African Journal of Science, Technology, Innovation and Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rajs20

Technology management practices and innovation: Empirical evidence from medium- and large-scale manufacturing firms in Ethiopia

Mesfin Mala Kalko, Obsa Teferi Erena & Sara Adugna Debele

To cite this article: Mesfin Mala Kalko, Obsa Teferi Erena & Sara Adugna Debele (2022): Technology management practices and innovation: Empirical evidence from medium- and large-scale manufacturing firms in Ethiopia, African Journal of Science, Technology, Innovation and Development, DOI: 10.1080/20421338.2022.2040828

To link to this article: https://doi.org/10.1080/20421338.2022.2040828

Published online: 27 Mar 2022.

African Journal of Science, Technology, Innovation and Development, 2022
https://doi.org/10.1080/20421338.2022.2040828

Technology management practices and innovation: Empirical evidence from medium- and large-scale manufacturing firms in Ethiopia

Mesfin Mala Kalko [1], Obsa Teferi Erena [2] and Sara Adugna Debele [2]

[1]*Faculty of Management and Economics, Tomas Bata University in Zlin, Mostni 5139, Zlin 760 01, Czech Republic*
[2]*College of Business and Economics, Hawassa University, P.O.Box: 05, Hawassa, Ethiopia*
**Corresponding author email: kalko@utb.cz*

In order to investigate empirically the effects of technology management on firm innovation, this paper considers the antecedents and multidimensional views of technology management mechanisms on innovation performance in medium- and large-scale manufacturing firms in a developing country, namely Ethiopia. Using simple random sampling, a total of 200 firms were chosen for this study to obtain responses from respondents. Four hypotheses were proposed for testing. Structural equation modelling and cross-sectional design were used to analyze the data using the LISREL 8.80 SIMPLIS program software tool. This study finds technology transfer and technology acquisition have significant positive effects on process innovation, product innovation, and method innovation. Technology process has a significant positive effect on process and method innovation. Technology absorption has a significant positive effect on product innovation. The major implication of this study is that technology management, coupled with appropriate technology management policies and strategies, is an appropriate resource to be used in the organization to enhance firm performance, particularly innovation and creativity. The paper contributes to the literature in that, unlike previous studies that are based on one aspect of technology management practices, this study examined the effects of each different type of technology management dimension on firms' innovation. Thus, this study helps to gain further insights into the effects of technology management practices on firm innovation.

Keywords: technology management, innovation, structural equation modelling, manufacturing firms, Ethiopia

Introduction

Technology management is defined as the cross-functional operations core competency of designing, managing, and integrating a firm's technological fundamentals to create a competitive advantage (Utterback 1971). Hitt, Ireland, and Lee (2000) recommend that technology advance is the main factor of firm performance in the twenty-first century. Hung and Chou (2013) reveal that technological innovation is one of the most important factors for a firm to enhance its performance in the current global industry. Hsu et al. (2014) confirm that technology management positively influences innovation. In addition, regardless of the industry in which they operate, innovative firms are more likely to enjoy revenue growth (Thornhill 2006). Ortega (2010) evaluates the positive role of technological capabilities in moderating the relationship between competitive strategies and a firm's performance. Building technological or innovative capacity requires a huge amount of resources (human and financial) and takes a long time to attain the optimum benefits. However, if a firm needs to operate a business (deliver products or services), there is no alternative but to elevate its technological innovation capability through investing in research and development, learning, and exploiting existing or new knowledge. Furthermore, as competition in global markets becomes more intense and frequently driven by technology, technological knowledge may become even more important for firms with global ambitions (Boudreau et al. 1998).

The innovative capacity of a firm usually reveals the extent of its competitiveness at the national or international level. The mode of foreign technology procurement also determines the firm's innovative capacity and performance. Nevertheless, acquiring external technology alone is not enough to increase productivity. It needs to be changed, modified, improved and conceptualized locally to promote innovation. In this regard, empirical evidence (Wakeford et al. 2017; Oqubay 2018; UNDP, 2018; Chebo and Wubatie 2020) confirms that the Ethiopian manufacturing sector is characterized by low technological know-how, a shortage of skilled labour, a lack of industry knowledge, a low rate of technological products and innovation, weak inter-and intra-sectoral linkages, and weak links with universities and research institutions. In addition, the World Economic Forum's (2019) Global Competitiveness Index report ranked Ethiopia 126th out of 141 economies, suggesting that the sector needs enormous structural changes in terms of technological capacity, innovation, organizational learning, leadership, and corporate governance in order to be competitive both in national and international markets. As a result, the issue of what empowers innovative activity and later enhances firm performance in Ethiopian manufacturing firms continues to be on the research agenda. The World Bank's (2014) report on doing business however confirms that Ethiopia has better ease of doing business and an innovative environment for industrial development than many other African countries. It recommends that improvements in this regard should be coordinated with R&D and skills development to foster technological investment at the firm level. The United Nations report (2015) also supports

African Journal of Science, Technology, Innovation and Development is co-published by NISC Pty (Ltd) and Informa Limited (trading as Taylor & Francis Group)

the idea that no industrial policy is complete without an accompanying innovation policy.

There have been few studies on the relationship between technology management practices and innovation. For example, Hussen and Çokgezen (2019) analyzed the external factors of firm innovation in Ethiopian manufacturing firms. Kang, Jo, and Kang (2015) used a binomial regression model to evaluate whether external technology acquisition is complementary or substitutive to internal research and development operations and activities in South Korean firms. García-Vega and Vicente-Chirivella (2020) applied propensity score matching techniques to investigate the influence of technology transfers on firm innovativeness in Spanish firms. Lim (2004) analyzed the effects of basic and applied research on innovation in semiconductor and pharmaceutical firms worldwide. Cepeda-Carrion, Cegarra-Navarro, and Jimenez-Jimenez (2012) also examined the association between absorptive capacity and company innovativeness in large Spanish companies. However, most of these studies focused on a single aspect of technology management practices and on developed economies, leaving a gap regarding other dimensions of innovation and developing economies. This study attempts to fill that gap in the literature by examining the effects of each different type of technology management dimension on firms' innovation using structural equation modelling in medium- and large-scale manufacturing firms in Ethiopia. Thus, this study helps to gain further insights into the effects of technology management practices on firm innovation.

In the current study, technology management (introduced as the independent variable) is represented by four constructs, namely: technology process, technology acquisition, technology absorption, and technology transfer. Innovation is introduced as the dependent variable and operationalized by three construct variables, namely: process, product, and method innovation. This study contributes to the theoretical notation that technology is a source of competitive advantage, which is achieved through encouraging technological innovation. Technology management is an essential strategy that helps firms identify, select, acquire, exploit, and protect technology (Gregory 1995; Durrani et al. 1998). However, it would be challenging for firms characterized by low-skilled human resources, insufficient know-how about technology, and inadequate investment in R&D because the technology base cannot be built in a one-off process; rather, it takes time and huge capital investment. Like other scientific research, this study has certain limitations that are addressed in forthcoming research projects in the area. First, the sample size used is not large enough, as structural equation modelling requires a large sample size to test the hypothesis. Second, most of the items applied to measure technology management constructs and innovation constructs have been designed by researchers, so further investigation needs to be performed to ensure the validity and reliability of the items in different countries. Finally, we used one-time data to test the conceptual model. Future researchers should use more comprehensive data consisting of time series and cross-sectional data to examine the impact of technology management on innovation in depth.

The remainder of the paper is organized as follows. The next section provides an overview of the relevant theoretical framework and hypothesis development on the subject. This is followed by a section that describes the research methodology. The section thereafter presents the results of the study. Findings are discussed in the penultimate section. Finally, the last section concludes the results and discussions.

Conceptual framework and hypotheses

Researchers have investigated and identified technology management mechanisms, namely, technology process (Henard and McFadyen 2005), technology acquisition (Tsai and Wang 2007), technology absorption (Fosfuri and Tribo 2008; Lichtenthaler 2009; Pradana, Pérez-Luño, and Fuentes-Blasco 2020), and technology transfer (Rajan, Dhir, and Sushil 2021) that are crucial to the entire value creation (i.e., antecedents) and enhance innovations in the organization. Prior literature on the relationship between technology management and firm innovation is large, but most studies focus on a single aspect of technology management practices (see Guan et al. 2006; Cepeda-Carrion, Cegarra-Navarro, and Jimenez-Jimenez 2012; Kang, Jo, and Kang 2015; Lin, Qin, and Xie 2020, among others). This study intends to fill this gap in the literature by examining the effects of each different type of technology management dimension on firms' innovation. Thus, this study helps to gain further insights into the effects of technology management practices on firm innovation.

Technology process

This study defines the technology process as an ordered sequence of steps that a company follows and implements in investing in basic and applied research initiatives to encourage creativity, innovation, and firm performance and maintain a continued competitive advantage. Prior studies (e.g., Henard and McFadyen, 2005) have indicated that investments in applied and basic research were crucial for innovative research initiatives. Firms that rely on a continuous flow of product innovations to provide a stable income source should generally invest in applied research initiatives. Further investments in directed basic research initiatives will increase future applied projects and constitute a sustainable competitive advantage (Henard and McFadyen 2005). The theoretical underpinning of the relationship between the technology process and innovation is based on the perspective of knowledge creation theory (e.g., Cohen and Levinthal 1990; Simon 1991; Nonaka 1994), which states that knowledge is formed or created via the sharing and combining of information and ideas (which are fundamental premises of applied and basic research initiatives) through exchange interactions (Simon 1991; Nonaka 1994), which in turn, facilitates the creation of new knowledge, and ultimately, new products, and enhances innovative activities. Prior studies (Nelson 1959; Aghion and Howitt 1996) pointed out that fundamental advances in technological knowledge occur through basic research, which in turn, opens up doors for subsequent research. This basic research helps applied research build upon it, allowing these opportunities to be realized. In a similar spirit, Akcigit, Hanley, and Serrano-Velarde (2020) indicated that although basic research appears to command a significant premium over applied research, both basic and applied research contribute to firm productivity and generate spillovers that influence subsequent innovation within a specific industry. Furthermore, Belderbos, Kelchtermans, and Leten (2021) find a positive relationship between internal basic research and a firm's innovative performance. The authors further suggest that by investing in basic research, firms can use both internal and external scientific knowledge as a map for technology developments. On the basis of this theoretical and empirical evidence, we hypothesize that:

H1: The technology process is positively linked to innovation.

Technology acquisition

External technology acquisition refers to a company's attempts (activities) to gain access to technical knowledge located outside of its borders (Cassiman and Veugelers 2006; Tsai and Wang 2008). Similarly, Vanhaverbeke, Duysters, and Noorderhaven (2002) and Hoegl and Wagner (2005) defined external technology acquisition as the process of absorbing technologies from outside sources, such as through in-licensing or strategic alliances. The theoretical basis for supporting the association between technology acquisition and firm innovation is based on the perspective of the transaction cost theory (Williamson 1975, 1991) and the knowledge-based view (Grant 1996). Transaction cost theory posits that the decision to acquire technology from outside their boundaries leads to a higher return on investment, lower costs, increased flexibility, access to specialized skill sets, and creativity (i.e., the relative costs of developing internally in relation to buying a technology). According to the knowledge-based view, a firm gains a competitive advantage through exploring, exploiting, and integrating different specialized skills and knowledge through external technology acquisition and internal research and development activities.

Prior studies on the relationship between technology acquisition and innovation indicate indecisive findings. One stream of literature finds technology acquisition is positively associated with innovation, whereas other studies indicate no such linkage. Some studies (see Vanhaverbeke, Duysters, and Noorderhaven 2002; Calantone and Stanko 2007; Montoya, Zárate, and Martín 2007; Jeon et al. 2015; Charmjuree, Badir, and Safdar 2021) confirmed a positive relationship between technology acquisition and innovation. Calantone and Stanko (2007) indicate that external technology acquisition has been regarded as a vital competence for long-term product and process innovation success. They further indicate that firms have increasingly sourced technology beyond their borders in order to decrease development time and costs, share risks, and access expertise not accessible in-house because of increasing technological complexity, shorter product life cycles, and rising technology development expenses. Jeon et al. (2015) also found a positive relationship between external technology acquisition and innovation performance in US pharmaceutical industry. External technology acquisition, as indicated by inward technology licensing, has a positive impact on the firm performance of high-technology firms in Taiwan, especially when the level of the firms' internal research and development (R&D) efforts increases, and is, thus, in turn, viewed as an important strategy adopted by firms to achieve/foster innovation (Tsai and Wang 2007). Firms can better cope with the increasing speed, cost, and complexity of technological developments by obtaining and acquiring technologies from outside sources (Vanhaverbeke, Duysters, and Noorderhaven 2002). This practice of acquisition can increase a company's technological capacity, resulting in long-term performance advantages over competitors (Montoya, Zárate, and Martín 2007). Furthermore, using data from a sample of Spanish manufacturing firms, Nieto and Santamaría (2007) revealed that technological collaborative networks with different partners (except competitors) positively influence the degree of novelty in product innovation. In addition, Charmjuree, Badir, and Safdar (2021) also indicate that both external technology acquisition and external technology exploitation have a positive effect on a firm's process innovation performance in small- and medium-sized software development firms in Thailand. Conversely, Tsai and Wang (2009) found external technology acquisition, as indicated by inward technology licensing, does not improve innovation performance in low- and medium-technology firms in Taiwan. Kessler et al. (2000) indicated that a firm that spends a lot of time and money on knowledge integration for better technological innovation may lose its competitive advantage if it is more active in internal R&D and, at the same time, outsources more R&D. Thus, we posit that:

H2: Technology acquisition is positively associated with innovation.

Technology absorption

Absorptive capacity is the ability of firms to perceive the importance of new information, assimilate it, and apply it to business goals (Cohen and Levinthal 1990, 128). In a similar fashion, Lewin, Massini, and Peeters (2011) and Zahra and George (2002) defined absorptive capacity as a company's ability to use external knowledge through the acquisition, assimilation, transformation, and exploitation phases of organizational learning processes. It is a key driver of a firm's competitive advantage (Lichtenthaler 2009). The theoretical foundation for the relationship between technology absorption and innovation is based on organizational learning theory, which states that firms should be able to perceive and recognize the value of new knowledge, assimilate that knowledge, and apply it to value creation in order to innovate (Cohen and Levinthal 1990; Todorova and Durisin 2007).

Existing research (see Becker and Peters 2000; Kostopoulos et al. 2011; Pradana, Pérez-Luño, and Fuentes-Blasco 2020; Pinheiro et al. 2021) has found a positive relationship between technology absorption and innovation in manufacturing firms. For instance, Pinheiro et al. (2021) indicate a strong, positive, and direct effect of absorptive capacity on innovation (both exploitative and exploratory) competencies in Portuguese manufacturing firms. Becker and Peters (2000) also found a positive relationship between absorptive capacity and innovation output in German manufacturing companies. Kostopoulos et al. (2011) indicated that absorptive capacity serves as a means to attain superior innovation and financial performance over time and translate external knowledge inflows into tangible gains in manufacturing and service firms in Greece. Using a sample of 138 Spanish companies from the wine industry, Pradana, Pérez-Luño, and Fuentes-Blasco (2020) found that absorptive capacity allows firms to fully capture the benefits of innovation.

In a similar vein, Cohen and Levinthal (1989) indicated that absorptive capacity assists firms in identifying and exploiting useful external knowledge from universities, government laboratories, and competitor spillovers. This exploitation capability assists the company in converting knowledge into new products (Gao et al. 2008). Using data from 246 Spanish technological firms, Garcia-Morales, Ruiz-Moreno, and Llorens-Montes (2007) also pointed out that absorptive capacity facilitates changes in R&D investment, organizational culture, interaction mechanisms, and other factors, all of which have a great influence on organizational innovation. Furthermore, Kneller and Stevens (2006) state that the firm's capacity to absorb new technology impacts innovation. On the basis of this theoretical and empirical evidence, we hypothesize that:

H3: Technological absorption is positively linked with innovation.

Technology transfer

Technology transfer is a deliberate, goal-oriented interaction between two or more social entities during which the pool of technological knowledge remains stable or grows when one or more constituents of technology are transferred (Autio and Laamanen 1995). Similarly, Appiah-Adu, Okpattah, and Djokoto (2016) defined technology transfer as the process of transferring novel methods, technologies, inventions, and specialized technical abilities and skills from one organization to another to foster creativity, innovation, and firm performance. To assure the production of new products and services, organizations must identify and manage technology transfer operations and activities (Bozeman 2000). Any technology transfer has the primary goal of introducing new technologies and processes, improving existing technologies, and developing new knowledge (Hsiao et al. 2017), all of which are thought to encourage organizations to innovate (Masa'deh, Obeidat, and Tarhini 2016; Novickis, Mitasiunas, and Ponomarenko 2017). The relevant theories underlying the relationship between technology transfer and innovation are the knowledge-based view and organizational learning perspectives, which state that technology transfer requires transmission of knowledge as well as knowledge absorption and use (Davenport and Prusak 1998). Prior studies (Lichtenthaler 2005; Lichtenthaler and Ernst 2007; Cinar et al. 2021) found a positive relationship between technology transfer and innovations. Lichtenthaler (2005) indicated that technology transfer has a positive influence on innovation processes. According to Lichtenthaler and Ernst (2007), organizations can strengthen their research and development efforts by leveraging new technology and knowledge by transferring technology from other organizations. Similarly, using data obtained from 252 Turkish export firms, Cinar et al. (2021) found a positive effect of technology transfer on innovation and firm performance. Shenkoya and Kim (2020) pointed out that technology transfer coupled with appropriate technology transfer policies is essential to economic development and the generation of income while fostering innovation in South Korea. Cardamone, Pupo, and Ricotta (2015) also indicated that the activities of technology transfer by universities play a critical role in the probability of innovation by manufacturing firms in Italy located in the same province as the university. In a similar vein, Lin, Qin, and Xie (2020) find that foreign technology transfer generates significant localized spillovers in terms of growth in patenting activities and higher productivity and revenue growth among firms close to the direct receivers of foreign technologies in the high-speed rail sector of China. Thus, we posit that:

H4: Technology transfer is positively associated with innovation.

The proposed conceptual framework of the study is depicted in Figure 1.

Research methodology

Study design

To test the hypothesis, we used cross-sectional data, which assumes observation over a single period across various firms. It has several advantages: For example, the effect of time among sample firms could be minimized. All firms have a chance to be considered in the study, regardless of their age, business experience, or size. This could also minimize biasedness among firms and increase the representativeness of the sample size (Cresswell 2014; Malhotra et al. 2017). The study was carried out in 2019.

Population and sample size

The target population for this study comprises medium- and large-scale manufacturing firms in Ethiopia. The Ministry of Trade and Industry report provided us with information on a list of medium- and large-scale manufacturing firms. The list consists of 3500 firms registered and operating in the country in the year 2019. To classify enterprises into medium- and large-scale manufacturing firms, we used benchmarks from the Federal Democratic Republic of Ethiopia's Ministry of Trade and Industry and the Ethiopian CSA (2018). Firms with more than 10 but fewer than 51 employees are classified as medium-scale, while those with 51 or more employees are classified as large-scale. This study focuses on medium- and large-scale manufacturing firms because they are more likely to engage in creative or innovative activities (Gebreeyesus 2009). In addition, medium- and large-scale firms are mature, knowledge-based firms and they

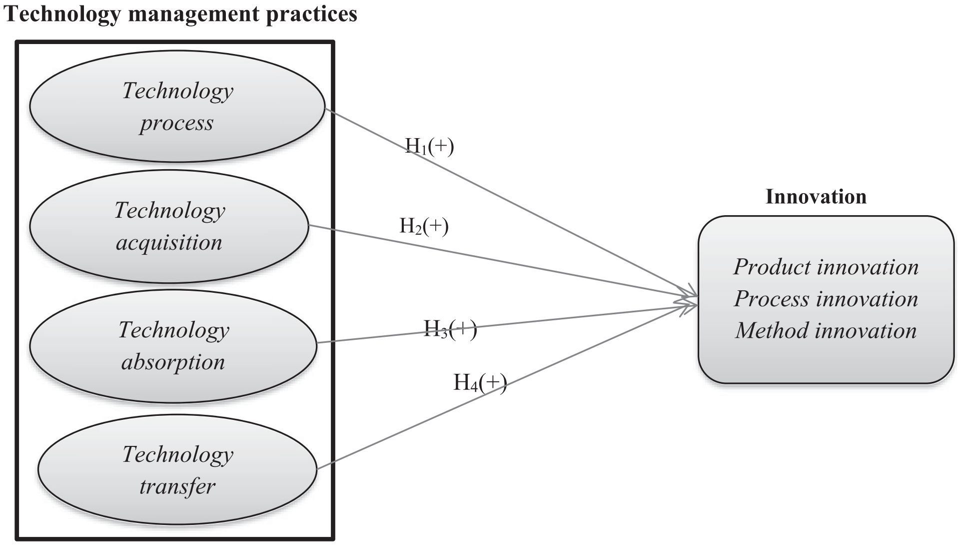

Figure 1: Conceptual model.

have increased opportunities to develop innovative solutions and are additionally conscious of gaining a competitive advantage (Sözbilir 2018). Around 45% of the sampled firms are medium-scale, while the remaining 55% are large-scale manufacturing firms. With regard to sectoral distribution, Ethiopia's manufacturing firms are engaged in various sub-sectors, namely the production of food and beverages, tobacco, textile manufacturing, wood, pulp and paper, chemicals, rubber and plastic, non-metallic minerals, metal, furniture, and others. The food and beverage sector is the dominant sector in terms of output and employment, followed by the non-metallic mineral manufacturing sector (CSA 2018; Erena, Kalko, and Debele 2021). Even though the number of target firms is larger, they are not organized into industrial zones or clusters and are geographically scattered across parts of the country. So, in the current survey study, 200 firms were randomly approached via questionnaire, and a total of 153 usable responses were received, resulting in a response rate of 76.5%. We have followed a sort of procedure in collecting data from the target firms: Firstly, a pilot study was conducted on 10 manufacturing firms in order to examine the reliability and validity of the instruments in terms of readability, language clarity, coherence, and appropriateness. Second, the original version of the questionnaire was revised and reworded while retaining its original meaning based on the feedback from the pilot study. Third, we recruited and trained professional data enumerators. Lastly, the questionnaire was distributed or supplied to the company's production or technical department.

Item development

The survey questionnaire was designed after a thorough review of the literature, with a focus on producing a pool of items that reflect the key theoretical constructs. In this study, technology management is operationalized by four constructs, namely, technology process, technology acquisition, technology absorption, and technology transfer. The technology process is scrutinized with twelve-question items. Technology acquisition is interrogated as an eight-question item. Technology absorption is measured with four question items. Technology transfer is measured with ten question items. We developed/prepared measures of technology management constructs based on empirical studies on technology management roadmaps (Gregory 1995; Durrani et al. 1998; Phaal, Farrukh, and Probert 2001; White and Bruton 2011; Small and Wainwright 2014; Fartash et al. 2018). Survey respondents were asked to evaluate their firm's technology management practice using a five-point scale, with 1 representing 'nothing was done' and 5 representing 'very high'. The survey questionnaire on innovation addressed three innovation factors: product, process, and method innovation. Product innovation was operationalized with five question items. Process innovation was operationalized with four items. Five items were used to measure method innovation. Survey respondents were asked to rate their agreement with the statements using five-point Likert scales ranging from 1 = strongly disagree up to 5 = strongly agree.

Reliability, validity, and structural equation model goodness of fit

We tested the reliability and validity of survey items. Two reliability tests were performed, namely, composite/internal consistency and individual item reliability. Composite reliability is used to test whether the items measuring the same construct are similar in their scores. The individual indicators' reliability was tested using factor loading, and items with more than 0.65 loadings, significant at 1%, were taken. Similarly, two types of validity tests were performed: convergent validity and discriminant validity. The average variance extracted is used to assess the convergent validity. Discriminant validity was applied to test how the latent variables are unique and different from each other. After the reliability and validity tests were satisfied, we performed goodness of fit tests for measurement models, structural models, and second-order models. Unlike conventional multivariate analysis, the structural equation model provides several goodnesses-of-fit tests. The statistical indices and the recommended threshold rules of thumb are presented in Table 1.

Results

Measurement model

This study aims to examine the effect of technology management on technological innovation. The technology management factors involve technology process, technology acquisition, technology absorption, and technology transfer. Similarly, technological innovation was operationalized using product innovation, process innovation, and method innovation. As the usual procedure in structural equation modelling analysis, first, the measurement models were assessed for reliability, validity, and goodness of fit using confirmatory factor analysis in LISREL 8.80, a SIMPLIS program with a maximum likelihood estimation method. Table 2 and Figures 2 and 3 indicate the detailed results containing mean, standard deviation, standardized factor loadings, composite reliability (CR), average variance extracted (AVE), and fit indexes. In this study, an item with more than 0.65 standardized loadings (i.e., a squared correlation between a single manifest variable and its respective construct) and significant at 0.01 was taken. The results in Table 2 show that all items have sufficiently loaded on the constructs they measure, suggesting item reliability or internal consistency reliability. The composite reliability (CR), which assesses the internal consistency of the scale, ranges from 0.853 for technology absorption to 0.937 for technology process. It implies all constructs assumed in the current models have obtained reliability which is much higher than the general rule of thumb of 0.70.

The average variance extracted (AVE) for all constructs exceeded the cut-off criterion of 0.50, demonstrating sufficient convergent validity. In addition to convergent validity, the study evaluated discriminant validity, which refers to the degree to which a given factor or construct differs from other factors or constructs, or the extent to which given factor indicators are distinct from similar indicators designed to measure other constructs. The most common means of measuring discriminant validity is by comparing the square root of the average variance extracted from a construct to the correlation coefficient between two constructs (Fornell and Larcker 1981). The square root of AVE should be greater than the shared variance between constructs to provide evidence of discriminant validity. Table 3 presents the square root of the AVE diagonal printed in bold and constructs correlation in off-diagonal elements, which supports discriminant validity.

As clearly indicated in Figure 2, the technology management measurement model has yielded satisfactory goodness of fit statistics. These include Normed χ^2 = 1.458, RMSEA = 0.055, NFI = 0.95, NNFI = 0.98, CFI = 0.98, IFI = 0.98, and GFI = 0.90. Figure 3 depicts the innovation measurement model, and the fit indexes were Normed χ^2 = 1.578, RMSEA = 0.062, NFI = 0.97, NNFI = 0.99, CFI = 0.99, IFI = 0.99 and GFI = 0.90. Those values indicate a good fit between the model and the observed data. Furthermore, the assumptions of unidimensionality and normality were verified before running structural equation modelling to test the conceptual hypotheses. A confirmatory factor analysis was performed to check for cross-loading among observed variables or error terms. The result for the test indicated that each item was more loaded on its respective factor, suggesting that unidimensionality is satisfied. We tested both univariate normality and bivariate normality for ordinal data and the results are reported in appendices 2 and 3. No excess skewness or kurtosis was found in the data. To compute bivariate normality, root mean square error of appropriation (RMSEA) was used. The results for each pair of variables were at an acceptable level, which is less than 0.10 as recommended by Jöreskog (2005).

In Figure 2, we also assessed the reliability and validity of technology management constructs as a second-order model. Technology management (TM) is specified as a second-order construct, whereas technology process (TECHPROC), technology acquisition (TECHAC), technology absorption (TECHABS), and technology transfer (TECHTR) are first-order factors. The result shows all first-order factors have a significant positive correlation with the second-order construct, supporting convergent validity. The second-order construct has obtained strong construct validity as shown by the composite reliability score of 0.904 and the average variance extracted (AVE) score of 0.70.

The second-order model for innovation is reported in Figure 3, and all first-order factors are significantly and positively correlated to the second-order construct, innovation (INNOV). The values of CR and AVE statistics are 0.958 and 0.886, respectively, implying that construct validity is adequately satisfied in the model. The results in

Table 1: Model fit indices.

Indices statistics	Recommended cut-off rule	Reference
χ^2	–	
df	–	
p-value	>0.05	
χ^2/df	<5	Wheaton et al. (1977)
Root Mean Square Error of Appropriation (RMSEA)	≤0.1	Steiger and Lind (1980)
Normed Fit Index (NFI)	≥0.90	Bentler and Bonett (1980)
Comparative Fit Index CFI	≥0.90	Bentler (1990)
Incremental Fit Index IFI	≥0.90	Bentler (1990)
Goodness of Fit Ibdex (GFI)	≥0.90	Jöreskog and Sörbom (1989)

Table 2: Summary statistics of measurement models.

Constructs	Items	Mean	SD	Standardized loading (λ)	CR	AVE
Technology Process (TECHPROC)	TP1	2.75	1.01	0.73	0.937	0.554
	TP2	2.88	0.97	0.75		
	TP3	2.95	0.95	0.75		
	TP4	3.06	0.98	0.75		
	TP5	2.98	0.99	0.72		
	TP6	3.03	0.97	0.76		
	TP7	2.95	0.97	0.72		
	TP8	3.05	1.01	0.74		
	TP9	2.97	0.98	0.74		
	TP10	3.06	0.94	0.75		
	TP11	3.05	0.93	0.79		
	TP12	3.0	0.98	0.74		
Technology Acquisition (TECHAC)	TAC1	3.01	1.06	0.71	0.900	0.532
	TAC2	3.03	0.96	0.73		
	TAC3	3.07	0.91	0.72		
	TAC4	3.10	0.91	0.65		
	TAC5	3.03	0.98	0.71		
	TAC6	3.04	0.93	0.74		
	TAC7	3.11	0.93	0.80		
	TAC8	3.17	0.92	0.76		
Technology Absorption (TECHABS)	TAB1	3.09	0.94	0.82	0.853	0.595
	TAB2	3.14	0.93	0.63		
	TAB3	3.23	0.92	0.74		
	TAB4	3.29	0.91	0.68		
Technology Transfer (TECHTR)	TT1	2.99	1.02	0.70	0.924	0.553
	TT2	2.88	1.05	0.72		
	TT3	2.86	1.00	0.73		
	TT4	2.90	0.99	0.70		
	TT5	2.98	0.95	0.75		
	TT6	3.00	0.92	0.83		
	TT7	3.11	1.00	0.82		
	TT8	3.07	0.99	0.75		
	TT9	2.82	0.97	0.73		
	TT10	2.96	1.02	0.69		
Process Innovation (PCI)	PCI1	3.01	0.95	0.83	0.886	0.610
	PCI2	3.04	0.93	0.77		
	PCI3	3.10	1.03	0.73		
	PCI4	3.09	1.00	0.84		
	PCI5	3.03	0.96	0.74		
Product Innovation (PDI)	PDI1	2.92	0.99	0.71	0.864	0.560
	PDI2	2.98	0.98	0.82		
	PDI3	2.82	1.00	0.73		
	PDI4	2.90	1.00	0.76		
	PDI5	2.97	1.03	0.72		
Method Innovation (MI)	MI1	2.98	0.98	0.76	0.889	0.616
	MI2	2.93	0.96	0.75		
	MI3	2.95	1.03	0.86		
	MI4	3.03	1.02	0.77		
	MI5	2.97	0.99	0.79		

Figures 2 and 3 strongly assure that the measurement model scales are sufficiently valid and reliable, suggesting further analysis in structural equation modelling, i.e., testing the conceptual hypothesis.

Structural model

The structural model was performed in LISREL 8.8 to test the linkage between technology management, which is an exogenous variable, and innovation, an endogenous variable. In the literature of structural equation modelling, there is a consensus that in addition to sample size, the number of factors in a model influences the goodness of fit (Hair et al. 2019; Cheung and Rensvold 2002). Following the literature, we run two models by classifying the technology management constructs. Model 1 specified technology process and technology acquisition as exogenous variables. While technology absorption and technology transfer were specified in model 2.

The results of model 1 are summarized in Figure 4 and Table 4. Model 1 has obtained excellent goodness of fit statistics, and all fit indexes are within the acceptable range. The Normed χ^2 = 1.915, RMSEA = 0.078, NFI = 0.94, NNFI = 0.97, CFI = 0.97, IFI = 0.97, RFI = 0.93 and GFI = 0.90. Those results indicate the model reasonably fits the observed data. As shown in Table 4, the technology process has a significant positive effect on both process innovation (PCI) (UC = 0.23, *t*-value 2.50) and method innovation (MI) (UC = 0.18, *t*-value 1.99). No significant coefficient is found between the technology process and product innovation. The coefficients between technology acquisition and all three constructs of innovation are positive and strongly statistically

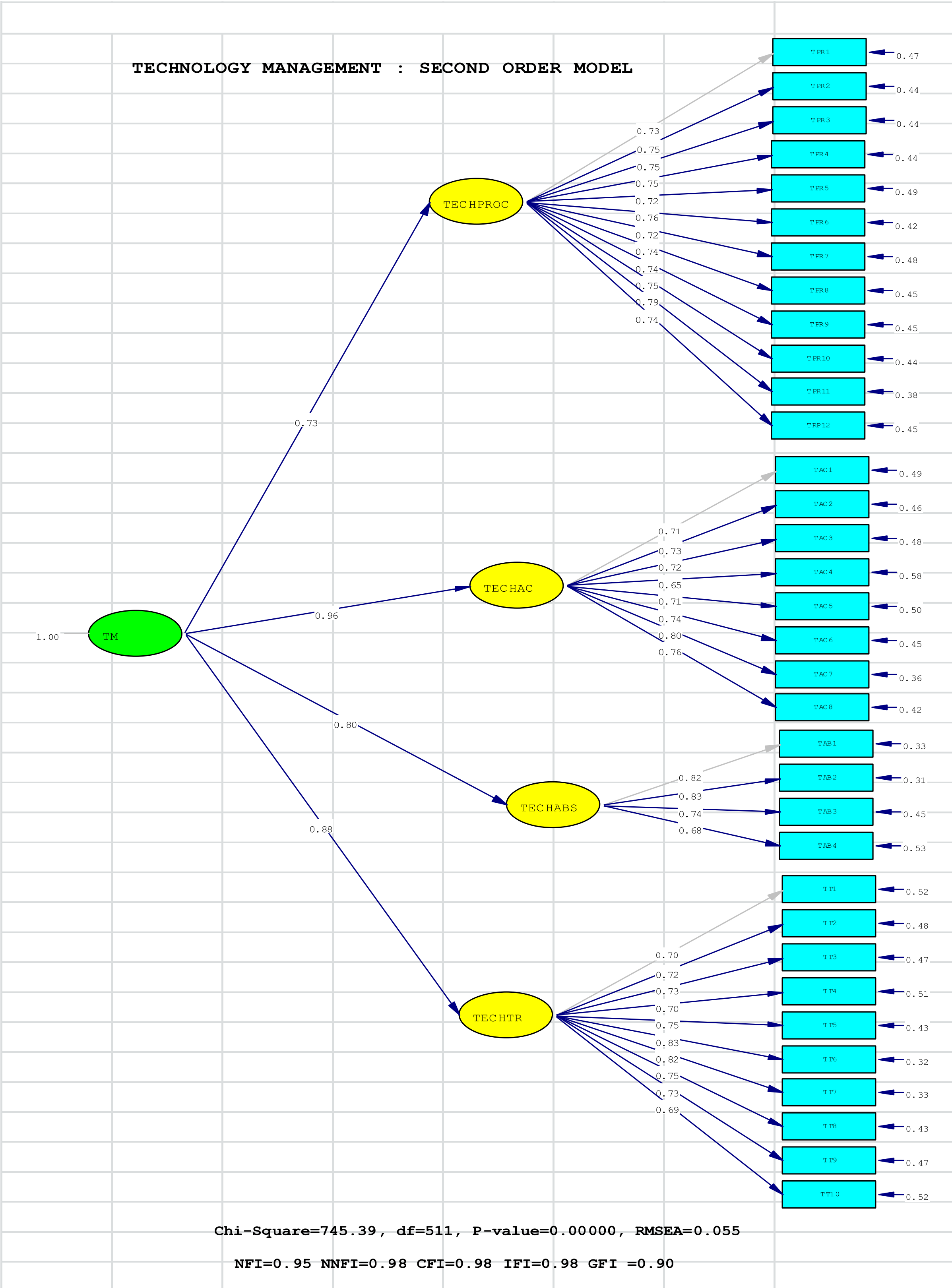

Figure 2: Technology management measurement model (i.e., technology management second-order model).

significant: process innovation (PCI) (UC = 0.62, *t*-value 6.07), product innovation (PDI) (UC = 0.83, *t*-value 7.35), and method innovation (MI) (UC = 0.62, *t*-value 5.83). Moreover, on average, model 1 has defined about 0.67% (R^2) of the variance in innovation, suggesting sufficient model validity.

The second model is graphically demonstrated in Figure 5, and the detailed result is reported in Table 5. The scores of all fit index statistics met the usual standard norms, Normed χ^2 = 1.787, RMSEA = 0.072, NFI = 0.95, NNFI = 0.97, CFI = 0.98, IFI = 0.98, RFI = 0.95 and GFI = 0.91. Thus, the overall goodness-of-fit indices indicate that the model is

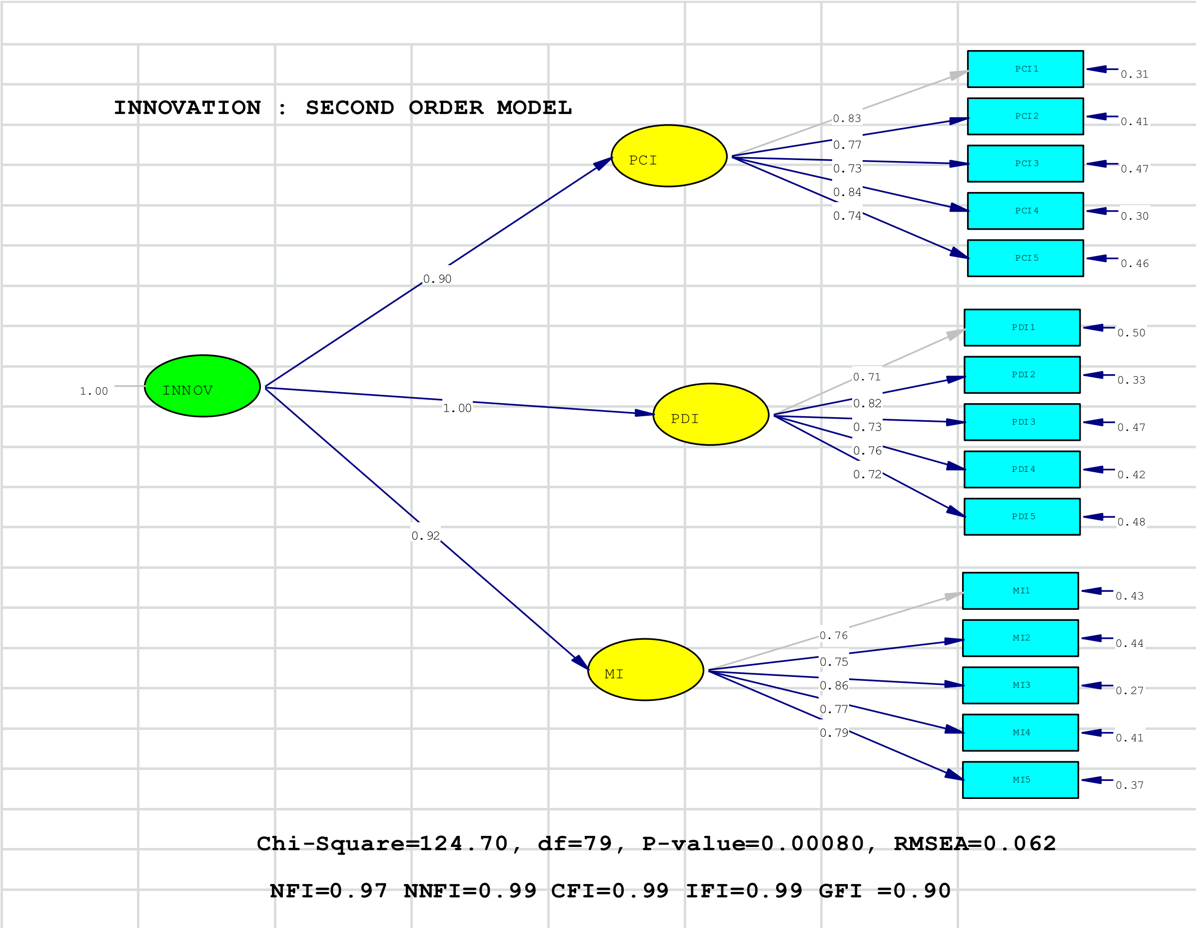

Figure 3: Innovation measurement model (i.e., innovation second-order model).
Note: RMSEA-root mean square error of approximation; NFI-normed fit index; NNFI-non-normed fit index; CFI-comparative fit index; IFI-incremental fit index; RFI-relative fit index; GFI-goodness of fit index.

Table 3: Discriminant validity.

Variable	1	2	3	4	Variable	PDI	PCI	MI
TECHPROC	**0.744**				PDI	**0.781**		
TECHAC	0.48	**0.729**			PCI	0.58	**0.748**	
TECHABS	0.46	0.33	**0.771**		MI	0.41	0.52	**0.784**
TECHTR	0.53	0.35	0.40	**0.743**				

Note: The square root of AVE values is shown on the diagonal and printed in bold; off-diagonal elements are the construct variables correlations. TECHPROC-technology process, TECHAC-technology acquisition, TECHABS- technology absorption, TECHTR-technology transfer, PDI- product innovation, PCI-process innovation, MI-method innovation, TM-technology management. Second-order (TM) CR = 0.904, AVE = 0.70.

acceptable. In Table 4, technology absorption has a significant positive effect on product innovation (PDI) (UC = 0.17, *t*-value 2.19). However, the coefficients for process innovation and method innovation are insignificant.

Technology transfer has a potential significant positive impact on process innovation (UC = 0.87, *t*-value 8.75), product innovation (UC = 0.81, *t*-value 8.03) and method innovation (UC = 0.77, *t*-value 7.29). This result implies that technology transfer is the key driver of firm innovation. Mode 2, on average, defined a 0.81% variance in innovation, showing strong model validity.

Discussion

The primary objective of this study is to investigate empirically the effects of technology management practices, including technology processes, technology acquisition, technology absorption, and technology transfer, on firm innovative development, such as process, product, and method innovation, in medium- and large-scale manufacturing firms in Ethiopia. Technology management is termed as a multidisciplinary study involving technology, science, and management. It is the process of planning, identifying, and implementing technological tools, equipment, skills, and knowledge into a manufacturing system. In this study, four dimensions were used to represent technology management: technology process, technology acquisition, technology absorption, and technology transfer. The results showed technology process has a significant positive effect on product innovation and method innovation,

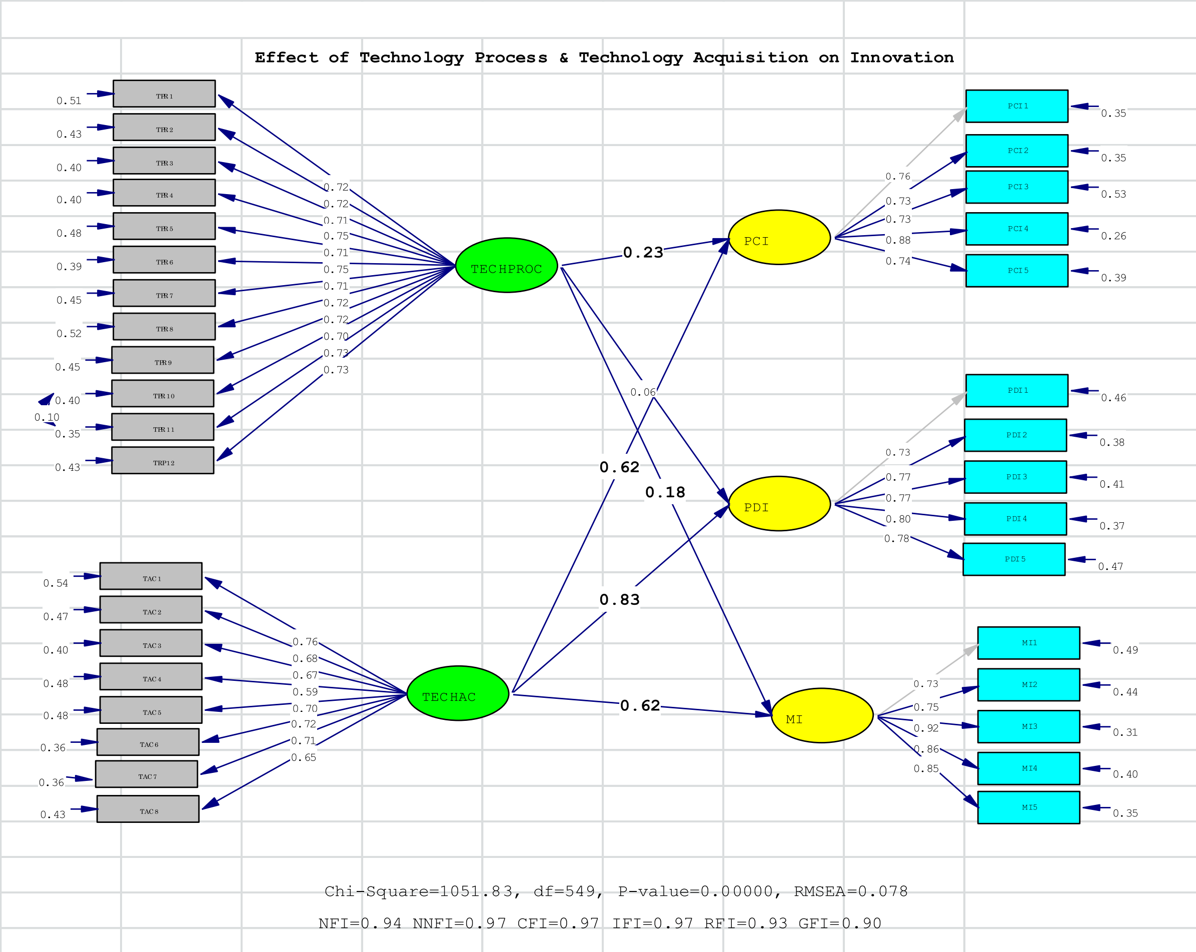

Figure 4: Effect of technology management (i.e., technology process and technology acquisition) on innovation.

Table 4: Structural model 1 results.

Variable	Standardized coefficient	Std. Error	*t*-value	*R*-square
TECHPROC -> PCI	0.23	0.091	2.50*	0.64
TECHAC -> PCI	0.62	0.10	6.07**	
TECHPROC -> PDI	0.06	0.084	0.74	0.76
TECHAC ->PDI	0.83	0.062	7.35**	
TECHPROC->MI	0.18	0.089	1.99*	0.63
TECHAC ->MI	0.62	0.11	5.83**	

Where TECHPROC–technology process; TECHAC-technology acquisition; PCI-process innovation; PDI-product innovation; MI-method innovation; RMSEA-root mean square error of approximation; NFI-normed fit index; NNFI-non-normed fit index; CFI-comparative fit index; IFI-incremental fit index; RFI-relative fit index; GFI-goodness of fit index. Note: **,* denote a significant level at 1% and 5%, respectively.
RMSEA = 0.078 NFI = 0.94 NNFI = 0.97 CFI 0.97 IFI = 0.97 RFI = 0.93 GFI = 0.85.

but no significant effect on process innovation. It implies that a firm that has invested in technology processes like applied research, basic research, technology production, implementation, and enhancement is more likely to improve its innovation performance and subsequently yield a competitive advantage. Moreover, firms need to build their internal competencies, for example, research and development capacity that helps to generate new knowledge or ideas and convert them into a product, process, or service. This result is in line with studies by Wu et al. (2010) and Phaal, Farrukh, and Probert (2001), who have suggested a firm with higher technology management capacity can have better innovation performance.

Technology acquisition appeared to be the major antecedent of three innovation constructs: product, process, and method innovation. This reflects the degree to which a firm engages in technology acquisition activities like joint-ventures, collaborating with other firms, contracting R&D, licensing, or buying technology (hardware or software), and the acquisition of new equipment significantly contributes to innovation. A strategy of technology acquisition from external parties can substitute or complement in-house development of technology that requires highly skilled human resources (researchers), a laboratory, a budget, equipment, and other tools. It can be inferred from this result that, given the capacity of the firm, appropriate external technology acquisition has

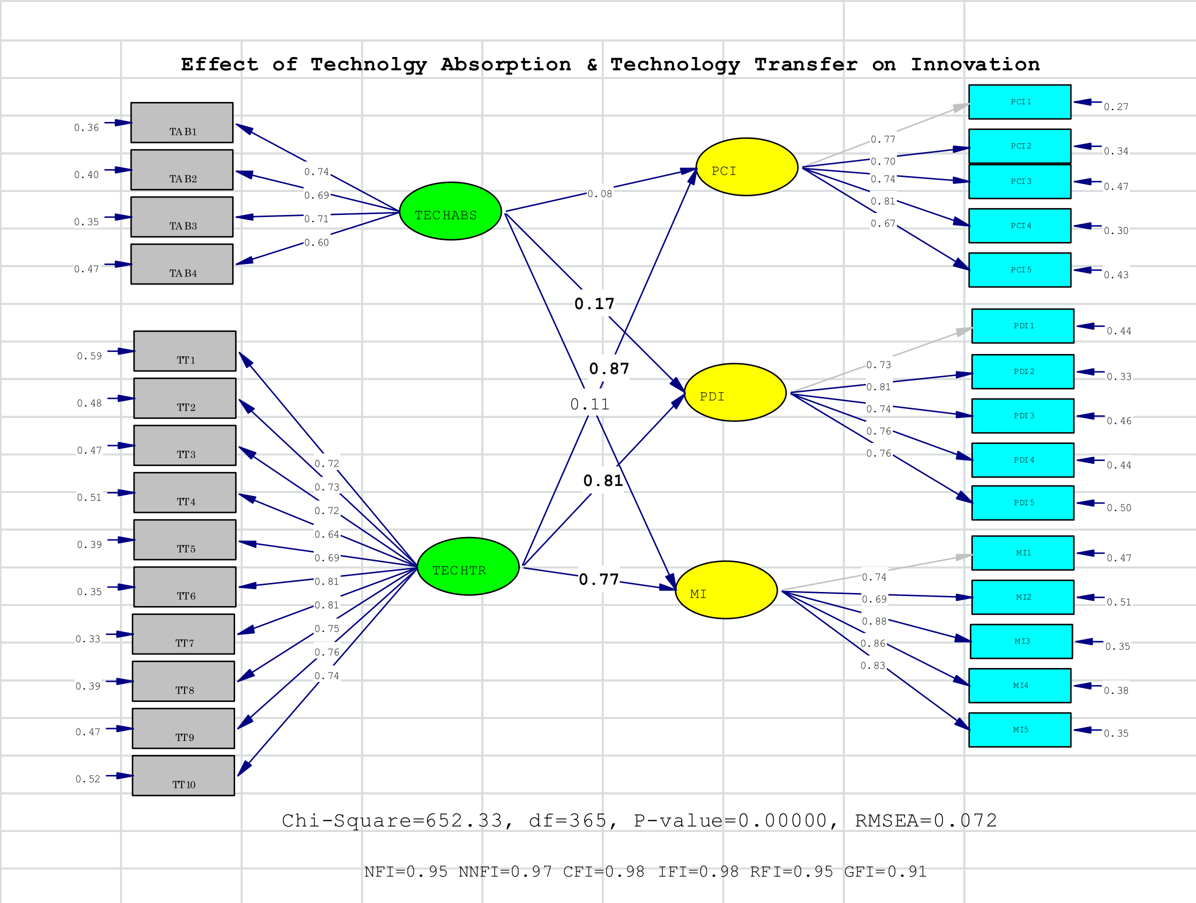

Figure 5: Effect of technology management (i.e., technology absorption and technology transfer) on innovation.

Table 5: Structural model 2 results.

Variable	Standardized coefficient	Std. Error	*t*-value	*R*-square
TECHABS -> PCI	0.08	0.081	0.97	0.79
TECHTR -> PCI	0.87	0.099	8.75**	
TECHABS -> PDI	0.17	0.077	2.19*	0.88
TECHTR ->PDI	0.81	0.10	8.03**	
TECHABS ->MI	0.11	0.083	1.27	0.78
TECHTR ->MI	0.77	0.11	7.29**	

Where, TECHABS-technology absorption, TECHTR-technology transfer, PCI-process innovation; PDI-product innovation; MI-method innovation; RMSEA-Root Mean Square Error of Approximation; NFI-Normed Fit Index; NNFI-Non-Normed Fit Index; CFI-Comparative Fit Index; IFI-Incremental Fit Index; RFI-Relative Fit Index; GFI- Goodness of Fit Index. Note: ** and * denote a significant level at 1% and 5%, respectively. RMSEA = 0.072 NFI = 0.95 NNFI = 0.97 CFI = 0.98 IFI =0.98 RFI = 0.95 GFI = 0.87.

a vital role in shaping new technological innovation. This result is consistent with the findings of Goedhuys and Veugelers (2012) that indicate that process and product innovation success occurs mostly through embodied technology acquisition (i.e., through external technology acquisition or technology buy strategy, particularly the purchase of machinery and equipment, either alone or in combination with internal development or technology make strategy) in Brazilian manufacturing firms.

Technology absorption has a significant positive influence on product innovation, but the coefficient for process and method innovations is insignificant. Thus, a firm that effectively exploits and learns technology from external parties can improve its product innovation. Our results are consistent with the findings of Engelman et al. (2018) that confirmed the positive influence of absorptive capacity on product innovation in Brazil. Our finding is also consistent with the results of several previous studies (Durrani et al. 1998; Lichtenthaler 2007; Lichtenthaler and Ernst 2009; Tsai, Hsieh, and Hultink 2011; Kang, Jo, and Kang 2015; Fartash et al. 2018) that have confirmed a positive relationship between technology management (as measured by technology acquisition and absorption) and innovation (product, process, and method).

Moreover, technology transfer has a significant positive influence on the three innovation constructs – process, product, and method innovations – suggesting it is an important driver of innovation. This implies that the practice of firms with respect to the internal flow of know-how, technical knowledge, equipment, data, and information (intellectual property) from government units, universities, technology providers, and other external parties is essential to scale-up firms' innovative capacity. It also suggests that a firm with better technological capacity (skilled human resources, expertise, experience) can more easily achieve the maximum benefits from transferred technology than those that have less capacity. This result supports the general view of the extant literature (Li-Hua and Khalil 2006; Chan and Daim 2011; White and Bruton 2011; García-Vega and Vicente-Chirivella 2020) that indicates technology transfer is a key antecedent for innovation. Furthermore, this finding is also consistent with Liang and Zhang's (2012) finding that technology transfer is an effective source of technological product and process innovation in Chinese high technology industries.

The current study contributes to the theoretical notion that technology is a source of competitive advantage, which is achieved through encouraging technological innovation. Technology management is a critical strategy that assists businesses in identifying, selecting, acquiring, exploiting, and protecting technology (Gregory 1995; Durrani et al. 1998). However, achieving effective technological management would be difficult for firms with low-skilled labour, insufficient knowledge of technology, and inadequate investment in R&D because the technology base cannot be built in a single process; rather, it requires time and large capital investment. In addition, policymakers should support firms in their efforts to improve technology, which will help them increase productivity and become more innovative.

Conclusion

The current highly impulsive and rapid change in the business environment changes the way firms have to operate and deliver products or services. Technology is a resource that can provide a competitive advantage if utilized well for the intended purpose. Technology processes, acquisition, absorption, and transfer are valuable indicators of technology management in the manufacturing sector. They show that firms engaging in developing technology in-house via R&D, acquiring, learning and exploiting, and transferring technology simultaneously would have a higher technology management capacity. It is further noted that innovation can be operationalized adequately through process, product, and method innovations. Thus, a firm's innovation strategy should consider these factors as important sources of innovation. Furthermore, technology management is an appropriate resource to be used in conjunction with appropriate technology management policies and strategies to enhance firm performance, particularly innovation and creativity, which in turn, are sources of competitive advantage.

It is noted that technology transfer is the most important driver of product, process, and method innovations. This indicates that the more a firm shares, transmits, and converts technology, data, and information with outside parties (universities, government units, firms, or others), the better its innovation performance. The result confirms the general view that technology transfer is a means for innovation and productivity where human creativity has not been well developed and the existing system is not capable of creating technology (Li-Hua and Khalil 2006; Chan and Daim 2011). The study also found technology processes, acquisitions, and absorption are valuable factors in explaining innovation. Overall, the results add to the body of knowledge that manufacturing innovation can best be driven through strengthened technological capacity. Finally, we conclude that building technological or innovative capacity requires a huge amount of resources (human and financial) and takes a long time to attain the optimum benefits. However, if a firm needs to operate a business (deliver products or services), there is no alternative but to elevate its technological innovation capability through investing in research and development, learning, and exploiting existing or new knowledge.

Availability of data and materials

Data are available from the authors upon reasonable request.

Acknowledgments

We acknowledge with appreciation the helpful and constructive comments of Prof. Angathevar Baskaran (Editor-in-Chief) and two anonymous reviewers.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The authors gratefully acknowledge the financial support for this study from Tomas Bata University in Zlin [grant number IGA/FaME/2020/003] and Hawassa University.

ORCID iDs

Mesfin Mala Kalko http://orcid.org/0000-0001-5153-4764

Obsa Teferi Erena http://orcid.org/0000-0003-4304-5359

Sara Adugna Debele http://orcid.org/0000-0002-9832-7049

References

Aghion, P., and P. Howitt. 1996. "Research and Development in the Growth Process." *Journal of Economic Growth* 1 (1): 49–73. doi:10.1007/bf00163342.

Akcigit, U., D. Hanley, and N. Serrano-Velarde. 2020. "Back to Basics: Basic Research Spillovers, Innovation Policy and Growth." *The Review of Economic Studies* 88 (1): 1–43. doi:10.1093/restud/rdaa061.

Appiah-Adu, K., B. K. Okpattah, and J. G. Djokoto. 2016. "Technology Transfer, Outsourcing, Capability, and Performance: A Comparison of Foreign and Local Firms in Ghana." *Technology in Society* 47 (1): 31–39. doi:10.1016/j.techsoc.2016.07.002.

Autio, E., and T. Laamanen. 1995. "Measurement and Evaluation of Technology Transfer: Review of Technology Transfer Mechanisms and Indicators." *International Journal of Technology Management* 10 (7/8): 643–664. doi:10.1504/IJTM.1995.025647.

Becker, W., and J. Peters. 2000. "Technological opportunities, absorptive capacities, and innovation." The Eighth International Joseph A. Schumpeter Society Conference Centre for Research in Innovation and Competition (CRIC), University Manchester, Manchester.

Belderbos, B., S. Kelchtermans, and R. Leten. 2021. "How Does Basic Research Improve Innovation Performance in the World's Major Pharmaceutical Firms?" *Industry and Innovation*, doi:10.1080/13662716.2021.1997723.

Bentler, P., and D. Bonett. 1980. "Significance Tests and Goodness of fit in the Analysis of Covariance Structures." *Psychological Bulletin* 88 (3): 588–606. doi:10.1037/0033-2909.88.3.588.

Bentler, P. M. 1990. "Comparative fit Indexes in Structural Models." *Psychological Bulletin* 107 (2): 238–246. doi:10.1037/0033-2909.107.2.238.

Boudreau, M.-C., K. D. Loch, D. Robey, and D. Straud. 1998. "Going Global: Using Information Technology to Advance the Competitiveness of the Virtual Transnational Organization." *Academy of Management Perspectives* 12 (4): 120–128. doi:10.5465/AME.1998.1334008.

Bozeman, B. 2000. "Technology Transfer and Public Policy: A Review of Research and Theory." *Research Policy* 29 (4): 627–655. doi:10.1016/S0048-7333(99)00093-1.

Calantone, R. J., and M. A. Stanko. 2007. "Drivers of Outsourced Innovation: An Exploratory Study." *Product Innovation Management* 24 (3): 230–241. doi:10.1111/j.1540-5885.2007.00247.x.

Cardamone, P., V. Pupo, and F. Ricotta. 2015. "University Technology Transfer and Manufacturing Innovation: The Case of Italy." *Review of Policy Research* 32 (3): 297–322. doi:10.1111/ropr.12125.

Cassiman, B., and R. Veugelers. 2006. "In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition." *Management Science* 52 (1): 68–82. doi:10.1287/mnsc.1050.0470.

Cepeda-Carrion, G., J. G. Cegarra-Navarro, and D. Jimenez-Jimenez. 2012. "The Effect of Absorptive Capacity on Innovativeness: Context and Information Systems Capability as Catalysts." *British Journal of Management* 23 (1): 110–129. doi:10.1111/j.1467-8551.2010.00725.x.

Chan, L., and T. U. Daim. 2011. "Technology Transfer in China: Literature Review and Policy Implications." *Journal of Science and Technology Policy in China* 2 (2): 122–145. doi:10.1108/17585521111155192.

Charmjuree, T., Y. F. Badir, and U. Safdar. 2021. "External Technology Acquisition, Exploitation and Process Innovation Performance in Emerging Market Small and Medium-Sized Enterprises: The Moderating Role of Organizational Slack." *European Journal of Innovation Management* Vol. ahead-of-print No. ahead-of-print, doi:10.1108/EJIM-07-2020-0263.

Chebo, A. K., and Y. F. Wubatie. 2020. "Commercialisation of Technology Through Technology Entrepreneurship: The Role of Strategic Flexibility and Strategic Alliance." *Technology Analysis & Strategic Management* 33 (4): 1–12. doi:10.1080/09537325.2020.1817367.

Cheung, G. W., and R. B. Rensvold. 2002. "Evaluating Goodness-of-Fit Indexes for Testing Measurement Invariance." *Structural Equation Modeling: A Multidiscplinary Journal* 9 (2): 233–255. doi:10.1207/s15328007sem0902_5.

Cinar, O., S. Altuntas, and M. A. Alan. 2021. "Technology Transfer and its Impact on Innovation and Firm Performance: Empirical Evidence from Turkish Export Companies." *Kybernetes* 50 (7): 2179–2209. doi:10.1108/k-12-2019-0828.

Cohen, W. M., and D. A. Levinthal. 1989. "Innovation and Learning: The Two Faces of R&D." *The Economic Journal* 99 (397): 56–59. doi:10.2307/2233763.

Cohen, W. M., and D. A. Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35 (1): 128–152. doi:10.2307/2393553.

Cresswell J.W. 2014. *Research Design: Qualitative, Quantitative, and Mixed Approaches*. Los Angeles: Sage Publications, Inc.

CSA. 2018. "Report on Large and Medium Scale Manufacturing and Electricity Industries Survey." Addis Ababa: The FDRE Statistical Bulletin.

Davenport, T. H., and L. Prusak. 1998. *Working Knowledge: How Organizations Manage What They Know*. Boston, MA: Harvard Business School Press.

Durrani, T. S., S. M. Forbes, C. Broadfoot, and A. S. Carrie. 1998. "Managing the Technology Acquisition Process." *Technovation* 18 (8/9): 523–587. doi:10.1016/s0166-4972(98)00047-9.

Engelman, R., S. Schmidt, C. Froehlich, and E. M. Fracasso. 2018. "The Influence of Absorptive Capacity on Product Innovation in Southern Brazilian Industries." *International Journal of Innovation and Learning* 24 (3): 345–365. doi:10.1504/IJIL.2018.094713.

Erena, O. T., M. M. Kalko, and S. A. Debele. 2021. "Technical Efficiency, Technological Progress and Productivity Growth of Large and Medium Manufacturing Industries in Ethiopia: A Data Envelopment Analysis." *Cogent Economics & Finance* 9 (1): 1–38. doi:10.1080/23322039.2021.1997160.

Fartash, K., S. M. M. Davoudi, T. A. Baklashova, N. V. Svechnikova, Y. V. Nikolaeva, S. A. Grimalskaya, and A. V. Beloborodova. 2018. "The Impact of Technology Acquisition & Exploitation on Organizational Innovation and Organizational Performance in Knowledge-Intensive Organizations." *EURASIA Journal of Mathematics, Science and Technology Education* 14 (4): 1497–1507. doi:10.29333/ejmste/84835.

Fornell, C., and D. F. Larcker. 1981. "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error." *Journal of Marketing Research* 18 (1): 39–50. doi:10.1177/002224378101800104.

Fosfuri, A., and J. A. Tribo. 2008. "Exploring the Antecedents of Potential Absorptive Capacity and its Impact on Innovation Performance." *Omega* 36 (2): 173–187. doi:10.1016/j.omega.2006.06.012.

Gao, S., K. Xu, and J. Yang. 2008. "Managerial Ties, Absorptive Capacity, and Innovation." *Asia Pacific Journal of Management* 25 (3): 395–412. doi:10.1007/s10490-008-9096-1.

Garcia-Morales, V. J., A. Ruiz-Moreno, and F. J. Llorens-Montes. 2007. "Effects of Technology Absorptive Capacity and Technology Proactivity on Organizational Learning, Innovation and Performance: An Empirical Examination." *Technology Analysis & Strategic Management* 19 (4): 527–558. doi:10.1080/09537320701403540.

García-Vega, M., and Ó Vicente-Chirivella. 2020. "Do University Technology Transfers Increase Firms' Innovation?" *European Economic Review* 123: 1–20. doi:10.1016/j.euroecorev.2020.103388.

Gebreeyesus, M. 2009. *Innovation and Microenterprise Growth in Ethiopia*. Tokyo: United Nations University.

Goedhuys, M., and R. Veugelers. 2012. "Innovation Strategies, Process and Product Innovations and Growth: Firm-Level Evidence from Brazil." *Structural Change and Economic Dynamics* 23 (4): 516–529. doi:10.1016/j.strueco.2011.01.004.

Grant, R. M. 1996. "Toward a knowledge-based theory of the firm." *Strategic Management Journal* 17 (2): 109–122. doi:10.1002/smj.4250171110

Gregory, M. J. 1995. "Technology Management: A Process Approach." *ARCHIVE: Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 1989-1996 (Vols 203-210)* 209 (52): 347–356. doi:10.1243/PIME_PROC_1995_209_094_02.

Guan, J. C., C. K. Mok, R. C. M. Yam, K. S. Chin, and K. F. Pun. 2006. "Technology Transfer and Innovation Performance: Evidence from Chinese Firms." *Technology Forecasting & Social Change* 73 (6): 666–678. doi:10.1016/j.techfore.2005.05.009.

Hair, J. F., W. C. Black, B. J. Babin, and R. E. Anderson. 2019. *Multivariate Data Analysis*. 8th ed. Hampshire, UK: Cengage Learning EMEA.

Henard, D. H., and M. A. McFadyen. 2005. "The Complementary Roles of Applied and Basic Research: A Knowledge-Based Perspective." *The Journal of Product Innovation Management* 22 (6): 503–514. doi:10.1111/j.1540-5885.2005.00146.x.

Hitt, M. A., R. D. Ireland, and H.-u. Lee. 2000. "Technological Learning, Knowledge Management, Firm Growth and Performance: An Introductory Essay." *Journal of Engineering and Technology Management* 17 (3/4): 231–246. doi:10.1016/s0923-4748(00)00024-2.

Hoegl, M., and S. M. Wagner. 2005. "Buyer-Supplier Collaboration in Product Development Projects." *Journal of Management* 31 (4): 530–548. doi:10.1177/0149206304272291.

Hsiao, Y. C., C. J. Chen, B. W. Lin, and C. I. Kuo. 2017. "Resource Alignment, Organizational Distance, and Knowledge Transfer Performance: The Contingency Role of Alliance Form." *The Journal of Technology Transfer* 42 (3): 635–653. doi:10.1007/s10961-016-9505-4.

Hsu, C-C., K. C. Tan, J. Jayaram, and T. Laosirihongthong. 2014. "Corporate Entrepreneurship, Operations Core Competency and Innovation in Emerging Economies." *International Journal of Production Research* 52 (18): 5467–5483. doi:10.1080/00207543.2014.915069.

Hung, K.-P., and C. Chou. 2013. "The Impact of Open Innovation on Firm Performance: The Moderating Effects of Internal R&D and Environmental Turbulence." *Technovation* 33 (10/11): 368–380. doi:10.1016/j.technovation.2013.06.006.

Hussen, M. S., and M. Çokgezen. 2019. "Analysis of Factors Affecting Firm Innovation: An Empirical Investigation for Ethiopian Firms." *Journal of African Business* 21 (2): 1–24. doi:10.1080/15228916.2019.1625020.

Jeon, J., S. Hong, J. Ohm, and T. Yang. 2015. "Causal Relationships among Technology Acquisition, Absorptive Capacity, and Innovation Performance: Evidence from the Pharmaceutical Industry." *PLOS ONE* 10 (7): 1–14. doi:10.1371/journal.pone.0131642.

Jöreskog, K. 2005. *Structural Equation Modeling with Ordinal Variables Using LISREL*. Chicago: Scientific Software International. Accessed June 10, 2020. http://www.ssicentral.com/lisrel/advancedtopics.html.

Jöreskog, K., and D. Sörbom. 1989. *LISREL VII. Analysis of Linear Structural Relationships by Maximum Likelihood, Instrumental Variables, and Least-Squares Methods*. Mooresville, Indiana: Scientific Software.

Kang, K. H., G. S. Jo, and J. Kang. 2015. "External Technology Acquisition: A Double-Edged Sword." *Asian Journal of Technology Innovation* 23 (1): 35–52. doi:10.1080/19761597.2015.1010265.

Kessler, E. H., P. E. Bierly, and S. Gopalakrishnan. 2000. "Internal vs. External Learning in New Product Development: Effects on Speed, Costs and Competitive Advantage." *R&D Management* 30 (3): 213–224. doi:10.1111/1467-9310.00172.

Kneller, R., and P. A. Stevens. 2006. "Frontier Technology and Absorptive Capacity: Evidence from OECD Manufacturing Industries." *Oxford Bulletin of Economics and Statistics* 68 (1): 1–20. doi:10.1111/j.1468-0084-2006.00150.x.

Kostopoulos, K., A. Papalexandris, M. Papachroni, and G. Ioannou. 2011. "Absorptive Capacity, Innovation, and Financial Performance." *Journal of Business Research* 64 (12): 1335–1343. doi:10.1016/j.jbusres.2010.12.005.

Lewin, A. Y., S. Massini, and C. Peeters. 2011. "Microfoundations of Internal and External Absorptive Capacity Routines." *Organization Science* 22 (1): 81–98. doi:10.1287/orsc.1100.0525.

Liang, H., and Z. Zhang. 2012. "The Effects of Industry Characteristics on the Sources of Technological Product and Process Innovation." *The Journal of Technology Transfer* 37 (6): 867–884. doi:10.1007/s10961-011-9206-y.

Lichtenthaler, U. 2005. "External Commercialization of Knowledge: Review and Research Agenda." *International Journal of Management Reviews* 7 (4): 231–255. doi:10.1111/j.1468-2370.2005.00115.x.

Lichtenthaler, U. 2007. "The Drivers of Technology Licensing: An Industry Comparison." *California Management Review* 49 (4): 67–89. doi:10.2307/41166406.

Lichtenthaler, U. 2009. "Absorptive Capacity, Environmental Turbulence, and the Complementarity of Organizational Learning Processes." *Academy of Management Journal* 52 (4): 822–846. doi:10.5465/AMJ.2009.43670902.

Lichtenthaler, U., and H. Ernst. 2007. "External Technology Commercialization in Large Firms: Results of a Quantitative Benchmarking Study." *R&D Management* 37 (5): 383–397. doi:10.1111/j.1467-9310.2007.00487.x.

Lichtenthaler, U., and H. Ernst. 2009. "Opening up the Innovation Process: The Role of Technology Aggressiveness." *R&D Management* 39 (1): 38–54. doi:10.1111/j.1467-9310.2008.00522.x.

Li-Hua, R., and T. M. Khalil. 2006. "Technology Management in China: A Global Perspective and Challenging Issues." *Journal of Technology Management in China* 1 (1): 9–26. doi:10.1108/17468770610642731.

Lim, K. 2004. "The Relationship Between Research and Innovation in the Semiconductor and Pharmaceutical Industries (1981–1997)." *Research Policy* 33 (2): 287–321. doi:10.1016/j.respol.2003.08.001.

Lin, Y., Y. Qin, and Z. Xie. 2020. "Does Foreign Technology Transfer Spur Domestic Innovation? Evidence from the High-Speed Rail Sector in China." *Journal of Comparative Economics* 49 (1): 212–229. doi:10.1016/j.jce.2020.08.004.

Malhotra, N. K., D. Nunan and D. F. Birks. 2017. *Marketing Research: An Applied Approach*. 5th ed. Edinburgh: Prentice Hall Inc.

Masa'deh, R. E., B. Y. Obeidat, and A. Tarhini. 2016. "A Jordanian Empirical Study of the Associations among Transformational Leadership, Transactional Leadership, Knowledge Sharing, job Performance, and Firm Performance: A Structural Equation Modelling Approach." *Journal of Management Development* 35 (5): 681–705.

Montoya, P. V., R. S. Zárate, and L. A. G. Martín. 2007. "Does the Technological Sourcing Decision Matter?: Evidence from Spanish Panel Data." *R&D Management* 37 (2): 161–172. doi:10.1111/j.1467-9310.2007.00465.x.

Nelson, R. R. 1959. "The Simple Economics of Basic Scientific Research." *Journal of Political Economy* 67 (3): 297–306. doi:10.1086/258177.

Nieto, M. J., and L. Santamaría. 2007. "The Importance of Diverse Collaborative Networks for the Novelty of Product Innovation." *Technovation* 27 (6/7): 367–377. doi:10.1016/j.technovation.2006.10.001.

Nonaka, I. 1994. "A Dynamic Theory of Organizational Knowledge Creation." *Organization Science* 5 (1): 14–37. doi:10.1287/orsc.5.1.14.

Novickis, L., A. Mitasiunas, and V. Ponomarenko. 2017. "Information Technology Transfer Model as a Bridge Between Science and Business Sector." *Procedia Computer Science* 104 (1): 120–126. doi:10.1016/j.procs.2017.01.083.

Oqubay, A. 2018. *The Structure and Performance of the Ethiopian Manufacturing Sector. Working Paper Series N° 299*. Abidjan, Côte d'Ivoire: African Development Bank.

Ortega, M. J. R. 2010. "Competitive Strategies and Firm Performance: Technological Capabilities' Moderating Roles." *Journal of Business Research* 63 (12): 1273–1281. doi:10.1016/j.jbusres.2009.09.007.

Phaal, R., C. J. P. Farrukh, and D. R. Probert. 2001. "Technology Management Process Assessment: A Case Study." *International Journal of Operations & Production Management* 21 (8): 1116–1132. doi:10.1108/EUM0000000005588.

Pinheiro, J., L. F. Lages, G. M. Silva, A. L. Dias, and M. T. Preto. 2021. "Effects of Absorptive Capacity and Innovation Spillover on Manufacturing Flexibility." *International Journal of Productivity and Performance Management*. Advance online publication. doi:10.1108/IJPPM-04-2020-0156.

Pradana, M., A. Pérez-Luño, and M. Fuentes-Blasco. 2020. "Innovation as the key to Gain Performance from

Absorptive Capacity and Human Capital." *Technology Analysis & Strategic Management* 32 (7): 822–834. doi:10.1080/09537325.2020.1714578.

Rajan, R., Dhir, S., and Sushil. 2021. "Technology Management for Innovation in Organizations: An Argumentation-Based Modified TISM Approach." *Benchmarking: An International Journal* 28 (6): 1959–1986. doi:10.1108/BIJ-01-2020-0019

Shenkoya, T., and E. Kim. 2020. "The Impact of Technology Transfer/Policies on the Economic Catch-up of the Korean National Innovation System and its Implications for Nigeria." *African Journal of Science, Technology, Innovation and Development* 13 (6): 685–699. doi:10.1080/20421338.2020.1799536.

Simon, H. A. 1991. "Bounded Rationality and Organizational Learning." *Organization Science* 2 (1): 125–134. doi:10.1287/orsc.2.1.125.

Small, A., and D. Wainwright. 2014. "SSM and Technology Management: Developing Multimethodology Through Practice." *European Journal of Operational Research* 233 (3): 660–673. doi:10.1016/j.ejor.2013.08.049.

Sözbilir F. 2018. "Innovation Capacity and Innovation Performance in Terms of Educational Level of Managers." *Journal of Business Research-Turk* 10 (2): 1–12. https://www.ceeol.com/search/journal-detail?id=329.

Steiger, J., and J. Lind. 1980. "Statistically Based Tests for the Number of Common Factors." Paper presented at the annual meeting of the psychometric society, Iowa City, IA.

Thornhill, S. 2006. "Knowledge, Innovation, and Firm Performance in High- and Low-Technology Regimes." *Journal of Business Venturing* 21 (5): 687–703. doi:10.1016/j.jbusvent.2005.06.001.

Todorova, G., and B. Durisin. 2007. "Absorptive Capacity: Valuing a Reconceptualization." *Academy of Management Review* 32 (3): 774–786. doi:10.5465/amr.2007.25275513.

Tsai, K.-H., and J.-C. Wang. 2007. "Inward Technology Licensing and Firm Performance: A Longitudinal Study." *R&D Management* 37 (2): 151–160. doi:10.1111/j.1467-9310.2007.00464.x.

Tsai, K.-H., and J.-C. Wang. 2008. "External Technology Acquisition and Firm Performance: A Longitudinal Study." *Journal of Business Venturing* 23 (1): 91–112. doi:10.1016/j.jbusvent.2005.07.002.

Tsai, K.-H., and J.-C. Wang. 2009. "External Technology Sourcing and Innovation Performance in LMT Sectors: An Analysis Based on the Taiwanese Technological Innovation Survey." *Research Policy* 38 (3): 518–526. doi:10.1016/j.respol.2008.10.007.

Tsai, K.-H., M.-H. Hsieh, and E. J. Hultink. 2011. "External Technology Acquisition and Product Innovativeness: The Moderating Roles of R&D Investment and Configurational Context." *Journal of Engineering and Technology Management* 28 (3): 184–200. doi:10.1016/j.jengtecman.2011.03.005.

UNDP. 2018. "Understanding African Experiences in Formulating and Implementing Plans for Emergence: A Case Study of Growing Manufacturing Industry in Ethiopia." Addis Ababa: UNDP. https://www.et.undp.org/content/ethiopia/en/home/library/poverty/understanding-african-experiences-in-formulating-and-implementin.html.

Utterback, J. M. 1971. "The Process of Technological Innovation Within the Firm." *Academy of Management Journal* 14 (1): 75–88. doi:10.5465/254712.

Vanhaverbeke, W., G. Duysters, and N. Noorderhaven. 2002. "External Technology Sourcing Through Alliances or Acquisitions: An Analysis of the Application-Specific Integrated Circuits Industry." *Organization Science* 13 (6): 714–733. doi:10.1287/orsc.13.6.714.496.

Wakeford, J. J., M. Gebreeyesus, T. Ginbo, K. Yimer, O. Manzambi, C. Okereke, B. Mairi, and M. Yacob. 2017. "Innovation for Green Industrialization: An Empirical Assessment of Innovation in Ethiopia's Cement, Leather and Textile Sectors." *Journal of Cleaner Production* 166 (1): 503–511. doi:10.1016/j.jclepro.2017.08.067.

Wheaton, B., B. Muthén, D. F. Alwin, and G. F. Summers. 1977. "Assessing Reliability and Stability in Panel Models." *Sociological Methodology* 8: 84–136. doi:10.2307/270754.

White, M. A., and G. D. Bruton. 2011. *The Management of Technology and Innovation: A Strategic Approach*. 2nd ed. Ohio, USA: Cengage Learning, Natorp Boulevard (Mason).

Williamson, O. E. 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free press.

Williamson, O. E. 1991. "Comparative Economic Organization: The Analysis of Discrete Structural Alternatives." *Administrative Science Quarterly* 36 (2): 269–296. doi:10.2307/2393356.

World Bank. 2014. "Doing Business: Understanding Regulations for Small and Medium-Size Enterprises." Washington, DC: World Bank.

World Economic Forum. 2019. "The Global Competitiveness Report." Geneva: World Economic Forum.

Wu, W. W., Y. Yang, Q. Deng and B. Yu. 2010. "Technology Management Capability and New Product Development Performance: The Mediating Role of Absorptive Capacity." In PICMET 2010 Technology Management for Global Economic Growth. Proceedings of Portland International Conference on Management of Engineering and Technology, Phuket, Thailand, 18-22 July 2010.

Zahra, S. A., and G. George. 2002. "Absorptive Capacity: A Review, Reconceptualization, and Extension." *Academy of Management Review* 27 (2): 185–203. doi:10.5465/amr.2002.6587995.

Appendix 1. Technology management and innovation constructs and measurement items.

Item code	Constructs and measurement items	Standardized loading (λ)
Technology Process		
TP1	The amount of basic research done so far to support the company's goal towards technology was enough.	0.73
TP2	The company has given higher priority to basic research to promote the company's performance.	0.75
TP3	The company considers basic research as its main competitive and developmental advantage.	0.75
TP4	Several indigenous ideas and technologies have emerged as a result of the company's basic and applied research.	0.75

(*Continued*)

Continued.

Item code	Constructs and measurement items	Standardized loading (λ)
TP5	The willingness of the organization's research and development division to involve and collect relevant ideas from different levels of workers.	0.72
TP6	The extent to which the company relied on applied research to support the company's growth and development in technology and innovation	0.76
TP7	The company's priorities towards basic research are to promote the product features and equip laboratories with the necessary supporting equipment and inputs.	0.72
TP8	The extent to which your company regards basic research as its primary competitive and developmental advantage, as well as its inclusion in its strategic plans.	0.74
TP9	As a result of applied research done in the company, several indigenous ideas and technologies have been obtained.	0.74
TP10	Different technologies resulting from basic and applied research were identified properly for development phases regularly.	0.75
TP11	Development of technologies was done in accordance with the company's policies by screening those that have promising rewards, enhancing growth and development.	0.79
TP12	Sounding numbers of technologies from research output were identified for further screening and to have more alternatives for flexibility and decisions.	0.74
Technology Acquisition		
TAC1	Several technologies and innovative ideas and outputs have been used and marketed diligently in the past five years.	0.71
TAC2	The management of imitated technologies or innovative ideas for further research and analysis to be used as a basis to improve the existing knowledge and creativity.	0.73
TAC3	Initiation and commitment of top management and other staff in engaging themselves in imitative innovations.	0.72
TAC4	Culture has developed throughout the company in the creation of an innovative and technology-responsive society	0.65
TAC5	How do you rate the number of adopted and/or adapted technologies that have been developed and used so far in your company?	0.71
TAC6	To what extent have the adapted technologies, innovative ideas, processes, and/or products have been used so far to enhance the company's performance?	0.74
TAC7	Attempts have been made to have a strong relationship between technology providers in order to facilitate further training and joint work with them.	0.80
TAC8	The number of technologies adopted so far that have been patented and/or registered as intellectual property in the last 3 years was satisfactory.	0.76
Technology Absorption		
TAB1	The integration of basic and applied research was made to innovatively enhance the company's growth and development.	0.82
TAB2	Efforts were made to exploit the existing abilities to create and use technologies to the maximum level.	0.63
TAB3	The company had devoted its efforts to technology exploitation from other industries through technology transfer.	0.74
TAB4	To what degree did the gains obtained from technology enhance the company's performance?	0.68
Technology Transfer		
TT1	The company's strategic goals associated with technology transfer have been designed to spur innovation and get acceptance at all levels and implemented/executed accordingly.	0.70
TT2	The company performs technology planning and reviews with respect to technology transfer and innovation and makes improvements on a continuous basis.	0.72
TT3	The number of technologies transferred internally aligns with the targeted quantities of technology transfer and strategies towards technology transfer to enhance innovation.	0.73
TT4	The trend and practice of your company to monitor the technologies owned by competitors.	0.70

(*Continued*)

Continued.

Item code	Constructs and measurement items	Standardized loading (λ)
TT5	The company tracks the technologies transferred across industries and makes important amendments and improvements to improve innovation.	0.75
TT6	The company reviews important technology information periodically, and certain measures/actions are taken according to the information obtained to inspire creativity and innovation.	0.83
TT7	The company assesses technology needs across industries and tries to fill the gap with any endeavour.	0.82
TT8	The company has allotted a budget to develop one or more of its core technologies internally to transfer to another organization.	0.75
TT9	The number of technologies that were identified to be transferred to other organizations was decided in advance.	0.73
TT10	The company has a clear policy and viable strategy towards technology transfer at the firm level for strengthening new product development and managing the innovation process.	0.69
Process Innovation		
PCI1	To what extent does process innovation streamline the internal manufacturing process/activities and simplify them?	0.83
PCI2	To what extent does process innovation contribute to reducing production cycle time and/or lead time and setup times?	0.77
PCI3	How do you rate the contribution of process innovation that has been made in your organization to increase productivity?	0.73
PCI4	To what extent did the process innovation contribute to creating a conducive working environment and simplifying tasks in the company?	0.84
PCI5	To what extent did the process innovation endeavour enhance the product features and add value to the customers?	0.74
Product Innovation		
PDI1	How do you evaluate the product innovations made in your organization in the past 3–5 years?	0.71
PDI2	Is there a policy and practice towards product innovations? If so, how can you rate the level of engagement in your company?	0.82
PDI3	To what extent does the product innovation process contribute to producing products with multifunctionality, attractive design, and appearance?	0.73
PDI4	Differentiation and variety, such as new designs introduced or improved existing designs of the product, were created as a result of product innovation.	0.76
PDI5	Enhancement of existing brands regarding user-friendliness, simplified operation, and safety.	0.72
Method Innovation		
MI1	The practice and know-how of the company towards method improvement are through innovative activities.	0.76
MI2	Methods of performing internal production activities have improved as a result of innovative thinking and practice.	0.75
MI3	Contributions of methodological innovations to create a conducive working environment reduced defects and reworks.	0.86
MI4	The extent that innovative methods played a role in cutting costs by avoiding non-value-adding activities.	0.77
MI5	The contribution of innovative methodologies to improve delivery times and methods enhances customers' experience with the company.	0.79

Note: All items are measured on a five-point scale, ranging from 1 (nothing was done) to 5 (very good).