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The Pathway towards Triple Helix

Technology Development Evaluation in Ethiopian Science & Technology Universities

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Abstract

In 2015, the Ethiopian government established two Science and Technology (S&T) universities with the objective to boost university-industry collaboration. Although both Addis Ababa S&T University and Adama S&T University encourage such collaboration through their offices of technology transfer (OTT), their links with local industry are weak. However, current literature on triple helix in developing countries does not explain how universities can internally stimulate interaction with external actors. This paper addresses this gap by asking how the two universities evaluate the technology development process and how the current approach can be improved to stimulate triple helix interactions. Insights from organizational control theory (OCT) and the Context, Input, Process, and Product (CIPP) evaluation model are integrated into the triple helix framework in a qualitative case study design. Our findings indicate the existing approach combines outcome- and behavior-based evaluation, which constrains engagement with the industry. We recommend that a more comprehensive, people-based evaluation system, built around shared goals and involvement of industry as external stakeholders, is adopted as a pathway to triple helix.

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Keywords

Ethiopia – university-industry – technology development – triple helix – organizational control theory – evaluation

1 Introduction

Since the 1990s, Ethiopia's government has pushed a profound transformation of the economy to lift the country out of poverty. This move accelerated in 2010 when the newly issued Growth and Transformation Plan (GTP) laid the objective of transforming one of the least developed countries in the world into a middle-income economy (MoFED, 2010). The GTP articulated the government's commitment to strengthen the connection between higher education and economic growth. Under the plan, two new, fully-fledged science and technology (S&T) universities were established in 2015, Adama S&T University (ASTU) and Addis Ababa S&T University (AASTU). Since their launch, their mission is explicitly linked to increasing ties with industry (AASTU, 2021b; ASTU, 2020b). Due to their shared mandate from the government, the two universities have a similar internal structure. They receive state funding to develop new technologies to support Ethiopia's transition from an agrarian to an industrial economy (MoFED, 2010). Specifically, the two institutions are encouraged to link with the industry through technology development programs, operated by an Office of Technology Transfer (OTT) in each university (OTTCS, 2017; VPRTT, 2013). However, connecting the university with the industry is a relatively new concept in Africa's second most populous country. Studies have indicated that Ethiopia suffers from a lack of coordination between higher education and industry (e.g., Kahsay, 2017). In this sense, Ethiopian higher education institutions (HEIS) are not different from other developing countries, which pay increasing attention to the third mission beyond teaching and research yet are inhibited by a similar set of challenges. These are, among others, modest levels of development, low average level of GDP per capita, limited public budgets, and generally low levels of innovation capacity, meaning the universities can find adequate partners for knowledge transfer only with difficulties (Göransson et al., 2009).

The establishment of the two universities can be interpreted through the lens of the Triple Helix (TH) model. Original TH literature placed democratic governance as a precondition to the interactions of the government, industry, and higher education (Etzkowitz, 2003). Although TH as a framework was initially developed in the global west, a mature body of literature showed TH

model is context-dependent (e.g., Cai, 2014). Many scholars applied the model in the global south even though local policymakers are not necessarily aware of the TH as a distinct model (Etzkowitz and Dzisah, 2007). Studies adopting the TH have assessed both the policy relevance (e.g., Cai, 2014; Brundin et al., 2008) and the importance of employing TH as a normative structure (e.g., Etzkowitz and Dzisah, 2007), showing that developing countries in the global south can speed up their economic growth by strengthening the role of higher education sector.

The university-industry literature has identified features particular to the non-Western context, including in Africa (e.g., Datta and Saad, 2011; Irawati, 2011). Naturally, TH requires managing a complex interface between organizations and individuals, building a shared culture, mobilizing resources (Ranga and Etzkowitz, 2013). However, a weak interaction among the three helices is common in developing countries (Mêgnigbêto 2019; Dzisah, 2011; Taylor, 2004). Universities themselves sometimes impede such collaborative relationships. For example, Razak and Saad (2011) identified that an overemphasis on internal control systems in technology development evaluation process limited commercializing technology outputs in Malaysian universities. Sarpong et al. (2017) showed how Malaysian HEIs can both facilitate and inhibit innovation through an internal control system. Indeed, too little control can also obstruct interaction with industry. Similar developments have been documented in the African context, as well. For example, a lack of government oversight in South Africa enabled universities to overlook links with industry (Brundin et al., 2008). These findings demonstrate that a university's internal operations play a role in TH study.

Despite the availability of TH literature in developing countries, existing studies have mostly targeted the macro level, mainly the higher education as a system (e.g., Mêgnigbêto, 2019, Dzisah, 2011) or the wider society (e.g., Etzkowitz and Dzisah, 2007; Razak and White 2015, Saad et al., 2008). This is understandable since one a key rationale for any country's transition towards the TH model is a targeted government policy (Leydesdorff and Meyer 2006, as cited in Cai and Etzkowitz, 2020). Recent approaches have stressed the importance of stretching the boundaries of TH and studying diverse contexts at the macro, meso and micro-level (Cai and Etzkowitz, 2020, Cai and Amaral, 2022). The TH model can also be used for a "micro-processes" analysis in the "reconfiguration" of relations among the "institutional sphere" (Etzkowitz, 2003, p. 332).

Nevertheless, an understanding of how TH can be "micro-nurtured" inside individual organizations is still largely lacking. We know too little about how the transition to the TH manifests at the organizational level; literature on the

rapidly transforming African setting is very scarce (Mêgnigbêto, 2019; Konde, 2004). Existing research does not show how individual universities can build TH-based interactions with local industry in a developing country which is still mostly agrarian, such as Ethiopia. This gap in the micro-level study exists in TH as a body of knowledge in general (Cai and Etzkowitz, 2020). This paper addresses this gap by looking into the evaluation of technology development in the two universities and its relation to the TH model. The two selected S&T universities have a similar internal structure and use the same evaluation process as a management tool for technology development. Namely, we ask two questions:

– How do the two universities evaluate technology development process?
– How can the current evaluation approach be improved to stimulate triple helix interactions?

We believe that by concentrating on the micro-level analysis, it is possible to address an important research agenda in TH, identifying shortcomings and opportunities within organizations to initiate the interaction of helices (Etzkowitz and Leydesdorff, 2000). Scrutinizing the internal system is especially important for universities in developing economies (Etzkowitz and Dzisah, 2007). Aside of the objective to contribute to the micro-level study of TH, this study also contributes to reducing the gap between TH as a theoretical exercise and actual practice (Cai and Etzkowitz 2020). That is why this article zooms in on the offices of technology transfer (OTTs) as these are the two universities' main linkage points with local industry. We analyze the OTTs' internal control system, by looking into how it carries out evaluation of projects they finance. Since the universities' OTTs use technology development evaluation as a part of their internal management, analyzing them could provide concrete recommendations on changing internal operations. This can then spur TH interactions (Etzkowitz and Leydesdorff, 1998; Etzkowitz, 2003). Given the scarcity of research on the micro-foundations of the relationship between the three helical spheres, TH offers a suitable tool to carry out our analysis when coupled with other theories. Scholars enhance TH through other concepts such as institutional theory (Brundin et al., 2008), institutional logics (Cai, 2014) and game theory (Mêgnigbêto, 2019), among others. Similarly, to construct the framework, we combined insights from organizational control theory (OCT) and the context, input, process, and product (CIPP) model, borrowed from evaluation theory.

Our findings show the current evaluation approach combines an outcome control over technology development process in combination with a behavior control over budget utilization. This is unfeasible in situations where

uncertainty reigns (for instance in technology development in resource-stripped countries, such as Ethiopia) and where neither outcome nor behavior can be properly monitored. Apart from diagnosing the status quo, our framework also enables us to give recommendations on how the evaluation can be improved. Finding the enablers and barriers of the TH in developing countries should be a research priority (Razak and White, 2015) as a TH study can also contribute not just to theory, but also policy in the global south (Williams and Woodson, 2012). The paper is organized as follows: after an overview of extant scholarship, the first section elaborates on the analytical framework and its contribution to the TH literature. Subsequently, the methodology is explained. Finally, we present the research findings, including concrete recommendations, together with proposals for a future research agenda.

2 Triple Helix in the Global South Context

2.1 *Triple Helix Initiatives in Ethiopia and the Global South*

The TH model can be an alternative path for development for countries with a negative experience with other growth models which were ineffective such as importing technology. It can be used to address systematic fragmentation (Saad et al., 2008) and ensure industrial sustainability (Quartey and Oguntoye, 2020). For example, Patra and Muchie (2018) highlighted TH model as a way for universities to cooperate with industry to promote South Africa's development agenda. In developing economies, universities act as a source of technology and governments as a funding agency (Guerrero and Urbano, 2017). However, fragmented relations among the helices were found to be one of the challenges, e.g., in Tanzanian universities (Fussy, 2019). The historical background of each country and the specific context of each university play a great role in the implementation of TH, as shown in South Africa (Kruss, 2008). The interaction between the three actors of TH has been at the center of the model since its foundation. Yet, the managerial challenges inside universities which could nurture TH are less researched – although equally important (Sekerbayeva and Tamenova, 2021).

In the last decades, Ethiopian higher education has vastly expanded and shifted its focus to industry and societal engagement. After the end of the Ethiopian civil war and the Derg regime in 1991, the new government launched a fundamental reorganization of the economy. Education, including higher education, became a major factor in this effort. In 1991, there were just two universities, but by 2007, there were nineteen (Bishaw & Melesse, 2017). In 2019,

49 state universities and dozens of private colleges and universities existed. The number of enrolled students rose from 180,000 in 2006 to 900,000 in 2018. Ethiopia's state expenditures on higher education surged by more than 250% between 2006 and 2018, far higher than comparable countries in sub-Saharan Africa and the global south (Williams and Usher 2022). Later, the authorities began to also consider universities' contribution to economic development through research and innovation. In 2010, the government announced the Growth and Transformation Plan I (GTP-I, followed by GTP-II in 2015), with the objective of accelerating the economic transformation and becoming a middle-income country. The GTP established two S&T universities and mandated them with educating future engineers (AASTU, 2021a; ASTU, 2022a; Eckl et al., 2017; MoFED, 2010). Addis Ababa Science and Technology University (AASTU) was established in 2011 with the motto „University for Industry" (AASTU, 2022a). The second S&T university was established at around the same time. Formerly Adama University, Adama Science and Technology University (ASTU) opened its doors in the town of Adama (previously known as Nazareth), around 100 km southeast of the Ethiopia's capital (ASTU, 2020a), in 2015. Initially, a German management team was recruited to adopt the "technische Universität" model (Baumann and Lauberbach 2019). The Germans were later replaced by a team of South Korean professors and experts, with the objective of emulating South Korea's development of higher education (Baumann and Lauberbach 2019). In its attempt to push the two universities to contribute to national development, the government gave them a special status and allocated additional budget for technology transfer (Eckl et al., 2017).

2.2 *The Pathway to Triple Helix: Why the Micro-level Matters*

One of the core features of TH is the relationship among the three helices, which develops into collaboration. By doing so, it encourages innovation and entrepreneurship. Ranga and Etzkowitz (2013) state that the TH is comprised of three components. Firstly, there are the three *actors*: higher education, government, and industry. The second component is their *relationship* and linkage points – one of them is through technology transfer from the university to industry. Finally, the *functions* refer to innovation systems' performance (Ranga and Etzkowitz, 2013). The relationships between the three are key to the TH model (Cai and Lattu, 2022; Cai and Amaral, 2021). Each has their distinct role, and at the same time, each also *takes the role of the other* (Etzkowitz, 2008; Etzkowitz, 2003). In the process, they become increasingly interdependent and complementary, adopting "unobvious links" (Cai and Lattu, 2022, p. 272). Over time, additional helices have been added to the theoretical TH "universe" in the form of *quadruple* (the public or the civil society as the fourth helix), and *quintuple*

helix (incorporating the natural environment as the fifth helix, see Carayannis and Campbell, 2010). The debate on how to integrate them into a unified framework continues (Cai, 2022; Carayannis and Campbell, 2022). In this article, we focus on the triad of university-industry-government, as it can help explain interactions among actors in innovation ecosystems (Cai and Lattu, 2022) and is most appropriate to investigate organizational interactions (Cai, 2022).

In one of the original propositions, Etzkowitz and Leydesdorff (1998) suggested four stages in the growth of the TH model. The first is the "internal change" that occurs *within* each helix. The second is the influence of one helix over another, and the third is the additional institutional setups because of the interactions. Finally, a reiterative effect of these entities on the larger society will be visible. Cai (2014), alternatively, identified four stages of the TH model, the first being a recognition of the need for TH interactions. The second stage is "intra-organizational transformation" (p. 4). At the same time, internal transformation means that each helix maintains their unique identity while "taking the role of the other"; bilateral relationships among the three are boosted through the process (Etzkowitz, 2008). In the third stage, the level of interdependence deepens, until eventually, such collaboration becomes an institutionalized routine (Cai, 2014). Etzkowitz and Dzisah (2007) assert that universities in the developing countries are incentivized by the government to play a role in economic development, albeit without explicitly mentioning TH. For example, a university mission can drive the interaction with industry (Razak and White, 2015). This justifies our focus on the internal transformation within the universities, to understand how TH interactions can develop in their infancy.

3 Analytical Framework

This research focuses on addressing the pathway towards TH in the Ethiopian context. The empirical analysis of TH helps to comprehend the past, analyze the present and develop a normative approach to identify the organizational innovations that can be "imported, re-interpreted and adapted" to the local context (Etzkowitz; 2003, p. 332). The TH model is suitable to analyze the dynamics within each helix and offers suitable concepts and frames for an independent analysis (Cai and Amaral, 2021). One of the trends in TH, particularly in developing countries, focuses on the role of universities in innovation and the enablers and barriers in their relation to industry, such as in technology transfers (Razak and White, 2015; Ranga and Etzkowitz, 2013) particularly in the management aspect (Sekerbayeva and Tamenova, 2021). Hence,

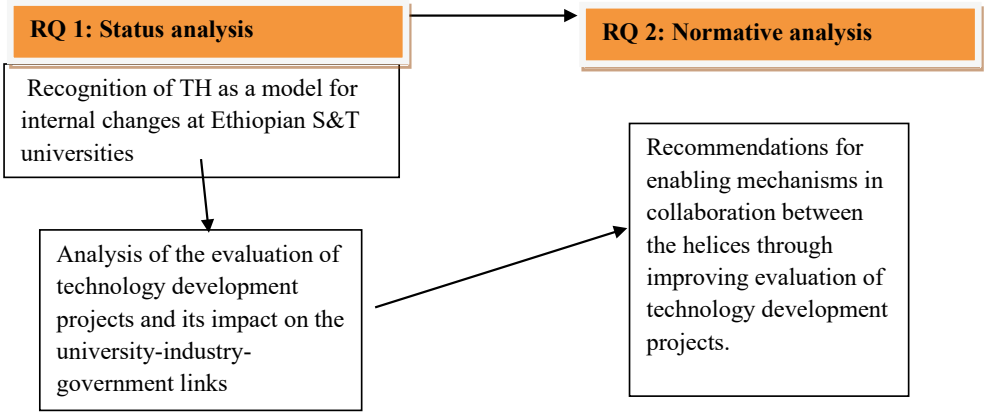

FIGURE 1 Analytical framework

the analytical model builds on the work of Cai and Amaral (2021) who assert that TH as a model can be used to analyze the favorable conditions for TH interactions.

The analytic framework illustrates, firstly, the analysis of the status quo and, secondly, the normative alternative to address the current deficiencies. The status analysis shows on one hand that the Ethiopian government recognized the importance of TH by committing the two universities to adopt missions in line with the TH model. On the other hand, it shows where the bottlenecks are that currently hinder links with industry. The subsequent normative analysis aims to propose solutions to improve the situation, to stimulate innovation by developing TH interactions. Our framework is summarized in Figure 1.

3.1 *Integrating Organization Control Theory (OCT) and the Context, Input, Process and Product (CIPP) into Triple Helix*

The objective of this paper is two-fold: First, to analyze the organizational practice of the two Ethiopian S&T universities and second, to suggest practical recommendations for their internal changes that could drive TH interactions. To operationalize the analysis, two organizational control models are integrated into the TH model. Our framework is based on organizational control theory (OCT; e.g., Johnson 2011, Sitkin et al. 2010) and the context, input, process, and product (CIPP) model, borrowed from evaluation theory in higher education (e.g., Chinta et al., 2016). This approach is in line with the work of Cairney (2013) which suggests a complementary approach to combine insights from multiple theories in public policy. The use of complementary theoretical frameworks stem from our need to apply different concepts at different levels

of analysis. The resulting framework, based on the OCT and CIPP's nexus with TH, helps us interpret the research data, answer the research questions, and formulate practical recommendations. Key complementary components of the combined concepts are explained below.

Organizational control theory (OCT) has been the subject of extensive research for many years. Its classic literature argues that an organization can achieve control in two ways: *outcome-based*, or *behavior-based*, either through the behavior needed to perform a given task, or through the outcome of such behavior (Ouchi, 1977, 1979, Eisenhardt, 1985, Johnson, 2011). The first type of control, behavior-based, involves programmability of tasks that lead to a desired result. It focuses on managing *activities* that turn inputs into outcomes (Cardinal et al., 2004). Nonetheless, a *definition* of the behavior for the specific task is necessary (Johnson, 2011). In contrast, outcome-based control is achieved through setting measurable outcomes (Johnson, 2011; Snell, 1992) that focus on the *result* of a particular process (Cardinal et al., 2004). If an outcome is measurable, outcome-based control is the more viable option; if a task can be programmed, a behavior-based control strategy is more appropriate. If both task *and* outcome are possible to measure, either approach can be applied. However, if *neither* task *nor* outcome can be easily designed, then a completely different strategy is needed. Such a strategy is called a *people-based control* or *clan socialization* (Cardinal, 2001). It implies building shared *goals* and *norms* as a control strategy (Snell 1992, Sitkin et al., 2010).

The OCT can be readily used for technology development in technology transfer offices (Johnson, 2011) and research and innovation context more broadly (Cardinal, 2001). Yet it requires special attention – every technology development involves risks that call for appropriate management (Eldred and McGrath, 1997). For instance, universities usually face accountability challenges, placing emphasis on compliance with financial regulations or output requirements (Kivistö, 2005).

Our second theoretical point of departure is the Context, Input, Process, and Product (CIPP) model, borrowed from evaluation theory (e.g., Christie and Alkin, 2012, Chinta 2016). The foundation of evaluation theory is *accountability*, crucial especially in projects or programs supported by the public and therefore, taxpayers. The CIPP evaluation model conducts evaluations of programs, projects, people, products, organizations, policies, and evaluation systems (Stufflebeam and Coryn, 2014, p. 309). CIPP involves external stakeholders that view evaluation as a holistic system that should go beyond assessing a project's final product (Stufflebeam, 2012). The CIPP model can be broken down into four components: 1. *Context* evaluation, this aims to identify the direct users

of programs or projects, their interests, and hurdles, and set goals suitable for the given environment. 2. *Input* evaluation, this identifies and rates relevant resources to assist decision-makers to prepare for the project's execution, 3. *Process* evaluation, this focuses on the implementation of the project in progress. Finally, 4. *Product* evaluation, this aims to "measure, interpret, and judge the project outcomes" (Stufflebeam and Coryn, 2014, p. 329).

In this paper, we use *control* to describe the overall monitoring approach of the organization and *evaluation* as a specific process taken by the organizations to achieve the control on the projects. The OCT refers to control as a means of "performance evaluation" (Eisenhardt, 1985, p. 135), hence stressing the importance of evaluation in organizational control. The CIPP model focuses on holistic performance evaluation (Stufflebeam and Coryn, 2014). What's more, OCT and CIPP also share complementary features with TH, ones that inspired this micro-level study. First, TH emphasizes the internal transformation of each helical actor (Etzkowitz and Leydesdorff, 1998). Similarly, TH accommodates the idea of building long-term goals strategically at HEIs and introduces the necessity of the measurability of outcomes (Leydesdorff and Etzkowitz, 1996). A shared feature of the CIPP with TH is the interaction with external entities in an organization, as the former supports the use of outside stakeholders in the internal evaluation system (Stufflebeam and Coryn, 2014). Similarly, application of a TH study at the micro-level can be conducted based on a project or specific activity (Brink, 2020), as advised by both CIPP and OCT. Moreover, the CIPP model requires a continuous improvement for an effective outcome (Frye and Hemmer, 2012) and, like TH, stresses the benefits of gradual progress. The contribution of each theoretical perspective to this analysis is summarized in Table 1.

4 Methodology

The main purpose of this study was to conduct the first-ever analysis of the practice of technology development in Ethiopian S&T universities through qualitative, exploratory research (Creswell, 2009). We adopted the case study as our research strategy, as it examines, using a variety of data sources, a phenomenon in its naturalistic context, with the purpose of "confronting" theory with the empirical world (Piekkari et al. 2009, p. 569). We used a qualitative case study's three principal tools – interviews, documents and fieldwork – to explore a new topic in-depth and create a comprehensive, holistic understanding of the case, based on its context (Simons 2009; Yin 2011). The research was conducted inside the universities themselves as "natural settings" (Creswell,

TABLE 1 Comparison of Key Themes in OCT, CIPP and Nexus with Triple Helix

Key theme	Organizational Control Theory (OCT)	Evaluation Theory Context, Input, Process and Product (CIPP)	Nexus with the Triple helix at the micro-level
Application rationale	Measurability of an outcome and/or programmability of a task	Accountability through following a holistic approach of evaluation	Accountability and control are a subsystem of TH
Stakeholder involvement	Internal management conducts control	Internal actors, external stakeholders, and self-evaluation	Continuous internal transformation of each actor resulting in taking the role of the other crossing organizational boundaries
Process outcomes	Offers control alternatives for internal control system	Continuous improvement of system	
Technology development project as an object of control	Technology development projects	Program, project, and task-level evaluation	Application of a TH study at the micro-level of projects or specific activities

2007, p. 39). Our approach was to carry out a multiple case study analysis, in which two bounded cases were purposefully selected to develop a deeper understanding of a task, method, or program (Creswell, 2007). The unit of analysis was the technology development evaluation process at two research sites, ASTU and AASTU, namely, their OTT (responsible for the technology development initiatives).

The data was originally acquired within the scope of the first author's master thesis, submitted at Tampere University, Finland (Liche, 2021), and simultaneously extended to the collaboration with the second author. The data comes from several sources. Firstly, data was collected through semi-structured interviews (Roulston and Choi, 2018) in 2021. The research participants were carefully selected among individuals with first-hand experience about the technology development process and evaluation in ASTU and AASTU. Due to the relatively small number of projects and officials, a diverse set of potential interviewees was considered (Creswell, 2012). The interviewees were selected from university staff who participated in the OTT projects as developers,

administrators, and other staff. The final interviewees included three OTT officials, three finance and procurement officials, 14 technology developers (five from AASTU and nine from ASTU), and three university-level officials (two from top management and one administrator involved in the transition of the two universities to S&T universities in 2014/2015). In total, 23 participants were interviewed for this research project. Seven potential research participants (four technology developers in AASTU and three in ASTU) could not be reached because they had left the universities. The interviews were conducted in Amharic language at the premises of ASTU and AASTU and each interview took 25 to 45 minutes based on the stage of the technology development process (i.e., ongoing, or complete). The list of all OTT-funded projects – altogether 14 – was compiled, using available data from both universities. Their overview is in Table 2.

TABLE 2 List of projects funded by ASTU and AASTU's OTTs since 2015

Nr	Project	University	Project description
1	Three–wheel electric vehicle	ASTU	Taxi service in the city of Adama is dominated by three-wheeled vehicles. The project aimed to replace these gasoline-powered cars with electric ones.
2	Energy saving *Mitad* baking machine	ASTU	*Mitad* is a machine commonly used to prepare *injera*, Ethiopian traditional bread, in almost every household. By modifying the machine's components, the project aimed to significantly reduce the machine's electricity consumption in comparison to existing machines.
3	Plastic recycling machine	ASTU	The objective of the project was to develop a machine to recycle a vast quantity of plastic waste for reuse.
4	Big capacity brick-making machine	AASTU	Current available machines produce few bricks at once. This project attempted to replicate Chinese machines that produce simultaneously multiple bricks.
5	COVID-19 ventilators (1)	AASTU	Two projects were initiated to develop ventilators for COVID-19 treatment using different designs with teams of various professional backgrounds.
6	COVID-19 ventilators (2)	AASTU	

7	COVID-19 tracking software	ASTU	This software was developed to gather regional data of COVID-19 patients and their distribution in the population.
8	Mechanical welding and Pressing machine	ASTU	The goal was to develop a machine that can substitute similar machines imported from abroad with multiple features of welding and pressing.
9	Sign language interpreter	AASTU	This project was designed to build a computer program to interpret sign languages to help people with hearing disability in communication.
10	Home security system	ASTU	This project attempted to copy a "doorbell" technology by adding context-based features.
11	Tuberculosis x-ray technology with mobile application	AASTU	The project developers identified a deficiency of Tuberculosis x-ray readers for initial diagnosis in rural and small-town settings. This method utilized a mobile application to transfer x-rays to experts in large hospitals.
12	Agricultural produce Harvesting machine	ASTU	The project intended to address the wastage during harvest. Ethiopian farmers mostly use manual harvesting which is time-consuming. Moreover, unexpected rain can damage the whole harvest on the field. Machines imported for harvesting are highly expensive for household farmers. This project intended to design convenient machines for farmers to collect their agricultural produce more easily.
13	Material property testing equipment in mechanical engineering labs	ASTU	Imported and expensive material property testing devices in laboratories are available rarely in the market. Consequently, the team intended to construct the machine for universities and other users by duplicating comparable technologies.
14	Learning management system	ASTU	During Covid-19 pandemic, the project aimed to build an online learning management system for teaching and faculty meetings.

Interviews were accompanied by analyzing comprehensive university and governmental documentation to triangulate the findings (Flick 2004). These included official documents, newspaper articles, government documents and official proclamations, various university documents including public mission and strategy statements and internal documents regarding the functioning of the OTT, technology development proposals and contractual agreements between technology developers and OTT. The documents were viewed as "products" of the two universities, representing their views, and reflecting their social reality (Coffey and Atkinson, 2017). Finally, we relied on a prolonged engagement of the first author in the field (Welch and Piekkari, 2017) as he has an in-depth understanding of the setting, he is of Ethiopian origin and familiar with local culture and languages. He is a long-term employee of ASTU, although not working for the OTT, and not involved with technology development. His proximity to the research sites is primarily a source of insight, not bias (Welch and Piekkari, 2017). Subsequently, the data were coded following the analytical framework, and categorized according to themes, with a focus on core issues in the two cases (Creswell, 2007, p. 75). The data were subsequently analyzed using thematic analysis. This involved taking both code repetition and context interpretation to overcome the limitations of content analysis, which is entirely dependent on the frequency with which codes are repeated by the research participants to interpret data (Joffe and Yardley, 2004).

5 Research Findings

5.1 *Current Approach: Triple Helix and Technology Development Evaluation*

In Ethiopia, the recognition for TH as an approach was first attested by hosting a Triple Helix Conference in 2006 (Etzkowitz and Roest, 2008). High-level policies such as the GTP highlighted the role of higher education in economic development, mainly through the development of S&T (Eckl et al., 2017). The government established the two S&T universities and the accountability relationship of the two HEIS towards the government were set forth in proclamation (Federal Negarit Gazette, 2014; Federal Negarit Gazette, 2011). The two universities stated their commitment to link with industry, in line with the fundamental tenets of TH: ASTU's mission statement claims to undertake "demand-driven research and community service … providing innovative knowledge to support the nation's socio-economic development" (ASTU, 2020b). AASTU makes a comparable commitment, which is "conducting applied

research to support productivity and competitiveness of industries (…) serving as a center for knowledge and technology adaptation, innovation, and transfer" (AASTU, 2021b). Both mission statements pledge to solve local problems by targeting local needs; a typical characteristic of developing countries' TH goals (see Dzisah, 2011; Razak and Saad, 2011). To sum up, the two S&T universities embraced a particular mission, one that can be accomplished using the TH approach, but they also placed a heavy emphasis on accountability and evaluation, as essential components to the management of technology development projects.

5.3 Outcome-based Control on Evaluation: a Barrier to Triple Helix

To answer our first question on how the two universities evaluate technology development process, let's start with a brief outline of the hierarchy. Two ministries oversee the two S&T universities: the Ministry of Education (MoE[1]) and the Ministry of Finance (MoF). The MoE requires the universities, including their respective OTT, to submit periodic reports on the number of launched, completed, and "transferred" projects. In other words, MOE practices outcome-based control. Concurrently, the Ministry of Finance (MoF) provides funding for the university, including financing for the OTT projects. The MoF supervises the fund and budget utilization of all federal institutions, including universities. Its financial supervision demands that universities' finance and procurement departments within institutions rigorously monitor compliance with MoF regulations. In other words, it practices strict behavior-based control. These characterize the relationship between government and universities – the government sets accountability through control based on *both* outcome and behavior.

In TH, technology transfer is an important channel for universities and industry to interact (e.g., Ranga and Etzkowitz 2013). Since their inception, the OTTs realized 14 projects (nine in ASTU, five in AASTU). To connect with industry, the OTT aimed for two outcomes: 1. the development of prototypes and 2. their transfer to industry, through commercialization (OTTCS 2017; VPRTT, 2013). However, our findings show neither objective materialized, and at the end of each OTT-funded project, the prototypes were not developed to a level of maturity that would allow them to be transferred. The reason was the conflicting control strategy of the OTT: The OTTs utilized outcome-based

1 Due to ongoing reforms in the Ethiopian higher education system, the two S&T universities were governed by the Ministry of Science and Technology (2015–2018), then the Ministry of Science and Higher Education (2018–2020) and finally, the Ministry of Education since 2020–2021.

control on prototype development (expecting a mature prototype at the end of a project). At the same time, behavior-based control was applied to the budget utilization. This was a control strategy acquired from the two overseeing ministries, MoE and MoF. This meant technology developers were required to submit both the expected outcome of their project *and* the budget breakdown, at the very start of their project. The finance and procurement offices of the universities supervised the budget utilization in accordance with MoF requirements. The technology developers were required to construct a prototype based on their initial estimates, and they had little to no room to deviate from their budgetary projections.

Furthermore, the agreement documents between OTTs and technology developers stipulated that the final product must be delivered *upon full budget utilization*. According to the research participants, this meant they had to meet "measurable" targets. These outcome-based indicators included goals such as "minimizing energy consumption", "lowering carbon emissions", and "attaining a particular processing capacity per unit of time" for a new technology. Project proposals also included impact outcomes, such as the development of "low-cost" and "import-substituting technologies". In addition, the same documents outlined measurable objectives such as "saving foreign currency", "creating a specified number of employment opportunities" and developing technologies with "custom functions" to meet local needs.

However, this approach was more effective on paper than in practice. Some of the interviewees stated that such outcome goals were measurable in theory, but not in reality. They encountered frequent deficiencies in skills, experience, infrastructure, as well as access to resources. For instance, one of the ASTU projects was to develop a local *mitad* (a baking machine commonly used to prepare *injera*, Ethiopian traditional bread), a product with low-energy consumption. But the lack of quality input materials complicated the development of an efficient prototype. The final product could not reach the target of "lowering energy consumption". Additionally, quality problems arose – namely unequal power distribution on the surface of the prototype, which caused the *injera* to bake unevenly. In the end, the *mitad* project used up all the budget, but it was not transferred out of the OTT and did not reach the community through commercialization.

The technology developers often lacked the technical expertise, knowledge, and capacity to create functional prototypes. Participants explained that it was technically difficult for them to duplicate imported technologies – a strategy that the OTT supported. As one interviewee stated, "the project tested my ability to translate theory into practice". He added that "lack of expertise" in the process of technology development was the primary bottleneck and the

reason for failure to develop a complete prototype of the technology. Other interviewees cited a lack of experience and knowledge regarding the properties of input materials, to develop the prototype they had promised to deliver in their project proposal. These factors made it difficult to achieve the "correct" outcomes, as required by their contracts. Such variables, which Rasmussen and Gulbrandsen (2012) refer to as *outcome uncertainty factors*, were not considered in a purely outcome-based control approach.

Thus, waiting for the perfect prototype was an obstacle for the OTT to connect with the local industry. The research participants deemed the OTTs' demand to measure impact-related objectives *before* the technology was transferred to its possible end users as impractical. Even when they established a proxy to assess output beforehand, it was insufficient. In the end, no technology was transferred from OTT to industry, even if some projects were dubbed as "complete". In other words, the control system only based on outcome made it harder to finish and transfer the projects.

5.3 *Behavior-based Control: a Budgetary Straitjacket for Developers*

The outcome-based control system was exacerbated by behavior-based budget utilization control. The technology development project evaluation focused on the final *product*, in combination with controlling budget utilization during the process. The OTT's contractual agreements with technology developers stipulated that the developers should abide by the financial proclamation of the Federal Government of Ethiopia and directives from the MoF. In similar fashion, the contractual agreement documents signed by ASTU OTT and project developers indicated that "the initiator is obligated to show that the project's outcome is commensurate with the budget utilized". The financial departments of the two universities used the MoF's categories to create a budget breakdown for each project, including the OTT's technology development, and then reported it back to the MoF. Like a line-item budgeting system (Newman, 2013), this is a behavior-based control method (Schillemans and Bjurstrm, 2020, Kivistö, 2005).

Nonetheless, this strategy was once again at odds with the reality of producing new technology in Ethiopia's resource-scarce environment. As one participant summarized it, "the financial rules and regulations that govern the procurement process of a student cafeteria are the same ones governing research and technology transfer projects". The budgetary regulations are implemented uniformly across all federal entities in Ethiopia. This clashed with the flexibility, necessary for the technology development. Top-down regulatory constraints prevented the developers from adjusting their initial budget estimates, essential to manage the dynamic process. The government's

tight financial control and procurement procedures also restricted developers from obtaining (foreign or domestic) high-quality materials. Even though the projects were technically completed because they ran out of the budget, their results were not used by local industry. Although OTT officials and technology developers asserted that the industry was expected to take over their prototypes and commercialize them, they encountered little demand. As one interviewee put it: "The industry can import technologies from abroad rather than commercialize the less matured technologies we develop". What's more, the Covid-19 pandemic exacerbated the shortcomings. The OTTs gave priority to projects which addressed pandemic-related societal challenges, and the MoE urged the two universities to develop innovative technology to lessen the impact of the pandemic in Ethiopia. As a result, the OTTs funded projects to produce locally scarce (and hence expensive) items such as ventilators. However, after exhausting their entire budget, locally developed ventilators were still not ready for use. The developers lacked technical expertise, which was aggravated by a lack of materials, required components, and insufficient laboratory facilities.

Due to the aforementioned factors, it was not possible to measure the *actual outcome* of technology development. Even though projects were concluded as "complete", the reality was that the prototypes were nowhere near completion, let alone ready for manufacturing or commercialization. The ASTU and AASTU staff acknowledged the shortcoming. As one OTT official put it, "it takes time for the developed technologies to be perfect outputs". Additionally, both university officials and technology developers admitted that strict financial supervision was causing project delays, interruptions, and ultimate prototype failure. Yet, the universities' relevant officials had no choice but to abide by the MoF regulations. In other words, the control system was incapable of accommodating the dynamic process technology developers faced on the ground, which was clouded with uncertainty at every step on their way.

5.4 *The Pathway to Triple Helix: Internal Transformation*

This section investigates how the current approach can be improved to encourage TH interactions. The TH model recognizes that the process of technology development is inherently fraught with unpredictability (Rantala et al., 2021). As demonstrated above, the challenge the OTTs faced was the unfortunate combination of outcome-based and behavior-based control. This complicated the developers to achieve project targets and for OTTs to receive, and subsequently transfer, prototypes useful for local industry. During the process, the developers lacked a support structure to address their lack of skills, knowledge,

and infrastructure. Since the landlocked country still counts as one of the least developed, such gaps are hardly surprising.

As this issue was exacerbated by the tight financial control, universities should allow greater budget utilization flexibility. Technology development should take precedence over rigid financial utilization oversight which should abandon the strict behavior-based control. However, given the MoF and MoE regulatory requirements on all Ethiopian universities, we are cognizant of the limitation of this recommendation. But, to encourage more bottom-up innovation, at the very least, it should be acknowledged that the status quo fits neither the mission of universities nor the local context.

Nevertheless, some adjustments are feasible within the universities' decision-making authority. At the OTT level, greater focus should be placed on addressing the developers' missing skills, and overall infrastructure. This can be accomplished by employing a *people-based* control strategy. In organizations where neither behavior-based control nor outcome-based control is viable, the management should foster *clan socialization* to establish shared goals (Johnson, 2011; Ouchi, 1979). Therefore, a people-based control strategy could gradually help reduce the uncertainty factors during the process. The OTTs should not focus merely on evaluating the final product. More inclusive approach is essential for addressing shortcomings in human and financial resources, as well as gaps in knowledge and infrastructure (Stufflebeam and Coryn, 2014). Therefore, we argue for the necessity of incorporating an evaluation not just of outcomes, but also of context, inputs, and process.

Another feasible way of linking the OTT with industry is ensuring the OTT-funded developers interact with the industry at an early stage of their project. The CIPP recommends involving external stakeholders who can express their needs in a task or project. In Ethiopia, these should mostly come from industry, technology development organizations and the higher education sector. External partners can assist bridging the gaps in skills and infrastructure; developing collaboration with them can help the OTT foster TH interaction. By bridging skill and competence gaps during the process of project development, external actors can take the role of the other (i.e., universities). By involving the local industry early on in the evaluation process (identifying their problems and needs), the connections can gradually evolve, which is what Ranga and Etzkowitz (2013) referred to as "creating new technologies and building new ways of interaction". Our recommendations are summarized in Table 3.

These recommendations can bring a gradual improvement in the OTT's interaction with its external environment, which can bring a systemic change. Eventually, the modified process can enable the two S&T universities to

TABLE 3 Recommendations for Internal Transformation of the Technology Development Process as the Pathway to Triple Helix

No.	Theoretical underpinning	Contribution	Potential condition for TH interactions to emerge:
1	Introduce clan socialization to slowly build up a system of shared goals (OCT)	Tackle outcome uncertainty factors during the process	Universities can effectively be as a source of innovation, Continuous improvement of an internal process of technology development
2	Introduce external stakeholders to evaluate the process of technology development (CIPP)	Involve industry and other relevant actors during the process to change the juncture of the relationship with industry, and help them bridge gaps in skills and resources	Industry and university collaboration to fill skill and expertise gaps and in the process take the role of each other, Continuous, gradual improvement of the system, A bottom-up feedback mechanism on finance and procurement for the government
3	Introduce context and input into the evaluation to understand the environmental conditions (CIPP)	Involve external stakeholders in identifying the needs of the industry, Incorporate them in the evaluation of projects	A collaborative relationship to emerge in identifying innovation needs and project evaluation, Collaboration with external stakeholders (industry, other HEIs and technology-related organizations)

become a source of new technology production (Cai and Etzkowitz, 2020; Leydesdorff and Meyer, 2006). The new evaluation approach can keep on improving the whole system. Such management solution at an early stage of technology development can enable transfer mechanisms that developing countries lack (Zhang et al., 2018). As Etzkowitz (2003) asserts, taking the role of the other is relevant where there is a gap in performance of one actor over the other. By gradually supporting such interactions, new TH relationships could eventually flourish. The OTTs should commence a continuous interaction between the three spheres at the micro-level, thus paving the ground for a possible stimulation of a circular collaborative relationship. These intrinsic alterations could gradually lead to a system-wide evolution.

6 Conclusion

This article addressed two questions, namely, how Ethiopian S&T universities evaluate the technology development process, and how the evaluation could be improved to stimulate TH interactions. Internal transformation is crucial as the initial stage of moving towards TH (Etzkowitz 2003) and it can be induced by organizational change (Cai, 2020). Our findings show that the current system employs both a behavior-based budgeting control and an outcome-based evaluation control. The universities should change the current practice, which is attempting to develop mature prototypes first and collaborating with the industry afterward. Instead, we propose that the universities' link with local industry could be improved by adopting a three-pronged approach: 1. Develop a people-based control system (clan socialization) by gradually building an internal and external support system for technology development. 2. Take a broader approach to evaluation that goes beyond assessing the product, and also incorporate context, input, and process as evaluation components. 3. Include outside experts from the industry at every stage of the technology evaluation. We created the recommendations with the understanding that any change would require official government authorization. This is important because the TH is enhanced by a planned, systematic set of actions and ongoing support from outside stakeholders (Etzkowitz and Leydesdorff 2000).

Our research has both theoretical and empirical contributions. The organizational environment was analyzed by a novel analytical framework, combining the OCT and CIPP into the TH. Additionally, this study adds to an empirical understanding of Ethiopian higher education's interactions with the industry and the government. In this regard, our findings confirm prior studies regarding TH in developing countries of the global south which is characterized by poor interactions between the three spheres, and a lack of local knowledge, experience, and skills (e.g., Razak and Saad, 2011, Mêgnigbêto, 2019, Fussy, 2019). As a result, our research contributes to the critically needed context-based literature on TH, in Africa in particular.

However, there is a significant need for further research in the context of Ethiopia's rapid development. This paper is limited to the practice inside two universities, therefore, we invite further studies to add to the findings, e.g., by analyzing the industry stakeholders' perspective. Furthermore, the massification and expansion of higher education in the East African landlocked country necessitate additional research into the ongoing reforms regarding the financing of technology development and transfer, efforts to close the skills gap, and support for university-industry ties. Finally, more studies will be necessary to evaluate the effects of the civil conflict in the Tigray region (and the resulting

political instability) on higher education and economic development. Our research also found distinctive characteristics of the OTT's efforts during the COVID-19 pandemic. In the context of the two S&T universities, the pandemic highlighted the necessity to accelerate the role of universities in technology development, especially because certain technologies became too difficult to obtain internationally. As stated by Da Silva et al. (2021), in the post-pandemic era, countries should strengthen their internal innovation and home-grown technical development capacities, but more research is required. We are pleased to bring the experiences of the two Ethiopian S&T universities to light, and hope our research can contribute to a growing understanding of how innovative university-industry partnerships can be nurtured in their infancy.

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