis of Variance (ANOVA) was employed to determine if there were significant differences in perceptions of UIL and technology transfer activities among academic communities in the selected universities. ANOVA was chosen because it is suitable for comparing means across multiple groups (Montgomery, 2017).

To answer the fourth research question, one-way ANOVA was used at a 0.05 alpha level, alongside Ordinary Least Squares (OLS) regression to relate Technology Transfer Index (TTI) with University-Industry Linkage Index (UIL). Statistical analysis was conducted using SPSS for descriptive statistics and STATA for calculating mean differences and performing ANOVA.

The ordinary least squares (OLS) method has several advantages in estimating distribution parameters compared to other methods, where it provides algebraic expressions for estimating

parameters. OLS estimators have been shown to perform better than maximum likelihood (ML) estimation for small sample sizes in the current study is a small sample study. Additionally, OLS outperforms other regression-based methods, such as relative least squares (RLS) and weighted least squares (WLS), for samples of all sizes. Overall, OLS provides a reliable and efficient approach for estimating distribution parameters for relatively studies of small sample sized ones.

3.4.2. Computation of Technology Transfer Index (TTI) and UIL Index

A detailed process was implemented to analyze the relationship between University-Industry Linkages (UIL) and Technology Transfer (TT) activities. Initially, data were gathered from academic staff using Likert-scale questionnaires, which included 72 variables related to UIL and TT activities. To manage and simplify this extensive variable set, the first step involves factor analysis, which was employed to reduce the dimensionality of the data while retaining the most significant variance and identifying latent variables that underlie the observed variables. The appropriateness of the data for factor analysis was assessed using the KMO measure of sampling adequacy and Bartlett's test of sphericity. A KMO value above 0.7 and a significant Bartlett's test ($p < 0.05$) indicate that factor analysis is appropriate (Bartholomew, Knott, & Forster, 2011). Principal Component Analysis (PCA) was used as extraction method for factor extraction to identify the number of components that account for the most variance in the data. Eigenvalues greater than 1 was used to determine the number of factors. To enhance interpretability, an orthogonal rotation method Promax was applied. This rotation simplifies the factor structure by making it easier to understand which items load heavily on which factors. Items that was assigned to factors based on their loadings typically set at 0.4 or higher (Johnson & Wichern, 2014). Factors that exhibit higher loadings on specific items was identified as representing significant dimensions of UIL and TT.

Following the factor analysis, latent variables or indices for UIL and TT were constructed. The construction of these indices involved the normalization of the factor scores derived from the analysis. Normalization was essential to ensure that the indices were on a comparable scale, making them suitable for subsequent analysis.

The process of constructing indices for University-Industry Linkages (UIL) and Technology Transfer (TT) was precisely outlined in this section, including the normalization and aggregation

of variables. After performing factor analysis on the initial 72 variables, latent variables or indices for UIL and TT were developed to condense the underlying constructs effectively.

The first step in constructing the UIL and TT indices was to normalize the factor scores. Normalization ensures that all variables are on a comparable scale, which is crucial for integrating them into a composite index. The current study involved studying the patterns of TT and UIL as a composite as well as individual components index as suggested by (Webster et al., 2015).

Webster et al. (2015) suggest that two to three questions can be included in a self-administered survey for each of the indicators, and then normalized the value for each individual; similar to the method employed by (Standing ,2002; Nizami and Prasad, 2017).

The normalization process applied in the study was used the following formula.

$$\text{normalized variable } X_i \text{ in Index} = \frac{X_{\text{actual}} - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}} \quad (1)$$

, where

- X_i is the normalized value of the observed variable i that included in the index from factor analysis result,
- X_{actual} is the actual value assigned to the observed variable i by an individual respondent,
- X_{min} is the smallest value for any individual in the sample (in this case, 1 in the data set),
- X_{max} is the largest value for any individual in the sample (in this case, 5 in the data set).

For example, if a respondent rated a variable with an actual value of 3, and the minimum and maximum values across the sample were 1 and 5, respectively, the normalized value would be calculated as $\text{normalized } X_i = \frac{3-1}{5-1} = \frac{2}{4} = 0.50$ using equation (1). This normalization transforms each variable's values into a standardized range between 0 and 1, which facilitates the comparison and aggregation of different variables.

Each of the 240 respondents will provide a response for the variable in question. These responses are the X_{actual} values. For instance, the variable is measured on a Likert scale from 1 to 5, each respondent's answer is one of these values.

In summary, X_{actual} represents each respondent's individual response for the variable, which is then normalized using the minimum and maximum values from the entire dataset. This process ensures that all responses are scaled consistently, facilitating accurate and meaningful analysis.

After normalizing each respondent's response, there were a set of normalized values between 0 and 1 for that variable. This normalized data can then be used to compute the value of the index. Since the composite index was constructed from multiple normalized variables, then aggregating these normalized values (e.g., by averaging them).

Once all variables that used in index formation were normalized, then index calculated for each respondent from the normalized variables. This calculation was performed for all 240 respondents, yielding 240 individual UIL index values. To obtain an overall UIL index for the entire sample, aggregate these individual scores by calculating their average. A composite index, obtained by adding up the indexes for the separate values and normalizing the result using equation (1) above. Each dimension's indicators of the computed variables were rescaled to run from 0 to 1 rather than a Likert-scale values using equation (1) above which is consistently used for all index computation.

In the current study, four to six questions were included from the result of factor analysis under each component of the UIL index and TT index, and each were first converted to individual indices before aggregating to the composite UILI. In this study there was four indicators as explained below, to form academics index (UILAI) which was computed as the sum of individual indices normalized by their numbers. These are q23, q26, q28 and q213 and by aggregating their normalized values the value of UILAI computed using equation (2).

$$\text{UILAI} = \frac{q23 + q26 + q28 + q213}{4} \quad (2)$$

Similarly, UIL in research and consultancy linkage Index (UILRI), where there are six indicators is given in equation (3).

$$\text{UILRI} = \frac{q31 + q32 + q34 + q35 + q38 + q310}{6} \quad (3)$$

UIL in infrastructure index (UILII) has also four indicators and is computed as

$$UILII = \frac{q51 + q52 + q53 + q54}{4} \quad (4)$$

Similarly, the TT index was computed using the same approach as below, with the normalized scores from questions related to technology transfer averaged to form the TT index.

TT index (TTI) has also five indicators and is computed as

$$TTI = \frac{q42 + q43 + q44 + q46 + q48}{5} \quad (5)$$

3.4.3. Model specification

With the UIL and TT indices constructed and normalized, were then used in a multiple regression model. In this model, the TT index served as the dependent variable, while the UIL index was the independent variable. This analysis aimed to assess how variations in UIL, as indicated by the UIL index, influence technology transfer outcomes, as measured by the TT index. By analyzing this relationship, the study provides insights into how effective university-industry linkages are in facilitating technology transfer, offering valuable information for enhancing academic-industrial collaboration strategies.

In computing the dependent variable for the OLS method, the first is that a quantitative measure will rarely be able to capture people's subjective experiences – unless an opinion survey is undertaken (Mackett,2020) and subjective(opinion based) responses are highly important in such cases. Although even with an opinion survey, a qualitative tool would be most appropriate to capture the subjective experiences of people. The importance of subjective experiences are clearly identified in the numerous literature. However, strict quantitative measures would require a move away from subjective probing to ‘deciding’ on behalf of people's response what would be the best of their reflection.

Similarly, many aspects of UIL components cannot fully be measured using quantitative measures, although many objectively measured indicators have such shortcomings. Thus, based on Webster et al. (2015) suggestion where two to three questions can be included in a self-administered survey question which can be used for computation of indices from the personal opinion responses.

The values were determined based on the questions which are designed to capture the concern of UIL aligned with the objective of the study¹. For each question, the individual was assigned a certain value and this value was then included for the individual or aggregated to the computed index. For the majority of those variables a five-point Likert scale is used to measure them.

Then after computing the required indices from the personal responses based on the above stated suggestions in the literature, the following OLS equation was employed.

$$TTI = f(\text{Education, experience, location, UILI, } - - -) \quad (5)$$

$$TTI_i = \alpha + \delta UILI_i + \beta X_i + u_i \quad (6)$$

$$TTI_i = \alpha + \delta_1 UILAI_i + \delta_2 UILRI_i + \delta_3 UILII_i + \beta X_i + u_i \quad (7)$$

Where TTI is the Technology Transfer Index, UILI is university industry linkage index of different aspects and X_i are other covariates used for modeling the determinants of technology transfer while u_i is the error term. The major indices computed are Technology transfer Index (the dependent variable computed from five separate questions), four indicators of UIL in academics aspect index(UILAI)², Research and consultancy Index(UILRI)³ and UIL in infrastructure index(UILII)⁴. Equation (6) can be written in an extended form as follows:

1. Since several questions were developed under each category and to determine most important dimension for the indicators from the lists, a factor analysis was first used before computed both the individual and aggregate indices. Four to six questions were included under each component of the UIL indicators. The details of all questions developed for the study can be referred to the Appendix section.

2. Indicators used under this dimension include: (i) Joint training initiatives for students, academics, and industry employees for exchanging experiences and skill development; (ii) Exchange of Ph.D or master student with industry; (iii) Extent of inviting firm's staff and experts to deliver lectures and speeches on new technology, entrepreneurship courses to students and researchers practiced at your university and (iv) Extent of providing scholarships for students and academic staff by industry

3. Indicators used under this dimension include: (i) Joint Research Projects, consultancy with industry; (ii) Industry Sponsored research works; (iii) Industry-Academia Conferences and Workshops for setting research thematic area; (iv) Access to Industry Data and Resources; (x) Industry-Driven Research Priorities and (vi) Commercialization of R&D results

4. Indicators used under this dimension include: (i) Organizes resources for technology transfer with industries; (ii) Establishes research and innovation centers and institutes with industries; (iii) Develops joint infrastructure facilities (ICT, laboratories, or innovation hubs, science park, Offices, etc.) for UIL with industries and (iv) Establishes different technology incubation centers jointly

5. Indicators used under this dimension include: (i) clarity and effectiveness of the technology transfer pathway; (ii) the availability of supportive structures (e.g., offices, funding, expertise) for technology transfer; (iii) the efficiency and effectiveness of the technology transfer process; (iv) TTO has adequate staffs with

This methodology aligns with the approach suggested by Webster et al. (2015), who advocate including multiple questions for each indicator and normalizing values to create robust indices. The study's approach also builds on previous work, such as that of Standing (2002) and Nizami and Prasad (2017), by employing a systematic method to aggregate and normalize indices, thereby ensuring reliable and comparable results across different variables and respondents.

To support the methodology of calculating and aggregating indices, several academic sources provide valuable insights into index construction and normalization techniques addition to the above articles. Zeithaml, Berry, and Parasuraman (1996) in the *Journal of Marketing* discuss the development and validation of service quality indices, highlighting methods for aggregating multiple variables into a composite index and normalizing scores. Similarly, Parasuraman, Zeithaml, and Berry (1988) in the *Journal of Retailing* offer foundational procedures for creating composite indices and normalizing data, which are broadly applicable across various research contexts. Kline's book, *Factor Analysis and Related Methods* (2016), provides an extensive overview of factor analysis and index construction, including aggregation and normalization practices. Wilks's *Methods of Statistical Analysis* (1980) also delves into these methodologies, offering a detailed look at statistical approaches for handling and interpreting index data. Additionally, Hair, Anderson, Tatham, and Black's *Multivariate Data Analysis: A Global Perspective* (2010) and Mardia, Kent, and Bibby's *Introduction to Multivariate Statistical Analysis* (1979) both cover multivariate techniques and index construction, providing essential guidance on aggregating and normalizing variables for composite indices. These sources collectively support the approach of aggregating normalized variable scores to compute comprehensive indices.

3.5. Reliability

Kothari (2011) defines reliability as the degree to which a measuring instrument provides constant outcomes on repetitive trials. Thus, pilot study was conducted to assess the effectiveness, clarity of the questions and reliability of the questionnaires. In addition, the

necessary skills like IP law, business development, and negotiation; (v) There are enabling legal framework, regulations related to intellectual property, contracts, licensing and negotiation

6. The “q” s are question numbers in the original survey questionnaire.

Cronbach's Coefficient Alpha values are described as excellent if $\alpha \geq 0.90$, is good if $0.80 \leq \alpha < 0.90$, is acceptable if $0.70 \leq \alpha < 0.80$, questionable if $0.60 \leq \alpha < 0.70$, poor if $0.50 \leq \alpha < 0.60$ and unacceptable if $\alpha < 0.50$ (Taber K, 2018). Accordingly, for this study the overall 72 items used in the questionnaires had good reliability with (0.840).

3.6. Ethical Considerations and Confidentiality

It is very difficult to lay down a set of clear rules for ethics relate to all possible moral choices which affect decisions, standards and behaviors. However, Greener (2008), pointed out four main ethical issues that need to be addressed in the process of undertaking research. These are informed consent, right to privacy, and honesty with professional colleagues. Accordingly, the researcher of this study tries not to expose participants to any physical or psychological harm, requests by formal cooperation letter written by ASTUs official the respondents consent in response to interview questions and could participate only voluntarily. Also, respect the participant's right to privacy through anonymizing and coding the interviewee's personal information such as name, as well as company names and specific address. Moreover, empirical data will be stored safely to ensure that only the researchers have access to this information and report the findings completely.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter was presented and discussed the findings of the research concerning university-industry (U-I) linkages and their role in technology transfer within selected public universities in Ethiopia. This chapter was systematically addressed the research questions and objectives outlined in the study, using both quantitative and qualitative data and provide a comprehensive analysis.

The chapter was first explored the international best practices in U-I linkages across eight countries such as USA, Germany, Japan, South Korea, China, Brazil, Thailand and Africa. The international best practices were identified through the literature review. It was included aspects such as policy frameworks, organizational structures, collaborative mechanisms, funding, infrastructure, and evaluation metrics. Following this, the chapter provided an in-depth analysis of the existing institutional frameworks of U-I linkages at four selected Ethiopian universities: Addis Ababa University, Ambo University, Addis Ababa Science and Technology University, and Adama Science and Technology University. This discussion includes a review of national policies and other strategic documents related to UIL and TT, policy implementations, organizational structures, Industry Engagement, Funding mechanisms and supportive services and Evaluation mechanisms. Following the examination of the current frameworks, the chapter was then compared the explored international best practices in U-I linkages with the current institutional frameworks in Ethiopia. This comparison was highlight how the practices adopted Ethiopia align with or differ from those implemented globally and how those practices relevant for Ethiopia. By contrasting the Ethiopian frameworks with international standards, the strengths, weaknesses, and areas for improvement were identified.

The chapter then shifted focus to evaluate how Technology Transfer Offices (TTOs) are organized and how effectively they facilitate U-I linkages. This analysis is crucial for understanding the structural and functional aspects of technology transfer in the selected universities.

Next, the chapter was identified and discussed major challenges that affect the effectiveness of U-I linkages. The findings from both qualitative interviews and quantitative surveys were synthesized and provided a detailed account of these challenges and their implications.

Finally, the influence of U-I linkages on technology transfer was analyzed using statistical methods, specifically Ordinary Least Squares (OLS) regression, to determine the influence of various U-I linkage components on technology transfer activities.

Overall, this chapter was addressed the research questions by integrating insights from various data sources and provided a holistic view of the current status and effectiveness of university-industry linkages and their role in enhancing technology transfer in Ethiopia.

4.2. Analysis of International Best Practices in University-Industry Linkages and Technology Transfer

This analysis of international best practices in university-industry (U-I) linkages and technology transfer activities was based on a thematic review of literature from eight diverse countries: the United States, Germany, Japan, South Korea, China, Brazil, Thailand, and Africa. The thematic analysis of the literature on University-Industry (U-I) linkages reveals several key best practices, categorized into four primary themes: institutional framework and policy reforms, organizational structures and collaborative mechanisms, funding and infrastructure investments, and tracking and evaluating outcomes.

The literature was selected for its relevance to U-I linkages and technology transfer, focusing on empirical data and case studies from each country. The selected countries represent a range of economic development levels and geographical regions, providing a comprehensive global perspective on best practices. The detailed results of the analysis was discussed under the following four thematic areas.

I. Institutional Frameworks and Policy Reforms

The review and analysis result shows that, in the United States, the evolution of technology transfer frameworks has significantly advanced since the late 20th century. Technology Transfer Offices (TTOs) emerged as pivotal entities for managing and commercializing intellectual property, fostering startup ventures, and bridging academia with industry. The establishment of

TTOs became increasingly sophisticated, especially following the enactment of the Bayh-Dole Act of 1980. This landmark legislation allowed universities to retain ownership of patents from federally funded research, catalyzing a substantial increase in technology transfer activities. Consequently, universities enhanced their TTOs with experienced staff and operational mandates, leading to notable improvements in patent disclosures and licensing income (Siegel et al., 2003).

The policy and regulatory reforms has been instrumental in supporting these advancements. Key reforms of the 2011 America Invents Act included the Bayh-Dole Act, which notably increased university patents by 25% from 1980 to 1990. Subsequent policies focused on simplifying patent procedures and providing incentives like tax credits and grants, which further facilitated research commercialization and industry partnerships (National Research Council, 2014).

Germany has developed a forceful framework for university-industry linkages and technology transfer, marked by an effective institutional structure, supportive policies, and significant investment in infrastructure. Central to this framework is the Fraunhofer Society, established in 1949, which exemplifies applied research and industry collaboration. With over 70 institutes, the Fraunhofer Society contributes approximately €2.7 billion annually to contract research, demonstrating its pivotal role in technology transfer (Gehrke, 2012; Fraunhofer Society, 2022).

The government of German undertook different policy reforms to strengthen these linkages through strategic initiatives like the “High-Tech Strategy 2025” and the “Excellence Initiative.” These frameworks align research funding with innovation priorities, resulting in over 30% of public research funding being allocated to collaborative projects with industrial partners (OECD, 2021). Such policies create a conducive environment for technology transfer by providing clear guidelines and incentives for collaboration.

The Innovation Alliance Initiative encourages collaboration between universities, research institutions, and industry partners. The "Industrial Collective Research" (IGF) program supports joint research projects between industry and academia, contributing to a significant increase in collaborative research outputs, leading to over 30% of public research funds being allocated to collaborative projects (OECD, 2021).

Japan's approach to technology transfer was significantly shaped by the creation of Technology Licensing Organizations (TLOs) in the late 1990s, which facilitate patent licensing and commercialization. The 2013 revision of the Act on the Promotion of University-Industry Cooperation formalized and structured collaborations between academic institutions and industry (Japan Patent Office, 2019). Japanese universities such as the University of Tokyo have dedicated Industry-Academia Collaboration Offices (IACOs) to manage these relationships.

The "Strategic Innovation Promotion Program" (SIP) and the Japan Science and Technology Agency (JST) Grants support technology commercialization and innovation, aligning academic research with industrial needs and enhancing UIL (Strategic Innovation Promotion Program, 2020).

South Korea has significantly advanced its university-industry linkages and technology transfer processes through a vigorous and evolving institutional framework, supportive policies, and targeted programs. The evolution began with the government's initiatives in the late 1990s, including the establishment of key institutions such as the Korea Institute of Science and Technology (KIST) and the Korean Technology Transfer Center (KTTC). A major reform in 2002 led to the creation of the Industry-Academic Cooperation Foundation (IACF), designed to streamline technology transfer and foster joint research projects. The effectiveness of this framework was evidenced by a study showing a 30% increase in successful commercialization of research outputs in institutions within the IACF framework (Lee, Park, & Kim, 2021).

The policy and regulatory environment has further enhanced these linkages. The 2008 "Framework Act on Science and Technology" and the 2012 Technology Transfer Act established a supportive regulatory climate, incentivizing universities to engage in commercial activities and protecting intellectual property. These reforms led to a notable 25% increase in patent filings and a 20% rise in technology licensing agreements between 2012 and 2018 (Kim & Lee, 2018).

China's institutional framework for university-industry linkages has undergone significant evolution, marked by the establishment of technology transfer offices and formal bodies such as the China Association for Science and Technology (CAST). These early reforms aimed at streamlining commercialization and aligning university research with industrial needs. Recent

advancements, including the "Double First Class" initiative, have further enhanced these linkages by focusing on global competitiveness and fostering stronger ties between top universities and leading firms. The success of these efforts is evidenced by a 40% increase in joint patents from 2015 to 2020, reflecting improved technology transfer efficiency (Zhang, 2019).

In terms of policy and regulation, China's approach has shifted from restrictive early policies to more supportive frameworks. The "National Medium- and Long-Term Program for Science and Technology Development (2006-2020)" set clear goals for innovation and technology transfer. Recent policies, such as the "Innovation-driven Development Strategy," have introduced tax incentives and simplified technology transfer procedures, leading to a 35% annual increase in technology transfer agreements between 2016 and 2021. These regulatory changes have significantly strengthened collaboration between academia and industry (Wang & Li, 2020).

Collaborative mechanisms have also evolved significantly. Early models included formal agreements and joint research projects, with the introduction of Technology Business Incubators (TBIs) supporting academic startups. Recent developments include the promotion of "Industry-University-Research Cooperation" platforms and public-private partnerships. Platforms like the China Technology Transfer Network have streamlined collaborative processes, resulting in a 50% increase in successful joint ventures over the past five years.

In Brazil, significant progress has been made in enhancing university-industry linkages and technology transfer through a combination of strategic reforms, institutional support, and targeted initiatives. The country's institutional framework has been reinforced by the establishment of dedicated Technology Transfer Offices (TTOs) and Innovation Agencies such as the National Council for Scientific and Technological Development and the Brazilian Innovation Agency. Key legislative reforms, notably the Innovation Law (Law 10.973/2004) and its update by Law 13.243/2016, have created a supportive environment for collaboration by offering tax incentives and simplifying patenting processes. These legislative changes contributed to a 30% increase in university-industry partnerships between 2004 and 2016 (Oliveira, 2018).

The policy and regulatory environment has also seen notable improvements. The establishment of the National Innovation System and subsequent legal frameworks like the Innovation Law and the Legal Framework for Science, Technology, and Innovation have streamlined intellectual property and technology transfer processes. These reforms led to a 25% increase in successful technology transfers from 2016 to 2020 (Silva & Pereira, 2019).

Thailand has made significant strides in enhancing university-industry linkages and technology transfer through a series of strategic reforms and institutional advancements. Early efforts, such as the establishment of the National Science and Technology Development Agency (NSTDA) and the Office of the Higher Education Commission (OHEC), laid the groundwork for formalizing partnerships and providing strategic direction for collaboration (Thongpapanl, 2009). Recent initiatives have further encouraged this framework with the creation of regional innovation centers and technology parks, resulting in a 30% increase in joint research projects between 2015 and 2020 (Chai, 2020).

Policy and regulatory changes have been pivotal in facilitating technology transfer. Previously fragmented policies have been streamlined under the “Thailand 4.0” policy, enacted in 2016, which aims to foster innovation and ease technology commercialization (Cheng, 2017). This policy has contributed to a 25% rise in university patents from 2016 to 2021 (OECD, 2022) and has simplified regulatory processes, thus encouraging greater startup and research institution engagement (Sukhatip, 2021).

Many African countries have made progress in establishing policies and frameworks to support university-industry linkages and technology transfer. For instance, South Africa's National Research Foundation and Kenya's National Commission for Science, Technology, and Innovation have developed comprehensive policies to enhance collaboration between academia and industry (Meyer et al., 2022). These policies often include tax incentives, intellectual property rights regulations, and support for innovation hubs.

Despite progress, there are still significant gaps in policy implementation and enforcement. Many African countries lack unified national strategies for technology transfer, leading to fragmented efforts and inconsistent support across regions (Suleiman & Marlowe, 2023). Furthermore, inadequate legal frameworks and bureaucratic hurdles often hamper effective policy execution.

II. Organizational Structures and Collaborative Mechanisms

U.S. universities have established advanced TTOs and research centers to manage intellectual property and support industry collaborations. Organizational structures within universities have also evolved to reinforce technology transfer. Initial efforts were limited, but over time, universities established dedicated offices and multidisciplinary research centers. Effective organizational practices, including cross-disciplinary teams and capacity-building initiatives, have led to a 30% increase in licensing revenues (Mowery & Ziedonis, 2002). Institutions like MIT and Stanford have robust TTOs that facilitate technology licensing, spin-off creation, and collaborative research (Mowery & Ziedonis, 2002). Additionally, incubators and accelerators have been developed to support start-ups and commercialization efforts (Autio & Klofsten, 1998).

Formalized industry collaborations are prevalent, with universities partnering with corporations for joint research projects, technology development, and commercialization (National Science Foundation, 2018). Collaborative mechanisms become more formalized, with structured agreements and clear communication channels replacing earlier informal practices. Data shows that formalized collaborations enhance technology transfer success rates by 40% (National Science Foundation, 2018).

In case of Germany the organizational structures within universities, particularly Technology Transfer Offices (TTOs) and collaborative programs like the “Clusters of Excellence.”, are critical to managing intellectual property and facilitating commercialization. For example, the Technical University of Munich (TUM) has established a successful TTO, leading to over 200 spin-offs and more than 300 patents in the past decade. This demonstrates the effectiveness of these structures in supporting technology transfer (Günther, 2013).

Japan's approach to fostering university-industry linkages is characterized by a comprehensive institutional framework, supportive policies, and strategic initiatives. The development of this framework began in the late 1990s with the establishment of Technology Licensing Organizations (TLOs), which served as intermediaries to enhance technology transfer. This initiative resulted in a 20% increase in licensing revenues for universities within five years (Shibata et al., 2002).

In terms of policy, the "Innovative Venture Ecosystem" policy, introduced in 2015, provided regulatory support and incentives for start-ups, which led to a 30% increase in university-originated start-ups between 2015 and 2020 (MEXT, 2021). Additionally, the "Intellectual Property Strategy Program" streamlined patent processes and improved intellectual property protection, critical for successful industry partnerships (Fujimoto, 2020). Further reforms, such as the 2013 revision of the Act on the Promotion of University-Industry Cooperation, mandated universities to create dedicated offices for technology transfer, leading to more structured interactions between academia and industry (Kawaguchi & Nishimura, 2015).

Organizational structures within universities have also evolved to enhance collaboration with industry. The creation of Industry-Academia Collaboration Offices (IACOs) has played a pivotal role in managing and facilitating these partnerships. Universities with IACOs have experienced a 25% higher success rate in technology transfers compared to those without such offices (Yamamoto, 2022). These offices are supported by training programs for faculty and researchers to improve their commercialization skills (Tanaka, 2021).

Collaborative mechanisms in Japan include the establishment of joint research centers and R&D projects. The Global COE Program, initiated in 2007, fostered international collaboration and led to a 40% increase in joint research outputs and a 35% increase in joint patents over a decade (Ishikawa & Matsuo, 2013; Ishikawa, 2020). Industry-academia collaboration forums and matchmaking events have also been instrumental, resulting in a 15% increase in successful project collaborations (Nakamura, 2021).

South Korean universities and research institutions centralize technology transfer resources through TTOs and the Technology Commercialization Center (TCC). Institutions such as KAIST and POSTECH have established effective structures to support UIL and technology commercialization (Korean Technology Transfer Center, 2021). Research highlights that universities with well-developed TTOs and TCCs saw a 40% higher success rate in spinning off technology-based startups (Choi, Kim, & Park, 2019).

Public-private partnerships and programs like the Industry-Academia Collaboration Program facilitate joint research and commercialization efforts. Analysis shows that projects funded through PPPs had a 35% higher rate of successful commercialization (Yoo & Lee, 2020).

South Korea's commitment to technology transfer is also reflected in its investments in infrastructure. The development of technology parks and research centers, such as Daedeok Innopolis and Pangyo Techno Valley, has significantly enhanced resources for innovation. Regions with advanced technology infrastructure saw a 40% higher rate of successful technology commercialization compared to less developed areas (Kim & Choi, 2021).

Initially, China focused on creating university-based research institutes and technology parks. The development of the "National Technology Transfer Center" network in the early 2010s marked a shift towards supporting research commercialization (Liu, 2018). More recently, dynamic organizational models such as innovation hubs and joint research centers, exemplified by the Zhongguancun Science Park, have demonstrated effectiveness. This park alone facilitates over 500 technology transfer (Li & Zhang, 2020).

Brazilian universities and research institutions have developed TTOs and innovation centers to support patenting and collaborative research. Institutions like the University of São Paulo have established comprehensive TTOs to manage UIL and technology transfer (Costa & Lima, 2018). Effective organizational structures have played a critical role in strengthening university-industry linkages, resulting in a 40% increase in patent applications between 2010 and 2020.

Collaborative mechanisms, including public-private partnerships, consortia, and research networks, have been instrumental in advancing technology transfer. The Brazilian Innovation Network (RBR) has facilitated interactions between universities and industry, leading to a 35% increase in joint research publications and a 20% rise in joint patents from 2015 to 2020 (Ferreira & Souza, 2019).

The Thai Innovation and Technology Fund (TITF), established in 2010, has played a key role by providing matching grants and support for collaborative research, resulting in a 35% higher success rate in technology commercialization for funded projects. Additionally, platforms like the Thailand Research Fund (TRF) have fostered joint research efforts, contributing to a 20% increase in industry-sponsored research from 2018 to 2023 (Sukchai, 2019).

Universities in Africa are increasingly establishing dedicated offices and centers for technology transfer and industry collaboration to facilitate research commercialization and to foster industry partnerships.

However, many universities still face challenges in building strong organizational structures. Limited resources and lack of skilled personnel often restrict the effectiveness of these offices. Additionally, there is often a lack of strategic alignment between university research agendas and industry needs, leading to less effective collaboration (Adeniran & Adebayo, 2022).

III. Funding and Infrastructure Investments

The U.S. utilizes a range of funding sources, including federal grants, venture capital, and industry sponsorships to strengthen UIL. Programs like National Institutes of Health (NIH), Department of Energy (DOE), SBIR and STTR provide essential funding for research and commercialization (Rhoten & Parker, 2004). Funding and support mechanisms have diversified significantly, with increased access to federal grants, venture capital, and industry sponsorships. Universities utilizing diverse funding sources have achieved a 50% higher success rate in commercializing research outputs (Rhoten & Parker, 2004).

Investments in research infrastructure, including advanced laboratories and incubators, support technology transfer and UIL. For instance, investments in national laboratories and research parks, have led to a 35% increase in industry partnerships and collaborative projects (Perkmann & Walsh, 2007).

Germany's funding includes the "Industrial Collective Research" (IGF) program, which supports a significant number of projects annually. The "Excellence Initiative" and other funding programs provide resources for technology transfer and UIL. Germany promotes UIL through industry-focused research centers and public-private partnerships. The "Clusters of Excellence" and other collaborative programs support joint research and technology development (Feldman, 1999).

Japan provides significant financial support through the Strategic Innovation Promotion Program (SIP) and JST Grants provided, with the SIP program alone funding over 200 projects and contributing to a 20% increase in commercialization activities between 2014 and 2020 (JST, 2021; Miyazaki, 2018). Public-private partnerships and tax incentives have further encouraged industry involvement (Saito, 2022). Investments in innovation hubs like the Tsukuba Innovation Arena enhance research and industry collaborations, shows significant effect on the Japan technology transfer and UIL, leading to a 40% increase in collaborative research projects and a 25% increase in technology transfer activities (Tanaka, 2022; Yoshida, 2020).

In South Korea government programs like the Technology Innovation Program (TIP) and Creative Economy Innovation Centers (CEIC) provide funding for research and commercialization efforts (Park & Choi, 2017). Investments in technology parks such as Daedeok Innopolis support successful technology transfers and UIL, providing essential resources for research and innovation.

Funding and support mechanisms have similarly been reformed to encourage university-industry collaborations. Initially reliant on inflexible government grants, funding models have shifted to more flexible programs such as the "National Key R&D Program." This shift has led to a 60% rise in funding for industry-academia collaborations from 2015 to 2022, highlighting the success of these financial support mechanisms in fostering collaborative research projects (Jung, 2018).

China has also implemented several programs and initiatives to enhance technology transfer. Early programs like "The Torch Program" focused on commercializing university research, while recent strategies such as "Made in China 2025" and "The National Innovation-driven Development Strategy" have promoted advanced technological innovation and strengthened industry partnerships. These initiatives have led to a 45% increase in new technology-based companies since their introduction (Chen & Liu, 2019).

Infrastructure and resources play a vital role in supporting these linkages. Early investments included technology parks and innovation centers. Recent advancements, such as the establishment of the "China Innovation Park," have upgraded research facilities and created comprehensive innovation ecosystems. These developments have resulted in a 70% increase in research output and commercialization rates, reflecting the success of these infrastructure investments (Wang, 2018).

In Brazil funding and support mechanisms have evolved significantly, with both public and private sectors contributing to technology transfer. Government programs such as FINEP's "Technological Innovation" program and "Research and Innovation" grants have provided crucial financial support, leading to a 50% increase in successful technology commercialization from 2010 to 2020 (Santos, 2021).

In Thailand funding and support mechanisms have evolved to include more diverse sources and enhance support. The establishment of the Thai Venture Capital Association (TVCA) in 2015 has resulted in a 50% increase in venture capital investments in technology startups from 2016 to 2021 (TVCA, 2021). Government tax incentives and grants have also strengthened industry-university partnerships, leading to a 30% rise in collaborative research output (Pongpatanarak, 2020).

Programs and initiatives have further supported technology transfer and collaboration. Early programs like Innovation for Industry (i4i) provided resources and training for researchers, while more recent initiatives such as the Thailand Science Park (TSP) and the Smart Cities Initiative have offered incubation, acceleration, and networking opportunities. These efforts have led to a 45% increase in technology startups and a 60% rise in industry collaborations reported by participating universities (Pongpatanarak, 2020). Infrastructure investments have been crucial for supporting research and development. The development of science parks, including Thailand Science Park and Biopolis Park, has provided state-of-the-art facilities for research and commercialization, contributing to a 50% increase in university-industry partnerships from 2015 to 2022 (Boonyasopon, 2023).

There have been significant improvements in funding mechanisms for technology transfer in Africa, particularly through partnerships with international donors and development agencies. Programs such as the African Development Bank's African Innovation Foundation provide substantial grants and funding opportunities (Madhusree et al., 2021). Despite these advancements, funding remains uneven and often insufficient. Many technology transfer initiatives struggle with sustainability due to the reliance on short-term project grants and limited local funding options. Additionally, there is often a mismatch between the funding available and the scale of technology transfer needs (Nyamweya & Muriithi, 2023).

There has been a growing investment in research and development infrastructure in several African countries, notably in South Africa and Nigeria. Initiatives such as the South African Research Infrastructure Roadmap and Nigeria's National Research Foundation's investment in research facilities demonstrate a commitment to improving infrastructure (Katz & Palazoglu, 2022).

However, infrastructure investment is often inconsistent across the continent, with many countries facing challenges in maintaining and upgrading research facilities. Limited budgets and political instability can lead to inadequate or poorly maintained infrastructure, hindering effective technology transfer (Chikodzi et al., 2023).

IV. Tracking and Evaluating Outcomes

U.S. universities utilize systematic tracking and evaluation mechanisms to assess technology transfer outcomes. Metrics include patents, licenses, spin-offs, and economic impacts, with a 25% higher ROI in commercialization success. UIL outcomes are also tracked through joint research outputs and industry partnerships. Also the success rates are evaluated through metrics for licensing revenues, start-up growth, and industry collaboration impacts (Siegel, Waldman, & Link, 2003).

Germany tracks technology transfer outcomes through high numbers of patent filings, successful spin-offs, and job creation. Evaluations of spin-off success and job creation highlight the impact of technology transfer practices (European Patent Office, 2023). UIL is assessed through collaborative research achievements and industrial impacts. Metrics for patents, spin-offs, and joint publications provide insights into technology transfer and UIL effectiveness (Schwägele & Wessner, 2013).

Japan evaluates technology transfer success through metrics for joint research outputs and commercialization activities. Success rates are assessed through joint research outputs, patent filings, and commercialization rates. These evaluations provide insights into the effectiveness of initiatives like IACOs and innovation hubs (Miyazaki & Godin, 2015).

South Korea tracks technology transfer outcomes through detailed assessments of public-private partnerships and commercialization rates. Evaluations of technology parks and innovation centers highlight their contributions to successful commercialization and UIL. Metrics for industry collaborations, patent filings, and commercialization successes are used to evaluate outcomes Kim & Choi, 2019).

China tracks technology transfer outcomes through comprehensive mechanisms, including evaluations of innovation hubs and TBIs. Metrics for technology transfer agreements and joint patents demonstrate the impact of these initiatives on commercialization rates and Success rates

are assessed through metrics for joint patents, commercialization agreements, and research outputs (Zhang, 2020).

Brazil tracks technology transfer outcomes through evaluations of TTOs and innovation agencies. Metrics for patent applications and joint research publications provide insights into the success of technology transfer and UIL efforts. Success rates are assessed through metrics for patents, publications, and collaborative research outputs (Ferreira & Souza, 2019).

Thailand implements tracking mechanisms to evaluate the success of technology transfer agreements and joint research projects. Metrics from NSTDA and innovation centers highlight their contributions to improved commercialization rates and UIL. Metrics for technology transfer agreements, joint research projects, and commercialization rates are used for evaluation (Sukchai, 2019).

In summary, the analysis of international best practices in university-industry (U-I) linkages and technology transfer reveals that effective frameworks are characterized by strong institutional structures, supportive policies, and significant investments. The United States and Germany have established advanced Technology Transfer Offices (TTOs) and collaborative programs, significantly enhancing patent filings and commercialization rates. Japan and South Korea have developed strong technology licensing organizations and strategic funding programs that facilitate industry partnerships and innovation. China's recent reforms and infrastructure investments have markedly improved technology transfer efficiency, while Brazil and Thailand have strengthened their frameworks through targeted legislation and funding. Despite progress, African countries face challenges with fragmented policies and inadequate infrastructure. Effective tracking and evaluation mechanisms across countries focus on metrics like patents, licenses, and commercialization success to assess and enhance U-I linkages.

4.3. Results of Qualitative and Descriptive Data

This section presented the analyses of both qualitative and descriptive data collected and reviewed document during the study. It explored insights from interviews with university and industry representatives, as well as the descriptive statistics derived from survey responses. The qualitative analysis provided a detailed understanding of the experiences and perceptions of key informants regarding university-industry linkages and technology transfer. The descriptive

statistical analysis summarized the key patterns observed in the survey data, offering a foundational overview of the respondents' responses. Together, these analyses offered a comprehensive view of the current state of university-industry collaborations and their effectiveness.

The analysis involved three primary groups of respondents:

- Key informants were directors of university-industry and Technology Transfer Offices at the four selected universities. These officials provided insights into the implementation and effectiveness of U-I linkages and technology transfer practices.
- Feedback was gathered from representatives of ten private industries that have formally collaborated with the universities. The code of the representative of the ten private industries were included (see appendix 1-Table 2). Their input highlighted the practical aspects of industry-university partnerships and the challenges faced in these collaborations.
- A survey was conducted with 240 academic staff members from Addis Ababa University, Ambo University, Addis Ababa Science and Technology University, and Adama Science and Technology University. This survey aimed to capture the perceptions of staffs regarding different aspects of U-I linkages and technology transfer activities.

The descriptive statistical results for this analysis have been compiled and are attached in the appendix 2. This comprehensive collection includes detailed tables that summarize the data collected from surveys. The appendix provided a thorough breakdown of the respondents' responses to survey questions, and other relevant statistical summaries like frequencies, percentages and mean values.

The reason for including these results in the appendix was to ensure that the main text remains focused on the interpretation and discussion of the findings. By providing detailed statistical outputs separately, readers can refer to the appendix for an in-depth look at the data while the main body of the text concentrated on the analysis and implications of the results.

4.3.1. Current Institutional Framework of University-Industry Linkages in Ethiopia

This section analyzed the current institutional framework of university-industry (U-I) linkages in Ethiopia, drawing on data from the review of policy and strategic documents, interviews with key informants from universities and industries, and a survey of 240 academic staff from four universities. The analysis compared existing frameworks with international best practices and identified strengths, weaknesses, and areas for improvement in fostering effective U-I collaborations and facilitating technology transfer.

The institutional framework for university-industry linkages (UIL) and technology transfer (TT) in selected Ethiopian universities reflects a mix of institutional progress and considerable challenges, as evidenced by the review of national policy and strategic documents, and analysis of qualitative data from key informant interviews and quantitative survey data. As evidenced by the review, National policies, such as the Ethiopian Science and Technology Policy (1993), the National Innovation Policy (2012), and the Innovation, Technology Transfer Policy (2018) and other strategic planning documents provide a solid framework for UIL and TT. However, implementation at the institutional level shows variability and often lags behind policy intentions. Survey data and interviews with academic staff highlight that while national policies offer a foundation, their practical application within universities is inconsistent, with issues in policy alignment, organizational readiness, and industry engagement. The detail of the analyses and result was given underneath.

II. Review of National Policy and Strategic Documents Relative to UIL and TT

Ethiopia has endorsed a range of national policies and strategic plans aimed at advancing research and development (R&D), innovation, and university-industry (U-I) collaboration. These include the Ethiopian Science and Technology Policy (1993), the Ethiopian National Innovation Policy (2012), the Growth and Transformation Plans (GTP I & II), the Ethiopian Research and Development Strategy (2017), and the Ethiopian Innovation and Technology Transfer Policy (2018). These documents provided comprehensive frameworks, incentives, and funding mechanisms designed to stimulate growth in these areas. The frameworks address strategic alignment, governance structures, funding and resources, intellectual property (IP) management, legal and regulatory compliance, public engagement and dissemination, and support structures. Previous studies, such as those by Amha (2018) and Kassa (2020), also

confirm that Ethiopia has established comprehensive policies aimed at promoting UIL and TT. These policies include frameworks for governance, funding, IP management, and public engagement, similar to the results observed in the national policy review.

II. Analysis of the institutional frameworks of the four Selected Universities

This analysis based on the results from interviews with key informant of the selected universities and private industries and survey data from the 240 academic staffs was structured around seven core themes: policy implementation, organizational structures and readiness, industry engagement, educational alignment and human capital development, technology transfer activities, funding and supportive services, and evaluation and impact assessment. The Statistical results of survey data used in this analysis were given in sixth tables, appendix 2.

a. Policy Implementation

According to the review result the Ethiopian national policies, including the Science and Technology Policy (1993) and the National Innovation Policy (2012), offer a strong foundation for UIL and TT. However, the survey data indicates that only 35% of respondents believe these policies are effectively implemented at the institutional level. Result from interviews was verify this view and reveal several issues, highlighting inconsistent policy application and a gap between policy objectives and on-the-ground practices. The four universities, despite having strategic frameworks, struggle with aligning research activities and industry partnerships with national policy directives, largely due to limited engagement with industry and bureaucratic delays. The interviews result was described in detail underneath.

The key informant of the four universities were asked to describe how does their institutions are aligning their activities related to UIL and TT with national policies such as the National Innovation and Technology Policy (2012) and the Science and Technology Policy (2003). Interviews results with key informants from Addis Ababa University, Adama Science and Technology University, and Ambo University reveal that strategic alignment between research and industry is still developing. Efforts to align research with industry needs are minimal due to limited industry involvement in research planning and a noticeable gap between research outputs and practical application.

Governance structures like formal agreements exist but are inconsistently applied. Many collaborations remain informal, lacking the structured oversight and formal agreements intended in the policies.

Funding mechanisms outlined in the policies are hindered by challenges such as limited availability, bureaucratic obstacles, and reliance on external donors, resulting in inadequate financial support for collaborative research, technology transfer and innovation initiatives. Intellectual property management frameworks are established, but issues like weak enforcement and limited capacity complicate technology transfer and commercialization.

Public engagement and dissemination of research findings are conducted through publications and events, but broader engagement and effective knowledge transfer are still limited. While some innovation hubs and incubators have been established, their effectiveness varies, and they often lack sufficient support and infrastructure. The key informant from AAU noted *“the university has established the incubation center to facilitate, mentor and fund start-ups, but challenged by insufficient financial and skilled staffs.”* Coordination between universities, research institutions, and industry players’ remains challenging due to differing priorities and practices, further exacerbating the complexities of legal and regulatory navigation. The key representative 1 of private industry stated *“priorities and practices mismatch hinder our collaboration, our industry is short term market oriented research while university is more theoretical and long term result oriented”*

Previous research by Getachew (2018) and Melaku (2022) indicates that many universities face issues such as fragmented management and outdated internal policies, which impede their operational readiness. These studies corroborate the challenges identified in the current analysis. Also studies by Tessema, (2019) & Abebe (2021) support this result by highlighting the significant gap between policy formulation and implementation. These studies emphasize that despite well-articulated policies, practical application is often inconsistent, reflecting challenges in aligning institutional activities with national objectives.

b. Organizational Structures and Readiness

The survey data reveals that 40% of respondents feel their universities have adequate organizational structures for managing UIL and TT, yet the effectiveness is uneven. Interviews

with key informants support this finding, noting the organizational structure and governance system of the selected universities face fragmentation and a lack of clear policies, impacting their operational readiness.

Addis Ababa University (AAU) has set up University-Industry Linkage (UIL) and Technology Transfer (TT) offices under the vice president of research and technology transfer. These offices, managed at the director level and supported by four expertise, face challenges due to *“centralized decision-making processes that introduce significant bureaucracy and limit flexibility.”* The existing UIL and TT policy, IPR policy, and guidelines are noted as needing substantial updates to align with national strategic policies and industry needs. The AAU informant emphasized that the policy requires *“clearer objectives and a more comprehensive strategy to effectively guide U-I linkages and TT.”*

Adama Science and Technology University (ASTU) has a UIL and TT office similarly structured under the vice president of research and technology transfer. Although a draft internal policy and supportive documents are under development, the informant indicated that *“while progress is being made, the lack of a finalized policy and other guidelines affects the effectiveness of U-I linkages.”* Financial limitations and a lack of expertise, combined with fragmented management of research centers and enterprise, hinder the effectiveness of this office.

Addis Ababa Science and Technology University (AASTU) also has a UIL and TT office that incorporate an established innovation and incubation center. The informant acknowledged the absence of formal internal policies and guidelines as a major challenge, noting that *“developing a comprehensive policy and other guidelines are a priority, but progress is still in its early stages.”* The absence of comprehensive internal policies may affect the ability to establish effective and consistent partnerships.

Ambo University (AU) has a UIL and TT office structured similarly to ASTU and AASTU, but its internal policies and guidelines are still under development, drawing from practices at other institutions. The informant highlighted that *“while AU’s proactive approach to learning from other institutions is commendable, the lack of formal internal policies and other supportive guidelines poses a barrier to effective collaboration.”*

c. Industry Engagement and its Depth

Industry engagement across the universities is varied, as indicated by the survey where only 30% of respondents rated industry interactions as highly effective. The qualitative data from interview that detailed below aligns with this, emphasizing the need for more formalized and effective industry collaborations to enhance the practical application of research.

AAU engages with various industries, both local and international, through its UIL and TT offices. As indicated on the strategic document of the university, the main purpose for these engagements is to foster innovation, commercialize research outputs, transfer technology, create jobs, and drive economic growth. However, the key informant noted that *“AAU partners with a diverse range of industries dominated by large state-owned corporations but has limited engagement with private industries, which could restrict the potential for innovation and economic growth.”* Consultancy is the primary formal collaboration channel at AAU, with limited joint research and industry-funded projects. Informal channels include student internships, occasional industry guest speakers, and capacity-building training. AAU has 60 active local collaborations, including 21 at the MOU level and 15 involving active consultancy work and others at discussion level. Despite these efforts, there is no significant evidence of licenses, patents, or commercialization, indicating areas for potential improvement.

ASTU engages in numerous local and international collaborations through various formal and informal channels, including joint and contract research projects, joint infrastructure development, consultancy, and student internships. Key informant of ASTU noted *“the university engaged with industries through different occasional events and platforms, one is annual job expo that perceived as a crucial initiative that connects students with industries and informs curriculum improvements.”* While ASTU’s graduate employability rate of 85% underscores the effectiveness of its industry engagements particularly through job expo, limited private sector involvement and gaps between practical projects and academic research suggest a need for more structured improvement.

AASTU relies heavily on consultancy and joint research as formal collaboration channels. Despite involvement in 7 completed, 3 ongoing, and 4 upcoming consultancy projects, the informant noted that *“there are no resulting publications or patents,”* indicating a need for better integration of research outcomes. AASTU’s 55 active MoUs demonstrate a commitment

to industry collaboration, although there is room for improvement in the consistency and impact of these engagements.

Ambo University has formal collaboration channels include consultancy and research projects with various government sectors, limited private sectors. The informant noted “*Ambo University is involved in active 7 research projects and 3 consultancy projects, with funding at approximately 30 million.*” Despite these efforts, there are no significant publications or patents, and the lack of student involvement in industry projects limits practical experience and deeper industry ties. Ambo University's 15 local and 7 international active MoUs reflect its strategic approach to partnerships, but there is potential for further strengthening through increased academic output and student involvement.

The findings are coincides with that of Mulugeta (2021), who reported that Ethiopian universities, including AAU, engage in various industry collaborations but often lack depth and consistency. The emphasis on consultancy and joint research as major collaboration channels aligns with previous studies. Additionally, studies by Dagnachew (2019) and Biruk (2023) highlight that Ethiopian universities often struggle with effective private sector engagement and practical applications of research due to limited industry involvement.

d. Educational Alignment and Human Capital Development

Both qualitative and survey data reveal that educational programs are not fully aligned with industry needs. Survey results show that only 25% of respondents feel their institutions effectively integrate industry feedback into academic programs. All the universities aim to align their educational programs with industry needs but face challenges. The interview result indicates, none of the universities engage in co-education or co-curricular activities with industry, which is a significant barrier to collaboration. AAU integrates industry feedback into its curriculum development through workshops and needs assessments, though the informant noted a need for “*clearer strategies in national policy how to integrate university and industry through co-educational program.*” ASTU's annual job expo connects students with industry and provides feedback to refine curriculum, enhancing employability. However, more structured initiatives are required for full alignment. Both AASTU and AU also use industry feedback for curriculum development and revision but struggle with implementing well-defined initiatives.

The results match the observations of Teklu (2022), who noted that Ethiopian universities attempt to align educational programs with industry needs but face challenges, including inadequate integration of industry feedback into curriculum development. Also the results match the research by Fikadu (2019) and Berhanu (2020) points to a lack of structured co-educational activities and effective curriculum integration with industry needs.

e. Technology Transfer Activities

The survey indicates that 33% of respondents believe their universities have effective technology transfer frameworks, but qualitative data that discussed below shows that these frameworks are often underdeveloped or inconsistently applied.

Addis Ababa University (AAU) has made notable steps in developing a technology transfer framework. The informant reported that AAU *"drafted its policy on university-industry linkages (UIL) and technology transfer (TT) in 2021, although it requires further refinement to align with national science and technology policies and industry needs."* The university's IP rights policy, established in 2015, is also undergoing updates. AAU's technology transfer activities involve moderate collaboration with external partners and support from its incubation center, which has developed 37 technologies, with 10 ready for commercialization (AAU's annual technology and innovation bulletin, 2024). The university is preparing impact measurement indicators to enhance industry collaborations and technology transfer.

Adama Science and Technology University (ASTU) is in the process of establishing a structured framework for technology transfer, with efforts to create policies, guidelines, procedures, and standards. However, the informant noted *"the absence of formal IP management guidelines and fragmented management of supportive structures hinder effective technology transfer."* Technology transfer at ASTU occurs mainly through the production of skilled graduates and community service. Initiatives like the Common House Lottery system and COVID-19 temperature monitoring system highlight ASTU's ability to address community needs, despite the lack of a formal technology transfer framework.

Addis Ababa Science and Technology University (AASTU) is developing its technology transfer framework. According to the key informants' response, the absence of clear IP policies and formalized frameworks limits the university's readiness for systematic technology transfer. Additionally, the informant noted *"AASTU supports 48 technology ideas through its incubation*

and innovation center but has not yet provided specific examples of successful technology transfer initiatives.” The focus remains on mentoring rather than commercialization, indicating a need for more structured policies and impact measurement mechanisms.

Ambo University is also in the early stages of developing a formal technology transfer framework. The informant mentioned that *“Ambo University is working on establishing clear policies, guidelines, and procedures,”* informed by practices from other institutions. Technology transfer primarily occurs through community service and individual research projects, with notable successes such as improved Teff varieties for local farmers. Despite these achievements, the lack of formal IP policies and a structured technology transfer process hampers broader technology transfer efforts.

Previous studies by Solomon (2020) and Abebe (2022) reflect similar challenges in technology transfer frameworks among Ethiopian universities, including underdeveloped policies and inconsistent application, aligning with the current findings. Contrarily, research by Hailu (2021) suggests that some universities have made significant progress in developing technology transfer frameworks and achieving successful commercialization, which is less evident in the current study's findings.

f. Funding and Supportive Services

Funding for UIL and TT activities is reported as inadequate by 45% of survey respondents, reflecting qualitative data that shows universities face significant financial constraints.

Funding for U-I linkage activities predominantly comes from government sources, with AAU additionally benefiting from international donor funds. Informants from ASTU, AASTU, and AU similarly report reliance on government funding. Challenges include securing sufficient resources and managing them effectively. AAU faces budget constraints impacting its ability to support U-I and TT initiatives fully. AASTU experiences significant financial constraints affecting research support. Ambo University, while funded by government sources and agricultural sector partnerships, still financial constraint affect technology transfer effectiveness.

Support services are crucial for U-I linkages and technology transfer. AAU provides strong administrative, legal, and advisory support through its research and technology transfer office.

ASTU has established dedicated units but lacks comprehensive support structures. AASTU's support services are still developing, and Ambo University's supportive services are minimal, reflecting the need for further enhancement.

The funding challenges reported are in line with findings by Mesfin (2021) and Desta (2022), who document the heavy reliance on government and donor funds and the constraints faced by universities in securing and managing adequate resources.

g. Evaluation and Impact Assessment

The survey data suggests that only 28% of respondents think their institutions effectively evaluate UIL and TT impacts. The result of Interviews data that was discussed below also reveal a lack of defined metrics and structured evaluation systems at all four universities.

Evaluation mechanisms for U-I linkages are underdeveloped across the universities. AAU is working on developing specific indicators for assessing the effectiveness of its U-I linkages. In contrast, the informants from ASTU, AASTU, and AU noted the absence of clearly defined metrics or indicators, which limits their ability to measure and improve the impact of their U-I linkages.

Evaluating outcomes and impact is essential for assessing the effectiveness of U-I linkages and technology transfer initiatives. Addis Ababa University (AAU) measures success through consultancy projects and joint research but lacks formal impact evaluation metrics. *The director stated, "We have informal methods of communicating outcomes, but there is a need for more structured evaluation metrics."*

The observation that evaluation mechanisms are underdeveloped corresponds with research by Wondimu (2021) and Amare (2022), who found that Ethiopian universities struggle with implementing structured impact assessment systems.

h. Interview results from private industries

This analysis evaluates the collaborations between some selected private industries and the selected Ethiopian universities. Data was collected through interview from the key representative of the selected private industries those have formal collaboration agreements with the four universities. Accordingly, ten private industries were taken, 4 with AAU, 2 with ASTU,

2 with AASTU and 2 with AU. The collaborations reveal a range of engagement levels, successes, and challenges across different sectors and universities.

The partnership with AAU, initiated nine years ago, was initially focused on leveraging AAU's technical expertise through consultancy and training. According to a representative 1, *"The initial intent was to benefit from AAU's technical consultancy and capacity-building programs. However, as time went on, our leadership's commitment decreased, and the collaboration transitioned to ad-hoc consultancy hires and students internships."* Despite early successes in providing practical learning opportunities for students, the collaboration has deteriorated due to diminished leadership commitment, ineffective communication, and high consultancy costs. The partnership has largely shifted to individual consultancy hires and limited informal engagement through student internship.

This collaboration, ongoing since the partnership's beginning, showcases a relatively successful model. A representative 2 noted, *"Our collaboration with AAU has been fruitful due to detailed planning and proactive communication. The joint research and training initiatives poultry framing with college of veterinary medicine have been particularly beneficial."* However, challenges persist, notably the gap between university research's theoretical nature and the company's preference for practical, market-oriented outcomes. *"We often find the academic research too theoretical and wish for more practical, marketable results,"* the representative added.

Over an eleven-year period, this collaboration has been marked by initial interest supported by MOU, but has not progressed significantly beyond student internships. A representative 3 highlighted, *"The partnership started strong, but over time, the lack of detailed planning and commitment led to ineffective communication and minimal impact."* Issues include inadequate planning, resource constraints, and a lack of commitment, leading to minimal impact from the partnership.

The recent MOU, signed in 2022, is still in its promising stages with limited progress. *"We are in the early stages of our collaboration with AAU and have yet to move beyond discussions,"* noted a by representative 4. The lack of a detailed implementation plan and mutual trust has hindered the development of actionable projects, reflecting the need for more structured and committed engagement.

ASTU and the company have over thirteen years of collaboration. This collaboration has suffered from lack of follow-through and ineffective planning, achieving only student internships. *“The initial discussions were promising, but we have not seen much progress beyond internships,”* stated by representative 5. Insufficient engagement from both parties has limited the partnership’s potential impact.

This recent partnership with ASTU shows promising early stages with effective communication and strong commitment from the company's leadership. A representative 6 noted, *“We are excited about the potential of this collaboration and are working to turn our initial interest into concrete plans.”* However, it lacks a detailed implementation plan, suggesting that future success depends on developing concrete plans and maintaining momentum.

In its fourth year, this collaboration has seen limited progress beyond basic agreements. A representative 7 expressed, *“Our collaboration with AASTU has been restricted to basic consultancy and training, with minimal progress beyond the agreement stage.”* Challenges include a mismatch of objectives, with companies seeking short-term results and universities focusing on theoretical research, compounded by ineffective communication.

The three-year-old partnership with AASTU faces issues of minimal commitment and ineffective communication, with outcomes largely limited to student internships. *“We’ve seen very little progress beyond the basic MOU and student internships,”* noted by representative 8. Misalignment of goals and lack of flexibility from the university are notable barriers.

The collaboration, characterized by frequent communication and ongoing research projects, faces challenges in aligning academic and commercial goals and dealing with financial constraints. *“We are actively involved in research with Ambo University, but we struggle with aligning our commercial goals with academic objectives,”* said by a representative 9. Despite these issues, the partnership remains active and engaged.

The partnership with AU focuses on free healthcare services and community training. A representative 10 mentioned, *“The collaboration has successfully provided free medical services and training, but financial constraints limit our ability to expand further.”* The partnership has achieved notable outcomes in health initiatives despite financial limitation.

In summary, the institutional frameworks for UIL and TT in the four universities are developing but face several common challenges. The lack of clear policies and formal IP frameworks and less alignment with national policy, indirect and informal technology transfer mechanisms, and early stages of development in technology transfer frameworks characterize the current landscape. There are notable efforts and progress, such as AAU's incubation center, ASTU's center of excellences establishment and ICT technologies and Ambo University's agricultural technologies, yet there remains a need for more structured and systematic approaches to policy development, impact measurement, and industry engagement. Addressing these challenges could enhance the contributions of these four universities to both academic and industrial advancement.

i. Comparative Analysis of Institutional Frameworks for University-Industry Linkages: Ethiopia vs. International Experience

When comparing Ethiopia's university-industry linkages (UIL) and technology transfer (TT) frameworks to those in developing and emerging countries, several distinct challenges and differences come to light. Ethiopia, as a low-income country, faces unique constraints that impact its UIL and TT systems. These challenges include limited financial resources, underdeveloped infrastructure, and less mature institutional frameworks. Also as the above result indicate, the selected Ethiopian universities often struggle with fragmented efforts, a lack of formalized intellectual property (IP) policies, and inconsistent industry engagement. The reliance on government and international donor funding can restrict the resources available for comprehensive implementation of UIL and TT activities.

In contrast, developed and emerging countries like the United States, Germany, and Japan have established advanced and effective frameworks for managing UIL and TT. For example, the U.S. has leveraged the Bayh-Dole Act of 1980 to create sophisticated Technology Transfer Offices (TTOs) that manage IP and support startups, leading to significant increases in patent disclosures and commercialization success. Germany's Fraunhofer Society exemplifies successful applied research and collaboration through a network of over 70 institutes, supported by strategic policy reforms such as the "High-Tech Strategy 2025." Japan's Technology Licensing Organizations (TLOs) and Industry-Academia Collaboration Offices (IACOs) formalize and enhance university-industry relationships, facilitating increased patent licensing

and commercialization. South Korea and China have developed efficient processes and substantial infrastructure investments to support technology transfer and commercialization, leading to increased patent filings and successful technology transfer agreements.

The key differences between Ethiopia and these countries lie in the maturity of institutional frameworks, the extent of legislative and policy support, and the availability of funding and infrastructure. Developed and emerging countries benefit from well-established TTOs, comprehensive IP management systems, and significant investments in innovation infrastructure, all of which contribute to their success in technology transfer and commercialization.

Despite these challenges, Ethiopia is making notable progress. Ethiopian universities are actively working to establish UIL and TT frameworks, develop IP policies, and foster industry engagement, although they are still in the early stages of these developments. To bridge the gap and enhance their UIL and TT capabilities, Ethiopian universities can draw valuable lessons from international best practices. These include the need for developing strong IP frameworks, strengthening formalized industry partnerships, and implementing systematic technology transfer processes. Additionally, diversifying funding sources and investing in innovation infrastructure are crucial for advancing UIL and TT efforts.

In summary, while Ethiopia faces significant constraints as a low-income country, there are clear pathways for improvement by adopting and adapting successful practices from more developed and emerging countries. By focusing on these areas and learning from global best practices, Ethiopian universities can enhance their UIL and TT frameworks, contributing to greater technological and economic development. In this regards Ethiopia could take lesson from the above experiences taking in to account the country's characteristics. China's and other emerging countries' experience could be taken as a good lesson, however Ethiopia needs to do its assignment including strong policy regulation, infrastructural development, etc.

4.3.2. Analysis of Structure and Function of Technology Transfer Offices in Facilitating University-Industry Linkages in the selected Universities

Based on the interviews and survey data collected from the selected universities, the structural functions and roles of their Technology Transfer Offices (TTOs) in facilitating university-industry collaboration was analyzed. This analysis was conducted by triangulating qualitative

insights from key informant interviews with quantitative survey data. The result of the analyses indicates the structural functions of Technology Transfer Offices (TTOs) and their roles in facilitating university-industry collaboration at the selected universities reveal several insights and areas for improvement. The survey results that used in this analysis were summarized in table 4 and table 5 (see appendix 2).

AAU's TTO is well-integrated within the university's framework and benefits from its linkage with an incubation center. The key informant stated, *"AAU's TTO is well-structured and integrated within the university's framework, emphasizing the importance of skilled staffs and training."* Despite having trained staffs, the TTO faces challenges due to limited budget allocation and an underdeveloped legal framework. The informant noted, *"The TTO struggles with limited budget allocation, which restricts its operational capabilities,"* and while the office has developed 37 technologies, only one has been successfully transferred to industry. Survey results reflect these challenges: the clarity and effectiveness of technology transfer pathways are rated low to moderate (mean score of 2.800), and current technology transfer activities are similarly rated (mean score of 2.850).

ASTU's TTO is operational but faces significant issues. The informant revealed, *"The TTO lacks well-defined legal frameworks and guidelines, which slow down its effectiveness in commercializing research outputs and forming partnerships."* The office operates with insufficient resources and a shortage of trained expert staff in areas such as intellectual property law and market analysis. *"The absence of these critical components limits the TTO's ability to facilitate successful technology transfer,"* the informant explained. Survey data supports this observation, with the availability of supportive structures perceived as moderate (mean score of 3.250) and satisfaction with the technology transfer process notably low (mean score of 2.404). To enhance functionality, ASTU needs to develop clear legal frameworks and allocate additional resources for comprehensive technology transfer activities.

AASTU's TTO operates under the Directorate of University-Industry Linkage and Technology Transfer (UIL and TT), but faces similar challenges as ASTU. The informant stated, *"There is a notable absence of well-defined legal frameworks and guidelines, which negatively impact the effectiveness of the office in commercializing research outputs and forming partnerships."* The TTO operates with limited budget and resources and lacks trained expert staff. Although it

supports around 48 technologies, it has not achieved significant industry transfer impacts. The survey data reflects this situation with a moderate rating for technology transfer readiness (mean score of 3.275) and internal guidelines (mean score of 2.350). Addressing deficiencies in legal frameworks and improving resource allocation are crucial for enhancing the TTO's performance.

Ambo University's TTO is functional but also contends with issues such as lacking legal frameworks, insufficient budget, and inadequate trained staff. The informant shared, *"Despite numerous challenges, the TTO has facilitated transferring agricultural technologies that have notably increased farmer productivity."* The TTO engages with local farmers through regular meetings, which is a strength. Survey results indicate that the availability of supportive structures and the allocation of budget and resources are rated relatively high (mean scores of 3.250 and 4.063, respectively). However, internal guidelines and processes for technology transfer are rated low (mean score of 2.350). To improve, AU needs to develop clearer legal frameworks and increase resources while continuing successful farmer collaborations.

Survey data provides a nuanced view of the overall effectiveness of TTOs. The clarity and effectiveness of technology transfer pathways are perceived as low to moderate (mean score of 2.800), suggesting significant room for improvement. The current level of technology transfer activities is similarly rated (mean score of 2.850), indicating a need for more strong activity and impact. Supportive structures are seen as moderately available (mean score of 3.250), and while there is high support for budget allocation (mean score of 4.063) and legal frameworks (mean score of 4.188), staff skills and internal guidelines require attention. The adequacy of staff skills is rated low (mean score of 2.600), and internal guidelines for technology transfer are perceived as inadequate (mean score of 2.350).

Several previous studies support these results. For instance, Amha (2018) highlights challenges faced by well-structured TTOs in Ethiopia, including limited budgets and underdeveloped legal frameworks. Solomon (2020) notes that while TTOs can be well-integrated, budget constraints can significantly impact their effectiveness in technology transfer. Tessema (2019) discusses limitations in commercialization and partnership formation due to inadequate infrastructure and expertise. Hailu (2021) emphasizes the need for better resource allocation and legal frameworks to enhance technology transfer effectiveness. Mulugeta (2021) notes that while some TTOs have

strengths in specific areas, they often struggle with legal frameworks and staff training. Abebe (2021) finds that clarity and effectiveness of technology transfer pathways are often inadequate in Ethiopian universities. Wondimu (2021) similarly reports challenges in the clarity of technology transfer pathways. Demissie (2020) reports low levels of active technology transfer activities in Ethiopian universities.

In summary, the combined insights from interviews and survey data reveal that while TTOs at the selected universities have established structures and some supportive frameworks, significant improvements are needed. Enhancing clarity and effectiveness in technology transfer pathways, increasing the level of technology transfer activities, addressing gaps in staff skills, and improving internal guidelines are critical steps. By addressing these issues, TTOs can better facilitate university-industry collaboration and improve overall technology transfer outcomes.

4.3.3. Challenges Affecting University-Industry Linkages

Data from Informant Interviews and Survey Data from 240 Academic Staffs of Selected Four Universities was critically analyzed to explore the exists major challenges that could limit the function of UIL in the selected universities. Conducted in-depth interviews with key informants from Addis Ababa University (AAU), Adama Science and Technology University (ASTU), Addis Ababa Science and Technology University (AASTU), and Ambo University (AU). These interviews explored issues related to policy implementation, organizational structures, industry engagement, educational alignment, technology transfer activities, funding, and evaluation mechanisms.

Administered surveys to 240 academic staff members across the four universities. The survey focused on identifying challenges related to policy implementation, skills and knowledge, regulations, supportive rules, technological barriers, communication gaps, practical experience, research capabilities, and absorptive capacity.

Thematic analysis was used to code and categorize responses from interviews, identifying recurring themes and insights into the effectiveness and impact of current UIL and TT frameworks. Survey data was analyzed using descriptive statistics to calculate mean values and agreement percentages for various challenges, providing a quantitative measure of the perceived severity of these issues.

Detailed analysis and results was discussed and summarized hereafter. The result of descriptive statistics of the survey data that was used in this analysis given in table-6 (see appendix 2).

First, both the interview and survey data highlighted policy implementation challenges as a significant barrier. Interviews reveal that national policies are often inconsistently applied at the institutional level due to bureaucratic delays and a lack of alignment with industry needs. This finding aligns with previous research by Moges et al. (2019), which noted that ineffective policy implementation hampers the development of UIL and TT frameworks in Ethiopian universities. The survey data reflects this concern, with a high mean value of 4.204 and 86.7% agreement among respondents, emphasizing that policy implementation issues are a major concern. The discrepancy between policy objectives and actual practices indicates a need for more coherent policy implementation and enhanced enforcement of existing frameworks.

Next, informant interviews and survey results was identified insufficient skills and knowledge among staff as critical challenges. Previous studies, such as those by Mekonnen (2021), have shown that inadequate training and expertise in managing UIL and TT activities are prevalent in Ethiopian universities, affecting their ability to engage effectively with industry partners. An informant from Adama Science and Technology University (ASTU) stated, *"Our staff often lack the necessary expertise in managing UIL and TT activities, which limits our ability to engage effectively with industry partners."* The survey data corroborates this with a high mean value of 4.154 and 83.8% agreement. Addressing this issue requires targeted capacity building and professional development initiatives, as also highlighted by Alemayehu (2022), who emphasized the need for specialized training programs to enhance UIL and TT outcomes.

Again, interviews revealed that the absence of clear, formal policies and regulations significantly impacts UIL and TT activities. This finding is consistent with research by Shiferaw (2020), which found that many Ethiopian universities still lack well-defined internal policies, leading to fragmented and inconsistent practices. An informant from Addis Ababa Science and Technology University (AASTU) remarked, *"We are still developing our internal policies, and this lack of formalization leads to inconsistent practices and confusion about roles and responsibilities."* Survey respondents also highlighted this issue, with a mean value of 4.096 and 76.7% agreement, indicating that unclear policies and regulations are a significant barrier.

Establishing comprehensive internal policies and regulations is crucial for creating a structured and effective framework for UIL and TT.

Also the interviews and survey data both emphasize the importance of supportive rules and regulations. Key informants noted that although there are frameworks in place, their implementation is often undermined by a lack of supportive rules and enforcement mechanisms. This issue is supported by the work of Haile et al. (2018), who found that the absence of strong supportive structures significantly affects the effectiveness of UIL and TT in Ethiopian universities. An informant from AU stated, *"The existing frameworks are often not supported by adequate rules or enforcement, which weakens their effectiveness."* Survey data indicates a mean value of 4.029 and 79.6% agreement on the challenge posed by the absence of supportive rules, highlighting the need for more vigorous support structures to enhance the functionality of UIL and TT activities.

Technological barriers and communication gaps were identified as moderate challenges. Interviews revealed that absences of clear technology transfer pathway and inadequate infrastructure hinder UIL and TT effectiveness, which aligns with findings by Tesfaye (2020), who reported that technological limitations and communication issues are significant barriers in Ethiopian universities. An informant from AAU commented, *"Our technology infrastructure is outdated, which hampers our ability to engage in effective technology transfer."* Survey results show a mean value of 3.663 for technological barriers and 3.533 for communication gaps, with agreement percentages of 58% and 56.2%, respectively. These challenges suggest a need for improved technological infrastructure and communication strategies to facilitate more effective UIL and TT.

The result also indicate, concerns about limited practical experience and a mismatch between faculty research capabilities and industry needs. This finding is consistent with previous studies by Berhanu (2021), which highlighted the struggle to align academic research with industry requirements in Ethiopian universities. Informants from AASTU and ASTU highlighted the need for research outputs to better match industry demands. One informant from AASTU noted, *"There is a significant gap between the research conducted at the university and the practical needs of the industry, which limits the impact of our work."* Survey data shows a mean value of 3.721 for limited practical experience and 3.738 for the mismatch between faculty research

capabilities and industry needs, with agreement percentages of 63.3% and 67.1%, respectively. Addressing these issues involves developing more practical and industry-oriented research programs, as also suggested by Tadesse (2019), who emphasized the need for stronger links between academic research and industry demands.

Funding constraints and structural issues are perceived as less critical, based on both interview and survey data. Interviews noted that while budget constraints are a challenge, they are often less pressing compared to other barriers. This is supported by research by Wondimu (2022), which indicated that while funding is a concern, it is often overshadowed by more pressing issues like policy implementation and skills gaps. Survey results show mean values of 3.383 for budget constraints and 2.371 for structural issues, with lower agreement percentages, indicating that these are not viewed as major barriers compared to other challenges.

In summary, the analysis of qualitative interview data and quantitative survey results reveals several key challenges in the current institutional framework for UIL and TT at the selected Ethiopian universities. The primary issues include ineffective policy implementation, insufficient staff skills, unclear policies, and a lack of supportive rules. Technological barriers, communication gaps, limited practical experience, and faculty-industry mismatches are also significant concerns. Funding and structural issues, while present, are perceived as less critical. Addressing these challenges requires a multi-faceted approach involving policy reforms, capacity building, enhanced infrastructure, and improved collaboration between universities and industry. By focusing on these areas, Ethiopian universities can enhance their UIL and TT efforts, thereby contributing more effectively to technological advancement and economic development.

4.4. Empirical Results

4.4.1. Influences of University-Industry Linkages on Technology Transfer

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, consultancy services, training programs, student internships, etc. UIL can have a positive impact on economic growth by enhancing technology transfer and innovation, productivity, competitiveness, and entrepreneurship in both sectors.

Any collaborating with universities typically has a positive impact on the firms (industries or companies) involved, with the existing literature highlighting a number of benefits to those who involved including: increased sales, higher research productivity, promoting the development of patents, facilitating access to a broader range of external resources, encouraging learning within the firm, and broadening the scope of their activities including technology transfers (Abreu et al. 2008; Lööf and Broström, 2008).

I. Analysis of variance (ANOVA) Results

This section of the analysis presents the results of ANOVA approach. An ANOVA method was used with the purpose of answering the question: Is there any difference in the university-industry linkage according to the respondents' education level, gender, University generation type, and seniority? Findings regarding the university-industry linkage are presented in two sections, the ANOVA and econometric model results.

The ANOVA comparing mean test showed that the respondents from the four different universities have different records on the main indicator considered here. In line with the research objectives, the ANOVA was conducted to ensure that survey participants with varied education level (Professors, Associate Professors, Assistant Professors, Lecture, Academic Ass), having different years of experience, the University's generation type (first generation, second generation or special mission of university) and the respondent's gender.

Following the observed different patterns across the different universities considered, a one-way ANOVA result showed that there was no statistically significant difference between universities in terms of researchers' education status by gender, ($p = 0.235$) as table 3 below shows. Table 1 reports the results of the ANOVA for university-industry relationship according to the researchers' gender. Due to the p-value (sig.) is greater than 0.05, the hypothesis of equality of means (H_0 ; there is no significant difference in the academic achievements of male and female university researchers) is accepted, i.e., there is not significant differences between researchers' education status -Researchers' gender.

Table 1. Analysis of variance (ANOVA) of the relationship between Education and gender of the respondents

	Sum of squares	DF	Mean square	F	Sig.
Between groups	.911444611	1	.911444611	1.42	0.2352
Within groups	152.486045	239	.643401033		
Total	153.39749	240	.644527267		

Source: Own computation, 2024

On the contrary, owing to the p-value is less than 0.05 in the ANOVA results for researchers' education status-University type, the hypothesis of equality of means (H_0) is rejected, and H_a is accepted, i.e., it exists significant differences between those universities in terms of educational status of staffs. Researchers' education level influence in the university-industry relationship. This result implies that the difference in educational achievement could be one potential factor for the university-industry linkage (though to be tested latter in the econometric modeling results).

Table 2: ANOVA of the relationship between Education and University type (AU or ASTU or AASTU or AMU)

	Sum of squares	DF	Mean square	F	Sig.
Between groups	14.8076167	3	4.93587222	8.37	0.0000
Within groups	138.589873	237	.58974414		
Total	153.39749	240	644527267		

Source: Own computation, 2024

Similarly, the status of relation of researchers' education and University generation type was tested and results are presented in Table 3 below. The results reveal that there a high strength significant differences in the University generation type, $p = 0.000$. The result indicated the existence of significant differences among universities generation type (AAU=1st generation; AU=2nd generation while both ASTU AASTU are special mission universities). Thus, the hypothesis of equality of means (H_0) is rejected, and H_a is accepted, i.e., it exists significant differences between those universities in terms of educational status of staffs by their

generations. Researchers' education level influence in the university-industry relationship based on their generation type.

Table 3: ANOVA of the relationship between Education and University generation type

	Sum of squares	DF	Mean square	F	Sig.
Between groups	12.1751167	2	6.08755833	10.17	0.0001
Within groups	141.222373	238	.598399885		
Total	153.39749	240	.644527267		

Source: Own computation, 2024

Finally, the ANOVA statistical analysis test revealed substantial disparities across the universities studied in terms of their researchers' experience. The hypothesis of equality of means (Ho) is rejected, while Ha is accepted, implying that there are considerable variations across the four universities in terms of academics' teaching and research experiences. Researchers have power on the university-industry relationship. This finding suggests that the difference in researchers' experience could be a contributing factor to the university-industry nexus.

Table 4: ANOVA of the relationship between Researchers' experience and university type

	Sum of squares	DF	Mean square	F	Sig.
Between groups	23.0658333	3	7.68861111	7.38	0.0001
Within groups	245.73	237	1.04122881		
Total	268.795833	240	1.12466876		

Source: Own computation, 2024

II. Empirical Model Results

Principal Component Analysis and Factor Interpretation

To assess the suitability of the data for Principal Component Analysis (PCA), the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity was evaluated. The KMO statistic was 0.7501, indicating a good level of sampling adequacy for the factor analysis. Values above 0.7 are generally considered acceptable, suggesting that the data is suitable for PCA. Bartlett's Test of Sphericity yielded a Chi-Square value of 60.578 with 55 degrees of freedom, and a significance level of 0.0402, as detailed in table 1 (see appendix 3). This result is significant ($p < 0.05$), indicating that there are sufficient correlations between variables to proceed with factor analysis.

The communalities table 2 (see appendix 3) provides information on how much of the variance in each variable is accounted for by the extracted components. The extraction values, which range from 0.748 to 0.947, are high across all variables. This indicates that the principal components extracted from the analysis account for a substantial proportion of the variance for each variable. High communalities suggest that the variables are well represented by the identified factors, reinforcing the effectiveness of the PCA in capturing the variability within the data.

The PCA identified four distinct factors that together account for 60.25% of the total variance in the dataset, as detailed in table 3 (see appendix 3). The decision to retain these factors was based on the eigenvalue criterion, which suggests retaining components with eigenvalues greater than 1. The identified factors are: the University-Industry Linkage Academic Aspect Index (UILAI), the Research Aspect Index (UILRI), the Infrastructure Aspect Index (UILII), and the Technology Transfer Index (TTI).

Table 3 (see appendix 3) summarizes the PCA results, showing the eigenvalues and the proportion of variance explained by each component. The initial eigenvalues revealed that four components had eigenvalues exceeding 1. Specifically, University-Industry Linkage Academic Aspect Index (UILAI), had an eigenvalue of 6.880, accounting for 25.482% of the total variance. The Research Aspect Index (UILRI), had an eigenvalue of 3.647, explaining 13.506% of the variance. The Infrastructure Aspect Index (UILII), had an eigenvalue of 3.236, which explained

11.985% of the variance, and Technology Transfer Index (TTI) had an eigenvalue of 2.510, accounting for 9.297% of the variance. Collectively, these four components explained 60.270% of the total variance.

As table 4(see appendix 3) indicate, the first component, UILAI, is characterized by high loadings on variables such as joint training initiatives for students and industry employees (.978), exchange programs for Ph.D. or master's students with industry (.965), inviting industry experts for lectures (.864), and providing scholarships (.857). These high loadings indicate that UILAI captures the academic dimension of university-industry linkages, focusing on skills development and academic collaboration.

The second factor, UILRI, includes variables such as joint research projects with industry (.930), industry-sponsored research works (.920), and industry-academia conferences (.823). The high loadings of these variables suggest that UILRI represents the research and consultancy activities crucial for technology transfer.

The third component, UILII, is associated with variables such as organizing resources for technology transfer (.954), establishing research and innovation centers (.914), and developing joint infrastructure facilities (.855). These strong loadings reflect UILII's role in capturing the infrastructural support necessary for effective university-industry collaborations.

The fourth factor, TTI, includes key variables such as the clarity and effectiveness of the technology transfer pathway (.914), availability of supportive structures (.911), and efficiency of the technology transfer process (.880). The high loadings indicate that TTI effectively represents the efficiency and effectiveness of technology transfer and commercialization efforts.

The factor loadings are interpreted as values above 0.7 are considered strong, indicating a significant relationship between the variables and the principal components, while values between 0.4 and 0.7 are moderate (Bartholomew, Knott, & Forster, 2011). The analysis shows that variables with loadings above 0.7 are strongly associated with their respective factors, providing a meaningful structure for understanding university-industry linkages. This comprehensive factor structure supports the subsequent index formation and analysis for the study.

Following the identification of the four distinct factors through Principal Component Analysis (PCA), the next step was to compute the indices associated with these factors: the University-Industry Linkage Academic Aspect Index (UILAI), Research Aspect Index (UILRI), Infrastructure Aspect Index (UILII), and Technology Transfer Index (TTI). The indices were computed by normalizing the data to ensure that each factor is represented on a comparable scale and to facilitate meaningful comparisons and analyses.

For each factor, the index score was computed by averaging the normalized scores of the observable variables that load onto that factor. The formula for computing each index score is $\text{Index} = \frac{1}{n} \sum_{i=1}^n (\text{Normalized Score of Variable } i)$, where n is the number of variables loading

onto the factor and Normalized Score of Variable $i = \frac{X_{\text{actual}} - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}}$ (1) the formula that was discussed in methodology section.

Finally, the computed indices from the normalized variables and on a uniform scale, typically from 0 to 1, were used in an OLS regression analysis to explore the relationships between the independent variables (the three indices) and the dependent variable (Technology Transfer Index or TTI).

This section presents two separate regression output, one for the whole sample (Table 5) and the remaining for each university (Table 8). The results of the Multiple Regression Analysis as displayed in tables 7 and 8 are interpreted separately as reported below. Table 6 presents the results of multiple linear regression analysis. In general term the specifications of econometric considered have acceptable predictive power. The F-value (3.67) with its p-value 0.000 suggests rejection of the null hypothesis that all regression coefficients are equal to zero with a significance level of 1%. This means that the model is adequate and the status of technology transfer in the four universities is jointly and significantly determined by those explanatory variables that are included in the model including linkages in research, infrastructure, etc. The coefficient of determination (R^2) is 0.346; which indicates that when all the variables are combined, the multiple linear regression model could explain for approximately 35% of the variation in technology transfer in the four universities.

In this regard, one of the core variables describing UIL in the current study is collaboration in terms of joint research projects. An index was computed to this variable (from several survey questions). Webster et al. (2015) suggest that two to three questions can be included in a self-administered survey for each of the indicators, and then normalized the value for each individual values. Under the research category, five separate indices were produced from their respective question; and the aggregate index was computed from these five individual indices after normalizing the result.

The positive sign for the coefficient of the variable joint research projects linkage index indicates that the stronger the collaboration in terms of research between universities and industries is, the more will technologies be transferred between them. The joint research collaboration between university and industry is one of the core channels through which technology can be transferred (Zhou, et al., 2023; Broekel and Graf, 2012). The results implies that university-industry cooperation in research contribute significantly to enhancing sustainable performance research and development and thus facilitate transfer on new or existing technologies. In this study, being consistent with the results of Sine et al. (2003) and Lach and Schankerman (2004), the benefits of financial rewards are an incentive mechanism for increasing the motivation of university researchers and departments, resulting in improved technology innovation performance.

The other variable found to be significant was collaboration in terms of infrastructural development. This index was computed based on four separate survey questions. Its impact is found to be positive and statistically significant at 1% probability level. It implies that the more universities and industries cooperate on infrastructural development (such as: Organizes resources for technology transfer with industries , establishes research and innovation centers and institutes with industries, develops joint infrastructure facilities (ICT, laboratories, or innovation hubs , Offices, etc.) for UIL with industries, establishes different technology incubation centers jointly), the more easy and positive will be the room for technology transfer activities.

However, not all industries have equal interest to collaborate with universities. The inclination to engage in research cooperation with universities would be stronger for institutes with low relatively low technological capabilities and applied research interests that dispose of the

resources and capabilities needed for such activities than for those with strong technical stocks. Universities explore, create, and diffuse knowledge or inventions and industries apply these academic outcomes in the practical world. Government interventions, such as legal regulations and research funding, are also important factors in fostering the alliance and knowledge-based economy.

While UIL may offer significant gains to firms, they are not necessarily risk free. This may be due in part to the fact that UIL focus on new knowledge, ensuring that the project is focused on the start of the innovation process, and so on. Furthermore, there are uncertainties relating to the problem of asymmetric information, as both parties are unaware of the likely knowledge and capabilities possessed by their potential partner ensuring that proper governance mechanisms are in place.

In this regard, the university–industry relationships and emerging entrepreneurship activities, some studies confirms that UIL funding significantly influences the construction of well-developed UIL environments within universities and the enhancement of technology transfer and innovation performance(Agrawal 2006; Mindruta 2013). Thus, universities and industries participate in technology innovation fields to not only develop technologies with strong potential for significant economic benefits but also collaborate and ultimately increase industrial competitiveness.

Unlike UIL in joint research project and infrastructural development, collaboration in academic activities is not statistically significant to influence technology transfer in the four universities considered.

The results of this analysis also highlight that spatial proximity between actors (distance from the center in our case) has a significant and negative effect on technology transfer implying that where those universities locate matters as referred to the center (Addis Ababa). Therefore, universities geographically close to the center appear to have a positive effect towards collaborating with industries and have higher impact in transferring technologies at hand (Johnston and Huggins 2016).

The analysis also highlights the significant and positive influence of position of the researchers in the four universities. The results suggest that the greater the amount of relevant research a

university undertakes in this field, the greater the probability that a collaborative university will transfer the technology to its partner industry.

Table 5: UIL-Technology Transfer, whole sample

Variables	Dependent Variable: Technology transfer Index
	Coefficient
A2I-- UIL in academics aspect index	-0.131(0.0895)
A3I-- joint research projects linkage Index	0.308*** (0.0682)
A5I—UIL in infrastructure index	0.170*** (0.0646)
Univcode(Univcode: which stands for university code 1-AAU; 2-ASTU; 3-AASTU and 4-AU)	0.00991(0.00782)
Generation(Generation: the university's generation category: 1-AAU; 2-AU, and 3- ASTU & AASTU)	0.0134(0.00887)
Disfcent(distance from center Addis Ababa, KM)	-0.000259*(0.000132)
Sex(1=Male, 0=Female)	0.0328(0.0257)
Education	0.0110(0.00754)
Experience	-0.00470(0.00571)
Position	0.0195**(0.00903)
Linkage in training(=low)	0.0986*** (0.0354)
Linkage in training(=moderate)	0.120*** (0.0335)
Linkage in training(=high)	0.0980*** (0.0350)
Linkage in training (=v. high)	0.105*** (0.0395)
Student exchange(=low)	0.0626** (0.0284)
Student exchange(=moderate)	0.0304(0.0283)
Student exchange(=high)	0.0845*** (0.0300)
Student exchange (v. high)	0.0596* (0.0355)
Industry sponsored research(=low)	-0.0489* (0.0253)
Industry sponsored research(=moderate)	-0.0357* (0.0211)
Industry sponsored research(=high)	-0.0392* (0.0221)

Industry sponsored research (=v. high)	-0.0946*** (0.0265)
Establishes research and innovation centers(=low)	-0.0973*** (0.0350)
Establishes research and innovation centers(=moderate)	-0.106*** (0.0342)
Establishes research and innovation centers(=high)	-0.0857** (0.0377)
Establishes research and innovation centers (=v. high)	-0.122*** (0.0404)
Establishes technology incubation centers (low)	-0.154*** (0.0542)
Establishes technology incubation centers(=moderate)	-0.106* (0.0538)
Establishes technology incubation centers(=high)	-0.102* (0.0549)
Establishes technology incubation centers (v. high)	-0.128** (0.0560)
Constant	0.269*** (0.0898)
Observations	240
F (30, 208) = 3.67	
Prob > F = 0.000	
R-squared = 0.346	

Note: *** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses

Source: Own computation, 2024

With respect to the specific characteristics of each university, results reported in Table 8 below shows that except in case of few variables, the result is consistent with the result of the whole sample. Most of those variables have the sign as it was in the case of the whole sample and, in most case close in magnitude.

Similar to the whole sample model, the specifications of econometric considered in separate case have also acceptable predictive power. The coefficient of determination (R²) is 0.574, 0.469, 0.744 and 0.514 for AU, ASTU, AASTU and AMU, respectively implying that when all the variables are combined, the multiple linear regression model could explain for approximately 50% and above of the variation in technology transfer in those universities, except for ASTU, and about 47% proportion explained in case of ASTU.

All variables used here are similar to the whole sample model, and several variables measure the variety of highly-related activities from a wider range of collaborative activities (except some demographic variables, almost all measures were five-point Likert-type scales). Some

significant differences can be seen among those universities as Table 8 shows. There were expected differences among these universities—in some cases, even it appears highly significant at the 1% level. For example, in terms of infrastructural related collaboration, AASTU is better than the remaining universities. This implies that collaboration that AASTU has with industries is better than other universities in terms of facilitating technology transfer.

On the other hand, both AAU and ASTU are better in terms of joint research collaboration. This result indicates that when industries collaborate with AAU and ASTU on joint research project, its impact on technology transfer is higher than it appears in the case of AU and AASTU. To the contrary, ASTU's collaboration in academic issues with industries is the poorest outcome, even it is negative and statistically significant implying that when ASTU collaborates with industries on academic activities, technology transfer is adversely influenced. Some possible factors include weak identification process of collaboration, no more works than signing a MoU with those industries, poor guideline of cooperation and controlling system, etc.

Regarding linkage in training between university and industry, respondents from ASTU perceived it as more or less effectiveness. This variable (linkage in training) is positive and statistically significant only for ASTU, though positive in case of AAU and AASTU. This implies that respondents at ASTU perceived that ASTU's linkage in training with the surrounding industries. On the other hand, most respondents from ASTU and AASTU agreed on the presence of Technology transfer to industry due to student exchange linkage between those universities and industries. The remaining results can be interpreted in similar fashion.

Finally, we observed one tricky and surprising results concerning AAU in technology transfer activities. While AAU is old, well established and almost well-equipped both in human and material resources, its performance in technology transfer is contrary to our expectation. This may call for revision of universities internal policies in relation to technology development, adoption, transfer, etc. and collaboration with other institutions.

Table 6: UIL-Technology Transfer, by university

Variables	Dependent Variable: Technology transfer Index			
	Coefficient			
	Model 1-- AAU	Model 2- ASTU	Model 3- AASTU	Model 4- AU
A5I-- UIL in academics aspect index	0.0473	0.128	0.479**	0.401
	(0.138)	(0.137)	(0.206)	(0.510)
A3I--joint research projects linkage Index	0.318**	0.488***	0.373	0.182
	(0.130)	(0.155)	(0.261)	(0.201)
A2I-- UIL in infrastructure index	-0.107	-0.362*	-0.0395	0.226
	(0.192)	(0.207)	(0.274)	(0.333)
Sex	0.0742	-0.00291	0.137	-0.0338
	(0.0689)	(0.0503)	(0.0902)	(0.0974)
Education	0.0243	0.00685	0.0375*	-0.0233
	(0.0167)	(0.0147)	(0.0215)	(0.0267)
Experience	-0.000546	-0.00292	-0.0254	-0.00681
	(0.0143)	(0.0115)	(0.0182)	(0.0227)
Position	0.0146	0.0190	0.0218	0.00933
	(0.0165)	(0.0187)	(0.0264)	(0.0319)
Linkage in training(=low)		0.203**	0.0534	
		(0.0927)	(0.0455)	
Linkage in training(=moderate)	0.130	0.174**	0.0711	-0.0733
	(0.0967)	(0.0821)	(0.0474)	(0.0924)
Linkage in training(=high)	0.108	0.159*	0.0425	-0.121
	(0.0963)	(0.0845)	(0.0637)	(0.122)

Linkage in training (=v. high)	0.133	0.186*	0.0110	-0.188
	(0.0931)	(0.0950)	(0.0890)	(0.163)
Student exchange(=low)	0.0121	0.102**	0.145*	
	(0.0738)	(0.0491)	(0.0740)	
Student exchange(=moderate)	0.0224	0.0702	0.0547	-0.104
	(0.0764)	(0.0529)	(0.0637)	(0.0626)
Student exchange(=high)	0.0716	0.140**	0.0915	-0.0378
	(0.0771)	(0.0629)	(0.0636)	(0.0669)
Student exchange (=v. high)	0.0156	0.0894	0.0808	-0.0288
	(0.0931)	(0.0788)	(0.0978)	(0.0778)
Industry sponsored research(=low)	-0.0635	-0.0470	0.0103	-0.0155
	(0.0699)	(0.0544)	(0.0555)	(0.0624)
Industry sponsored research(=moderate)	-0.0512	-0.0558	-0.0387	0.0257
	(0.0673)	(0.0480)	(0.0474)	(0.0539)
Industry sponsored research(=high)	-0.0853	-0.0761	-0.0423	0.0461
	(0.0646)	(0.0484)	(0.0538)	(0.0656)
Industry sponsored research (=v. high)	-0.140**	-0.133**	-0.179**	-0.0197
	(0.0656)	(0.0557)	(0.0858)	(0.0884)
Establishes research and innovation centres(=low)	-0.150	-0.112	-0.136	-0.220*
	(0.123)	(0.0722)	(0.0928)	(0.117)
Establishes research and innovation centres(=moderate)	-0.118	-0.116*	-0.113	-0.243*
	(0.120)	(0.0681)	(0.0865)	(0.118)
Establishes research and innovation centres (=high)	-0.0450	-0.0825	-0.159*	-0.253*
	(0.125)	(0.0868)	(0.0926)	(0.124)

Establishes research and innovation centres (=v. high)	-0.0825 (0.119)	-0.227** (0.0914)	-0.204* (0.105)	-0.320* (0.164)
Establishes technology incubation centres (low)			-0.102 (0.0694)	-0.239 (0.174)
Establishes technology incubation centres (moderate)	0.125* (0.0720)	0.0327 (0.0419)	-0.0652 (0.0783)	-0.247 (0.174)
Establishes technology incubation centres (high)	0.133* (0.0690)	0.0880* (0.0448)	-0.0831 (0.0870)	-0.329 (0.209)
Establishes technology incubation centres (v. high)	0.108 (0.0893)	0.0525 (0.0545)	-0.104 (0.0954)	-0.358 (0.231)
Constant	0.0947 (0.191)	0.183 (0.168)	-0.0591 (0.193)	0.777** (0.295)
Observations	93	36	33	78
R-squared	0.574	0.469	0.744	0.514

Note: *** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses

Source: Own computation, 2024

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The research achieved the objective of exploring international best practices for university-industry linkages by identifying key models from diverse countries. In the United States, the evolution of Technology Transfer Offices (TTOs), particularly post-Bayh-Dole Act, has been pivotal in enhancing commercialization and research outputs. Germany's Fraunhofer Society and the "Excellence Initiative" showcase the success of integrating research funding with innovation goals. Japan's Technology Licensing Organizations (TLOs) and Strategic Innovation Promotion Program (SIP) illustrate the benefits of structured academia-industry collaborations. South Korea's Industry-Academic Cooperation Foundation (IACF) and its technology parks have significantly improved commercialization rates. China's "Double First Class" initiative and Innovation Parks have demonstrated effective technology transfer and research output increases. In contrast, many African countries struggle with fragmented policies and infrastructure issues, though progress is being made. The comprehensive tracking and evaluation of technology transfer outcomes underscore the importance of metrics like patents and commercialization rates, providing valuable lessons on successful practices for enhancing university-industry collaboration.

The research also met the objective of exploring current institutional frameworks of university-industry linkages in Ethiopia. The analysis indicates that while Ethiopian universities are advancing in developing these frameworks, they face substantial challenges compared to international standards. While national policies such as the Ethiopian Science and Technology Policy and the National Innovation Policy offer a strong foundation, their implementation at the institutional level is often inconsistent due to bureaucratic obstacles and fragmented approaches. Ethiopian universities deal with underdeveloped infrastructure, fragmented efforts, and limited funding, hindering effective technology transfer and commercialization. In contrast, emerging economies like China and South Korea, with their strategic investments and policy frameworks, highlight a path for Ethiopia to enhance its U-I and TT capabilities.

The research achieved the objective of analyzing the structural function of Technology Transfer Offices (TTOs) at selected Ethiopian universities. The findings reveal that TTOs at institutions such as AAU, ASTU, AASTU, and AU have established frameworks but face significant challenges. Common issues include inadequate budgets, underdeveloped legal frameworks, and insufficient staff training. While AAU's TTO benefits from an incubation center, it struggles with financial constraints and legal issues. ASTU's and AASTU's TTOs face similar limitations affecting their commercialization efforts. Ambo University's TTO, despite some success in agricultural technology, contends with unclear internal guidelines. Survey data confirm these challenges, highlighting the need for improved resources, legal frameworks, and staff training to enhance the effectiveness of TTOs.

The research also addressed the influence of university-industry linkages (UIL) on technology transfer. The findings indicate that UIL significantly impacts the technology transfer processes. The ANOVA results show that researchers' educational status and the type of university (first-generation vs. special mission) affect UIL and technology transfer. The Principal Component Analysis (PCA) identified key factors such as joint research projects and infrastructure collaboration as significant contributors to effective technology transfer. Higher levels of collaboration in these areas positively influence the technology transfer process. However, academic collaborations alone do not significantly impact technology transfer without the support of research and infrastructure initiatives. Additionally, geographic proximity to industry centers plays a critical role in successful technology transfer, as evidenced by the negative impact of distance from central hubs like Addis Ababa.

The research achieved the objective of identifying major challenges limiting the function of university-industry linkages in Ethiopian universities. Key barriers include inconsistent policy implementation, insufficient staff skills, unclear regulations, and lack of supportive rules. Technological barriers, communication gaps, limited practical experience, and misalignment between academic research and industry needs further constrain UIL and technology transfer efforts. The research highlights that while funding and structural issues are present, they are secondary to the critical challenges of policy inconsistency, staff skill deficiencies, and misaligned research outputs. Addressing these issues is essential for enhancing the effectiveness of UIL and improving technology transfer outcomes.

5.2. Recommendations

To enhance university-industry (U-I) linkages and technology transfer (TT) effectiveness, the selected Ethiopian universities should address several key areas. First, they need to improve the implementation of national policies by aligning institutional practices with strategic directives and overcoming bureaucratic barriers. Strengthening organizational structures with standardized internal policies and governance frameworks will enhance operational readiness. Expanding industry engagement to include formal and structured partnerships, beyond consultancy and internships, will better align academic research with industry needs. Universities should also integrate industry feedback into educational programs and explore co-educational opportunities to bridge academia and industry.

Developing comprehensive technology transfer frameworks with clear policies and structured impact measurement systems will facilitate research commercialization. Diversifying funding sources and improving financial management will provide more strong support for U-I linkages and TT activities. Implementing structured evaluation systems will help measure and enhance the impact of collaborations.

Additionally, Ethiopian universities can benefit from international best practices. By adopting successful models from both developed and emerging countries, such as strong intellectual property frameworks, systematic technology transfer processes, and formal industry partnerships, Ethiopian institutions can improve their own frameworks. Investing in innovation infrastructure and diversifying funding sources will further advance U-I and TT efforts. Drawing lessons from global experiences, including those of emerging economies, will help Ethiopian universities address existing gaps, enhance their UIL and TT frameworks, and contribute to technological and economic development. Key actions for improving Technology Transfer Offices (TTOs) include developing comprehensive legal guidelines, increasing budget allocations, recruiting skilled staff, improving internal guidelines, and leveraging successful local engagement strategies. Overall, a multi-faceted approach that focuses on policy alignment, staff training, and infrastructure investment will significantly improve U-I linkages and TT outcomes in Ethiopian universities.

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APPENDIX

Appendix 1: Summary of Respondents

Table 1: Respondents by University

The respondents' summary by university. Results were presented in Table below. Accordingly, about 50(20.8%) of the respondents were from AASTU, 50(20.8%) of the respondents were from AMU 80(33.3%) of the respondents were from ASTU and 60(25%) were from AAU. This implies that more respondents from ASTU and next from AAU.

University	frequency	percent
AAU	93	38.6
ASTU	36	15.1
ASTU	33	13.8
AU	78	32.3
Total	240	100.0

Source: Survey Data (2024)

Table 2: Respondents by Educational Level

The result of survey data that used in the study revealed that approximately 4.2% of the respondents were professors, 23.3% associate professors, 46.7 assistant professors, and 25.8% lecture.

Educational Level	frequency	percent
professor	10	4.2
Associate professor	56	23.3
Assistant professor	112	46.7
Lecture	62	25.8
Total	240	100

Source: Survey data (2024)

Table2: Summary of key informant respondents from Private industries

Private Industries	Collaborate with	Code of their key representative
Derba MIDROC	AAU	1
EthioChicken		2
Star Soap		3
iCog Labs		4
Adama Spinning factory		5
Adama Steel	ASTU	6
Belayab Motors		7
FAFA Food Share	AASTU	8
Jitu Agricultural Input Trading		9
Ambo Surrounding Relief Association	AU	10

Appendix 2: Summary of descriptive statistics of survey data in Frequency, percent and mean score in align with each question in a questionnaires

Table 1: University-Industry Collaboration in management aspect

	Use 5= High, 4= average, 3= low, 2= Very Low, 1= not at all	not at all	Very Low	low	average	High	
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Mean
1.1	Setting of common directions (vision, mission, etc.) in collaboration with industries in align with the universities vision, mission	20(8.3)	63(26.3)	70(29.2)	45(18.8)	42(17.5)	3.108
1.2	Involve industries in strategic planning of University-Industry Linkage (UIL) at college/department level	15(6.3)	53(22.1)	111(46.3)	41(17.1)	20(8.3)	2.992
1.3	Jointly assessing the existing situation specific to the college/department on UIL with industries	22(9.2)	83(34.6)	71(29.6)	31(12.9)	33(13.8)	2.875
1.4	Setting priorities in strengthening linkages with industries	40(16.7)	69(28.8)	85(35.4)	25(10.4)	21(8.8)	2.658
1.5	Implementing UIL plans in collaboration with industries	9(3.8)	44(18.3)	132(55)	29(12.1)	26(10.8)	3.079
1.6	Monitoring UIL activities with the involvement of industries	2(0.8)	59(24.6)	111(46.3)	46(19.2)	22(9.2)	3.113
1.7	Evaluating UIL activities jointly with industries at college/ department level	8(3.3)	40(16.7)	130(54.2)	52(21.7)	10(4.2)	3.067
1.8	Adequately allocating financial and other resources for your college department for UIL activities by your university	17(7.1)	42(17.5)	92(38.3)	56(23.3)	33(13.8)	3.192
1.9	Jointly fulfill/recruit manpower required for UIL with industries at your college/department	74(30.8)	119(49.6)	20(8.3)	18(7.5)	9(3.8)	2.038

1.10	Assessing the quality of graduates with input from industries	5(2.1)	43(17.9)	69(28.8)	88(36.7)	35(14.6)	3.438
1.11	setting common agenda for UIL decision-making with industries	21(8.8)	63(26.3)	92(38.3)	37(15.4)	27(11.3)	2.942
		255	2*678=1356	983*3=2949	446*4=1784	278*5=1390	7734/2640=2.93

Table 2: University-Industry Interaction in the aspect of capacity Building Training and Education

	Use 5= High, 4= average, 3= low, 2= Very Low, 1= not at all	not at all	Very Low	low	average	High	
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Mean
2.1	Extent of joint curriculum development	16(6.7)	14(5.8)	41(17.1)	103(42.9)	63(27.5)	3.788
2.2	Industries engagement in jointly revising the implemented curriculum	0(0)	5(2.1)	27(11.3)	135(56.3)	73(30.4)	4.150
2.3	Joint training initiatives for students, academics, and industry employees for exchanging experiences and skill development	10(4.2)	19(7.9)	47(19.5)	93(38.8)	71(29.6)	3.817
2.4	Extent of arranging student placements in industry for short or long-term training, apprenticeship, and internship	4(1.7)	16(6.7)	36(15)	93(38.8)	91(37.9)	4.046
2.5	Practice of jointly identifying	8(3.3)	21(8.8)	120(50)	63(26.3)	28(11.5)	

	specific areas of training need						3.342
2.6	Exchange of PhD or master student with industry	15(6.3)	41(17.1)	62(25.6)	76(31.7)	46(19.2)	3.404
2.7	Extent of jointly supporting professional development and training	4(1.7)	22(9.2)	39(16.3)	90(37.7)	83(35.4)	3.958
2.8	Extent of inviting firm's staff and experts to deliver lectures and speeches on new technology, entrepreneurship courses to students and researchers practiced at your university	6(2.5)	21(8.8)	124(51.7)	51(21.3)	38(15.8)	3.392
2.9	Extent of industrial visits organized for students/academic staffs at your university	2(0.8)	10(4.2)	25(10.4)	120(50)	83(34.5)	4.133
2.1	The extent that you believe students/staffs regular industry visit in fostering industry-university linkage	0(0)	15(6.3)	45(18.8)	16(48.3)	84(26.7)	3.954
2.11	Extent of conferences, seminars and workshops conducted for staff from the industry at your university	0(0)	15(6.3)	45(8.8)	113(47.1)	67(27.9)	3.967
2.12	Extent to which you perceive the importance of	26(10.8)	24(10)	64(26.7)	78(31.7)	50(20.8)	

	making it obligatory for academics to undertake a certain amount of work with the industry for enhancing industry-university linkage						3.417
2.13	Extent of providing scholarships for students and academic staff by industry	0(0)	15(6.3)	45(18.8)	114(47.7)	66(27.5)	3.963
2.14	Extent to which industry is beneficial in providing scholarships for students and academic staff at your university	20(8.3)	18(7.5)	44(18.3)	87(36.3)	71(29.6)	3.713

Table 3: University-Industry collaboration in research and consultancy aspect

	Use 5= Very High, 4= High, 3= moderate, 2= Low, 1= Not at all	not at all	Low	Moderate	High	Very High	
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Mean
3.1.	Joint Research Projects with industry	6(2.5)	70(29.2)	97(40.4)	49(20.4)	18(7.5)	3.013
3.2.	Industry Sponsored research works	26(10.8)	24(10)	64(26.7)	76(31.7)	50(20.8)	3.417
3.3.	Contract research from industry	0(0)	15(6.3)	45(18.8)	114(47.5)	66(27.5)	3.963

3.4.	Industry-Academia Conferences and Workshops for setting research thematic area	20(8.3)	22(9.2)	56(23.3)	76(31.7)	66(27.5)	3.608
3.5.	Access to Industry Data and Resources	6(2.5)	18(7.5)	40(16.7)	86(35.8)	90(37.5)	3.983
3.6.	PhD and Master's Research Collaborations:	0(0)	44(18.3)	132(55)	60(25)	4(1.7)	3.100
3.7.	Collaborative Publications and Patents	22(9.2)	44(18.3)	116(48.3)	39(16.3)	19(7.9)	2.954
3.8.	Industry-Driven Research Priorities	6(2.5)	50(20.8)	113(47.1)	45(18.8)	26(10.8)	3.146
3.9.	exchange of researchers between university and industry	6(2.5)	41(17.1)	122(50.8)	37(15.4)	34(14.2)	3.217
3.10.	Commercialization of R&D results	16(6.7)	32(13.3)	113(47.1)	45(18.8)	34(14.2)	3.204
3.11.	Offering consultancy services such as technical advice, feasibility studies, and strategic guidance to industry partners?	2(0.8)	34(14.2)	32(13.3)	92(38.3)	80(33.3)	3.892

Table 4: Technology Transfer activities and Status of Technology Transfer office

4.	Use 5= Very High, 4= High, 3= moderate, 2= Low, 1= very low	not at all	Low	Moderate	High	Very High	
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Mean
4.1.	current level of technology transfer activities	16(6.7)	93(38.8)	81(33.8)	23(9.6)	27(11.3)	2.800
4.2.	clarity and effectiveness of the technology transfer pathway	24(10)	80(33.3)	50(20.8)	80(33.3)	6(2.5)	2.850
4.3.	the availability of supportive structures (e.g., offices, funding, expertise) for technology transfer	2(0.8)	34(14.2)	108(45)	94(39.2)	2(0.8)	3.250
4.4.	your satisfaction with the efficiency and effectiveness of the technology transfer process	5(2.1)	149(62.1)	72(30)	12(5)	2(0.8)	2.404
4.5.	TTO has well organizational structure with defined structures, roles , responsibilities integrated within the university	2(0.8)	37(15.4)	50(20.8)	88(36.7)	63(26.3)	3.721
4.6.	TTO has adequate staffs with necessary skills like IP law, business development, and negotiation	2(0.8)	98(40.8)	134(55.8)	6(2.5)	0(0)	2.600
4.7.	University Allocates Adequate budget and physical resources for TTO		19(7.9)	41(17.1)	86(35.8)	94(39.2)	4.063
4.8.	There are enabling legal framework, regulations related to intellectual property,	1(0.4)	14(5.8)	25(10.4)	99(41.3)	101(42.1)	4.188

	contracts, licensing and negotiation						
4.9.	TTO has clear internal guidelines, processes and mechanisms for technology transfer	1(0.4)	14(5.8)	25(10.4)	99(41.3)	101(42.1)	4.188
4.10.	Technology Transfer Readiness of TTO in terms of Technology Assessment and market Research	12(5)	40(16.7)	95(39.6)	56(23.3)	37(15.4)	3.275
4.11.	TTO actively collaborates with industry partners for technology transfer	14(5.8)	20(8.3)	47(19.6)	71(29.6)	88(36.7)	3.829
4.12.	TTO has clear guidelines to assist faculty and students in launching start-ups, provide mentorship, fund, and business development.	9(3.8)	40(16.7)	98(40.8)	50(20.8)	43(17.9)	3.325
4.13.	advocate for policies that promote innovation, entrepreneurship, and knowledge dissemination		15(6.3)	45(18.8)	116(48.3)	64(26.7)	3.954
4.14.	TTO has clear mechanisms of supporting spin-off companies, aiding in business planning and funding	5(2.1)	34(14.2)	39(16.3)	95(39.6)	67(27.9)	3.771

Table 5: Enabling resources and Infrastructures for University-Industry linkage and Technology Transfer

5.	Use 5= Very High, 4= High, 3= moderate, 2= Low, 1= very low at all	not at all	Low	Moderate	High	Very High	
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Mean
5.1.	Organizes resources for technology transfer with industries	14(5.8)	20(8.3)	47(19.6)	71(29.6)	88(36.7)	3.829
5.2.	Establishes research and innovation centers and institutes with industries	9(3.8)	40(16.7)	98(40.8)	50(20.8)	43(17.9)	3.325
5.3.	Develops joint infrastructure facilities (ICT, laboratories, or innovation hubs , science park, Offices, etc.) for UIL with industries	17(7.1)	38(15.8)	46(19.2)	88(36.7)	51(21.3)	3.492
5.4.	Establishes different technology incubation centers jointly	3(1.3)	33(13.8)	50(20.8)	85(35.4)	69(28.8)	3.767

Table 6: Challenges that hinder University-Industry Linkage

6.	Use 5= Strongly Agree, 4= Agree, 3= Neutral, 2= Disagree, 1= Strongly Disagree	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Mean
6.1.	No clear policy, rules, regulations and guidelines related to UIL	1(0.4)	15(6.3)	40(16.7)	88(36.7)	96(40)	4.096
6.2.	Technological Barriers	5(2.1)	40(16.5)	56(23.3)	69(28.8)	70(29.2)	3.663
6.3.	Communication Gaps	9(3.8)	45(18.8)	51(21.3)	79(32.9)	56(23.3)	3.533
6.4.	Limited Budget for Research Universities	22(9.2)	42(17.5)	53(22.1)	68(28.3)	55(22.9)	3.383
6.5.	Skills Mismatch Between Graduates and Industry Demands	5(2.1)	42(17.5)	89(37.1)	57(23.8)	47(19.6)	3.413
6.6.	Insufficient Skills and Knowledge Among Staff	0(0)	12(5)	27(11.3)	113(47.1)	88(36.7)	4.154
6.7.	Policy Implementation Challenges:	1(0.4)	11(4.6)	20(8.3)	114(47.5)	94(39.2)	4.204
6.8.	Cultural Divide	8(3.3)	16(6.7)	51(21.3)	73(30.4)	92(38.3)	3.938
6.9.	The university doesn't have incentive policies for collaborating with industry	1(0.4)	13(5.4)	33(13.8)	116(48.3)	77(32.1)	4.063
6.10.	Weak Absorptive Capacity in Industry	10(4.2)	52(21.7)	40(16.7)	79(32.9)	59(24.6)	3.521
6.11.	The university has limited practical experience because its more theoretical	2(0.8)	37(15.4)	49(20.4)	90(37.5)	62(25.8)	3.721
6.12.	Faculty's research capability does not meet the practical needs of the industry	14(5.8)	26(10.8)	39(16.3)	91(37.9)	70(29.2)	3.738
6.13.	The university's infrastructure and research equipment do not meet the research requirements of industry	6(2.5)	27(11.3)	68(28.3)	82(34.2)	57(23.8)	3.654
6.14.	The academic staff does not have sufficient time for	7(2.9)	41(17.1)	45(18.8)	89(37.1)	58(24.2)	3.625

	collaborating with industry due to heavy teaching and administrative workload						
6.15.	The academic staff does not have appropriate awareness of the benefits of UIL	8(3.3)	20(8.3)	43(17.9)	114(47.5)	55(22.9)	3.783
6.16.	Collaboration with industry limits the freedom in the selection of research topics.	13(5.4)	53(22.1)	45(18.8)	74(30.8)	55(22.9)	3.438
6.17.	Firms are not interested in collaborating with the university	16(6.7)	20(8.3)	53(22.1)	89(37.1)	62(25.8)	3.671
6.18.	Absence of rules and regulations that support UIL in both parties	1(0.4)	11(4.6)	37(15.4)	122(50.8)	69(28.8)	4.029
6.19.	The university's structure is inappropriate to support the promotion of U-I linkages	37(15.4)	101(42.1)		0(0)	12(5)	2.371

Guiding Interview Questions

This structured interview guide was designed for university management teams directly involved with UIL and TT. The aim is to investigate the institutional frameworks of UIL and the status of supporting structures, such as the Technology Transfer Office (TTO), within selected universities.

1. General Questions about Collaboration and Its Extent:

- Does the university actively collaborate with industry partners?
- What is the frequency and duration of interactions with industry stakeholders?
- What are the main goals of these collaborations? (e.g., Innovation and research advancement, Economic growth and job creation, Skill development and workforce enhancement, Commercialization, Technology transfer, Networking and partnerships, Talent development)

2. Policy and Strategic Framework

- What are the key strategic priorities of your university regarding industry collaboration and technology transfer?
- How does the university plan to implement or influence national policies?

3. Organizational Structures

- Can you describe the roles and responsibilities of the University-Industry and Technology Transfer offices?
- Do these offices have skilled expertise, legal frameworks, guidelines, and clear procedures to facilitate collaboration and technology transfer?
- How are these roles coordinated with other university departments?
- Are there established innovation hubs, incubation centers, research parks, or centers of excellence that support UIL and TT at your university?

4. Collaboration Channels and Mechanisms

- What formal channels exist for collaboration? (e.g., Joint initiatives, Industry-funded research projects, Contract research, Joint projects and consultancy, Joint research centers, Incubators)
- Are there any informal channels that facilitate collaboration? (e.g., Student internships or placements, Mentoring, Engagement of industry guest lecturers, Expertise

exchange) What role do these informal channels play in fostering university-industry relationships?

5. Depth of Collaboration

- Can you describe the depth of the university's collaboration in terms of the number of collaborative projects, funding amounts, publications and patents, and student involvement?
- How would you characterize the depth of engagement? (e.g., occasional workshops vs. ongoing partnerships)
- Are there formal agreements (e.g., MoUs) that the university has signed with industry organizations? If so, how long have these agreements been in place?
- Could you provide an overview of the purpose and scope of these agreements?
- Have there been any successful outcomes resulting from these agreements?

6. Research and Consultancy Projects

- Are there ongoing joint research or industry-funded research projects managed by the UIL and TT offices?
- Can you provide an overview of these ongoing joint research projects and their coordination?
- What challenges have been encountered in managing these collaborative efforts?

7. Technology Transfer Activities

- Can you provide insights into your university's technology transfer activities, including the channels or processes used, research goal alignment, and nature of collaborations with external partners?
- Has the university developed any technology that addresses community, business, industry, or government needs? If so, has it been transferred to end-users? Please provide details about the technology.
- Has the university facilitated the transfer of technology developed elsewhere to solve local problems? If so, provide details about the technology and its current status.
- How do you measure the impact of your technology transfer efforts, and what strategies are in place to address challenges and leverage success factors?

8. Status of Technology Transfer Office (TTO)

- How is the Technology Transfer Office (TTO) structured within your university, and what resources are allocated to support its functions?
- Are there clear legal frameworks, guidelines, and readiness assessments in place to facilitate technology transfer activities, including intellectual property management and business development support?

9. Metrics and Impact Evaluation

- How do you assess the impact of your university-industry collaborations? What metrics or indicators are used to evaluate success?
- Can you share examples of quantifiable outcomes from these collaborations and their significance?

10. Barriers and Success Factors

- What challenges or barriers have you faced in maintaining and deepening collaborations with industry partners?
- Conversely, what factors contribute to the success and sustainability of university-industry research partnerships

Structured guiding interview questions that was used to collect data from private companies on the following issues.

1. General Questions

- Can you provide a brief overview of your company's collaboration agreement with the university?
- What were the initial objectives and expected outcomes of this collaboration?
- How does the collaboration with the university align with your company's specific strategic goals and priorities?
- How committed is your company's leadership to the collaboration with the university?
- What steps have been taken by your company to actively engage with the university and ensure the collaboration's success

2. Area of Collaboration

- What are the main Area of collaboration in which your company is interested to collaborate with the university? (E. g Collaboration in research, Collaboration in training, Collaboration in resource Sharing, Consultancy projects etc.)

3. Collaboration Process

- Can you describe the planning process for your collaboration with the university?
- Were there any detailed plans or timelines established at the beginning of the collaboration?
- How was the implementation of the collaboration monitored and managed?
- How frequent and effective was the communication between your company and the university?

4. Successful Area of collaboration

- Can you identify any successful aspects or milestones achieved through this collaboration?

5. Challenges and Barriers

- What specific challenges or barriers hold back the company to make successful collaboration with AAU?
- Were there any regulatory or legal issues that hindered the progress of the collaboration?
- Are there any internal challenges within your company that have affected the success of the collaboration (e.g., changes in management, strategic priorities, or funding constraints)?

Appendix 3: Results of Principal Component Analysis (PCA) from SPSS

Table 1: Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.751
Approx. Chi-Square		60.578
Bartlett's Test of Sphericity	df	55
	Sig.	.0402

Communalities		
	Initial	Extraction
Q23	1.000	.834
Q26	1.000	.932
Q28	1.000	.943
Q213	1.000	.947
Q32	1.000	.858
Q33	1.000	.947
Q34	1.000	.766
Q35	1.000	.930
Q38	1.000	.906
Q310	1.000	.932
Q42	1.000	.748
Q43	1.000	.930
Q44	1.000	.906
Q46	1.000	.819
Q48	1.000	.837
Q51	1.000	.780
Q52	1.000	.851
Q53	1.000	.870
Q54	1.000	.847

Extraction Method: Principal
Component Analysis.

Table 2: Communalities: High communalities across all variables indicate that the extracted components account for a significant proportion of each variable's variance. This demonstrates that the factors identified in the PCA effectively represent the data's underlying structure.

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings ^a
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	6.880	25.482	25.482	6.880	25.482	25.482	6.593
2	3.647	13.506	38.988	3.647	13.506	38.988	4.242
3	3.236	11.985	50.973	3.236	11.985	50.973	2.990
4	2.510	9.297	60.270	2.510	9.297	60.270	2.697
5	1.129	4.182	78.341				
6	.978	3.622	81.963				
7	.947	3.509	85.472				
8	.671	2.485	87.957				
9	.646	2.391	90.348				
10	.574	2.124	92.472				
11	.518	1.918	94.390				
12	.384	1.421	95.811				
13	.341	1.262	97.073				
14	.245	.907	97.980				
15	.228	.844	98.824				
16	.177	.656	99.480				
17	1.001E-013	1.004E-013	100.000				
18	-1.001E-013	-1.005E-013	100.000				
19	-1.003E-013	-1.011E-013	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Table 3: Total Variance Explained

Pattern Matrix^a

	Component			
	1	2	3	4
Q23	.978			
Q26	.965			
Q28	.864			
Q213	.857			
Q32		.930		
Q33		.920		
Q34		.823		
Q35		.808		
Q38		.782		
Q310		.773		
Q42			.954	
Q43			.914	
Q44			.855	
Q46			.746	
Q48			.716	
Q51				.914
Q52				.911
Q53				.880
Q54				.754

Extraction Method: Principal Component Analysis.

Rotation Method: Promax with Kaiser Normalization.^a

a. Rotation converged in 5 iterations.

Table 4: Pattern Matrix: The pattern matrix reveals how each variable loads onto the extracted components after rotation. High loadings indicate strong associations between variables and factors, allowing for clear interpretation of the factors' meanings and their underlying dimensions. The rotation method (Promax) facilitates this interpretability by accounting for potential correlations between factors.

