Innovation and Development Policy
Available online at http://idp-journal.casisd.cn/

# Technology Transfer and Its Impact on Agribusiness Performance: Insights from Pakistan

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## Abstract

This study explores the impact of technology transfer on the performance of small agricultural businesses in developing economies, focusing on Pakistan, using the Barry Bozeman Contingent Effectiveness Model of Technology Transfer as its theoretical framework. A sample of 107 enterprises was analyzed using Structural Equation Modeling (SEM) to test hypotheses and fuzzy-set Qualitative Comparative Analysis (fsQCA) to identify configurational pathways. SEM results show that transfer providers, mechanisms, resource availability, and the demand environment significantly enhance firm performance, while recipient absorptive capacity does not exhibit a statistically significant effect. The fsQCA identifies two distinct configurations for achieving high firm performance: the first solution emphasizes the presence of robust transfer mechanisms, transfer providers, recipient capacity, and resource availability, while the second highlights a strong demand environment, effective transfer mechanisms, and adequate resources, with recipient capacity playing a peripheral role in both. These findings emphasize the need for governments to develop targeted plans for technology transfer with small agricultural businesses, focusing on resource allocation, efficient systems, and market-driven demand. Policies should include specific incentives for agrarian technology transfer to enhance efficiency and strengthen food security measures.

## Keywords

Technology transfer; Agribusiness; Developing Countries; Small businesses; Rural development

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10.20046/j.cnki.2096-5141.2025.0001

## 1. Introduction

Globalization's profound influence, coupled with rapid technological advancement, significantly shapes economic growth and national competitiveness. Technology transfer is essential in reducing reliance on foreign aid and technical expertise in developing countries due to the growing need for efficient and contemporary business practices (Joensuu-Salo *et al*., 2018). Technology transfer objectives depend upon the recipient sector's needs and context. In the case of economic development, technology transfer enhances the production capacity of a firm project or a country; whereas, in the case of agriculture, it might focus on improving productivity, sustainability, agricultural practices, or advancing technological literacy. Technology transfer is a strategic tool to bridge the technological and managerial competence divide among nations, facilitating the integration of developing countries into the global landscape along with a comprehensive, sustained plan for advancing technology and skill development for the long term (Chege *et al*., 2019; World Bank Report, 2017).

Scholarly perspectives on technology transfer exhibit diversity. From an evolutionary perspective, foreign transnational corporations are seen as pivotal agents in technology transfer, crucial in advancing technology among local suppliers in recipient countries. Given the constrained ability of many developing countries to generate indigenous knowledge, external technology transfer emerges as a predominant mechanism for importing technology into these countries (World Bank Group, 2017). Researchers have determined that technology transfer success relies heavily on countries or companies' capacity to acknowledge, generate, absorb, and spread technological expertise (Chege *et al*., 2019).

This study, focusing on Pakistan, explores how technology transfer impacts small agricultural businesses. It systematically examines dimensions within Pakistan's dairy farming, investigating components like the transfer medium, object, agent, demand, and recipient characteristics. Dairy is vital to Pakistan's economy. Livestock and dairy contribute 60.6% to agriculture and 11.7% to Pakistan's GDP. As the fourth global dairy producer, 97% is fresh milk, with 3% processed. Most dairy farms are smallholding, engaging in market-oriented or subsistence farming (Ministry of Commerce, 2022). Pakistan's average annual milk production is 50 million tons in the last decade, led by Punjab and Sindh provinces, with contributions from Khyber-pukhtukhwa (KPK) and Baluchistan (MNFSR, 2023).

Production distribution in Pakistan is approximately 63% in Punjab, 23% in Sindh, 12% in KPK, and 2% in Baluchistan (Ministry of Commerce, 2022). The dairy sector contributes to 45% of the employment and is a vital source of inputs for the agro-based industry (Khan *et al*., 2013). In agriculture, technology transfer involves adopting new techniques to boost crop yields. Farmers rely on this process to access modern knowledge and methods, enhancing production capabilities and maintaining a competitive edge (Jagoda *et al*., 2010) . Hence, scholars and practitioners recognize the significant role of technology transfer in bridging the knowledge gap between developed and developing countries (Chege and Wang, 2020a).

The Pakistan Agriculture Technology Transfer Activity (PATTA), financed by the US Agency for International Development (USAID), aimed to enhance agricultural technology adoption by mobilizing private sector investments, increasing access to modern technologies for small-scale farmers, boosting market demand for agri-tech products, and strengthening agro-technology companies. PATTA significantly improved smallholder farmers' access to financing, markets, and technology (PATTA, 2018; Shahid, 2023). Additionally, the government has launched initiatives such as the Prime Minister's Agriculture Emergency Program, which provides financial incentives for modernization and subsidies for machinery (Pakistan Agricultural Research Council, 2021). Agricultural extension services further support farmers by educating them about new technologies and practices.

Despite considerable government support for agribusiness in Pakistan, a notable gap persists between agribusiness expansion and technology adoption. Gunsel *et al*. (2019) highlight the barriers to implementing new technologies in developing countries, emphasizing the complexities and slow adoption rates that hinder progress. Similarly, Elahi *et al*. (2018) indicate that in Pakistan, low adoption of advanced technologies has created a gap between potential and actual production methods. Inadequate access to financing, limited infrastructure, and a lack of technical knowledge all contribute to these problems (Khan *et al*., 2021). As a result, the farming community continues to rely on archaic practices, limiting their access to modern agricultural technologies, and farmers are unable to implement contemporary agricultural techniques, resulting in considerable productivity losses.

While government subsidies exist to encourage modernization, many small farmers struggle to secure the necessary capital and guidance to leverage these technologies effectively. Additionally, bureaucratic inefficiencies can delay program implementation, underscoring the urgent need for more targeted and localized strategies to bridge the gap between agribusiness growth and technology adoption (Bhutto and Bazmi, 2007).

Researchers have elucidated why agribusiness has yet to fully embrace technology transfer and reap substantial advantages from it (Chege *et al*., 2019). However, much research has centered on examining the dynamics within the relationship of technology transfer (Han and Lee, 2011). The study of Tsai and Wang (2008) explored the relationship between technology transfer and firm performance, while others, including Battistella *et al*. (2016), Günsel (2015), and Han and Lee (2011) along with Muturi *et al*. (2013) scrutinized three elements—market performance, finance, and product—that impact both technology transfer and firm performance.

These studies investigate the impact of technology transfer, focusing on the transfer of technology dimensions. Limited attention is given to other aspects that could benefit Pakistan's dairy sector. Agribusiness in Pakistan struggles with low productivity and high unemployment due to a lack of essential skills for agricultural technology innovation (Bhutto and Bazmi, 2007). Technology transfer is vital for national economic growth (Cinar *et al*., 2021). Günsel (2015) emphasizes that successful technology transfer is essential for firm performance, as organizational success and economic growth rely on efficient technology transfer and a robust innovation system that effectively links the transferor with the recipient. Studies of technology transfer in Pakistan's agricultural sector SMEs are limited despite growing developments (Sherazi *et al*., 2013). This research explores the impact of technology transfer on dairy agribusiness in Pakistan, addressing questions on its performance and challenges. It emphasizes the need for context-specific solutions and efficient technology transfer to meet the needs of small-scale farmers and ensure sustainability. The research advocates integrating various dimensions of technology transfer to enhance understanding and guide future research in this field.

## 2. Literature Review and Hypothesis Development

Technology transfer initiates innovations through distribution and practical implementation (Saen, 2006). Technology encompasses processes, knowledge, means, procedures, products, and systems used to produce goods and services, influencing how we operate (Farhadikhah and Husseini, 2015). Technology transfer aims to promote awareness of new technologies, gain a competitive edge, foster strategic initiatives, and enhance production capabilities across industries (Gibson, 2005). When implemented effectively, technology transfer offers limitless potential benefits (Bozeman, 2015). The agricultural technology process transfers values, skills, knowledge, and best practices from the production site to the location where they are applied, enhancing farm production (Mgendi *et al*., 2019).

Agricultural technology innovation is essential for economic development and human dignity in developing countries (Takahashi *et al*., 2020). Adopting emerging technologies fuels essential advancements in livestock development (Rehman *et al*., 2016). Transferring agricultural technology aims to enhance local technological capacities and achieve broader socio-economic objectives (Adegbola and Gardebroek, 2007; Bandiera and Rasul, 2006; Case, 1992). The technology deficit in Pakistan's agriculture sector is primarily due to low adoption rates of technological advancements (Aslam, 2016). Therefore, examining factors influencing farmers' tech adoption for poverty reduction is essential. The dairy industry sees growth and evolution in production, marketing, genetics, breeding, and value enhancement. The dairy industry produces milk and contributes to fertilizer, asset storage, and wealth generation; It also generates employment in marketing, veterinary services, as well as in animal feed, extension, and breeding (Otto, 2003).

Academic scholars have elucidated agribusiness as enterprises intricately embedded within the agricultural value chain (Chege *et al*., 2019). The farm value chain involves producers, farmers, intermediaries, and service providers. It aims to improve farmers' skills through education and support services, focusing on food production in rural areas. However, the limited availability of suitable technology hinders businesses from expanding their market reach and enhancing value addition, impeding overall progress.

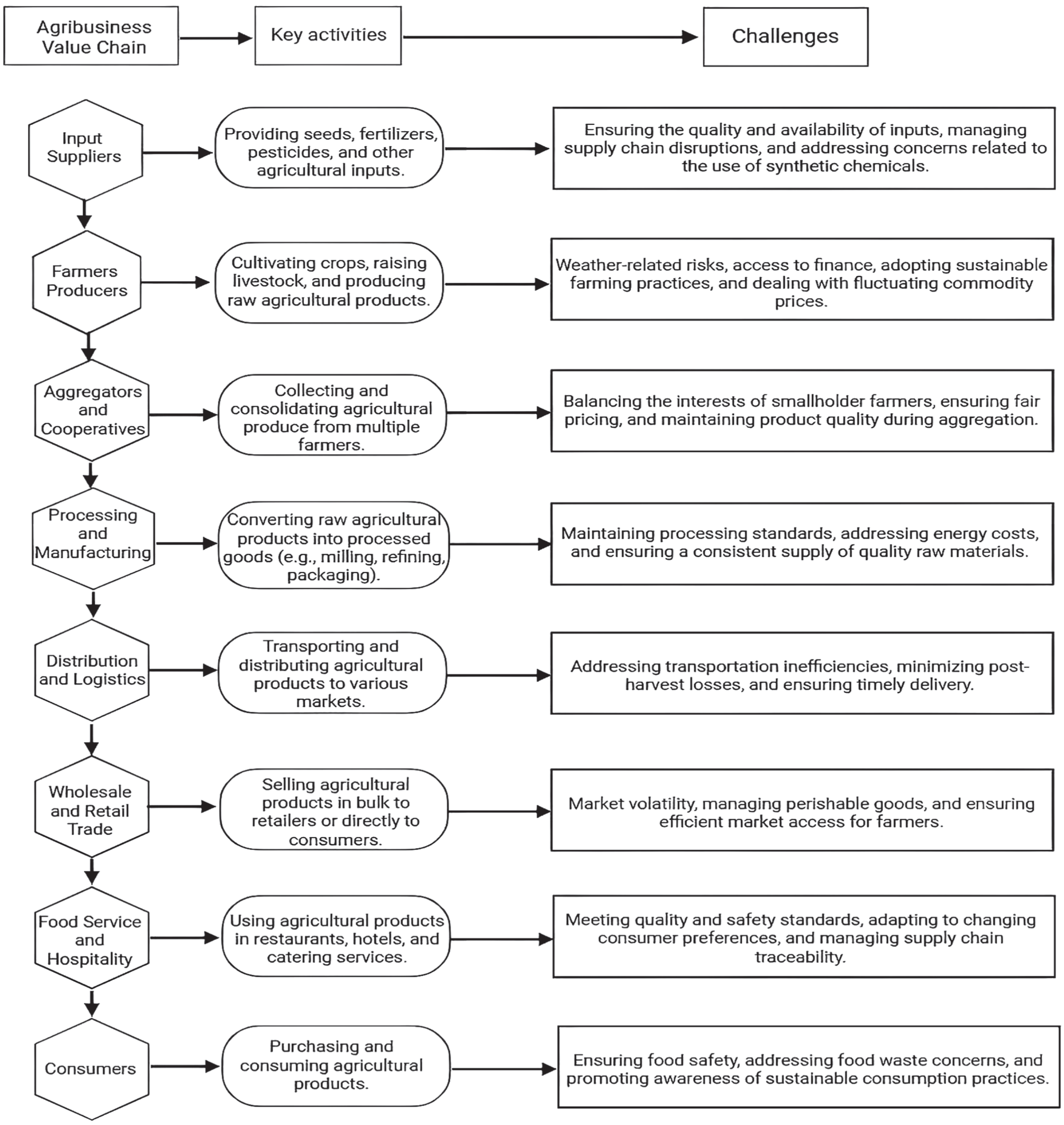


**Fig. 1.** Agriculture business value chain and associated challenges.

*2.1. Theoretical framework*

Research on technology transfer has delved into various factors impacting the process (Kumar and Garg, 2015). Ahmad and Iqbal (2004) studied agriculture in Pakistan highlighting responsible pesticide and fertilizer use and advocating for government support. Azumah *et al*. (2018) emphasized the significant role of technology transfer in Ghana's agricultural production. Awan and Aslam (2015) found positive links between workforce, agriculture value added, trade openness, and GDP, advocating for education and government support. Nakano *et al*. (2018) investigated integrating networks in technology transfer, while Aker (2011) emphasized the potential of advanced technologies in agriculture. Lee *et al*. (2018) examined factors and barriers in technology transfer.

Lu and Peng (2018) explores technology transfer in rural Laos, addressing poverty issues in Yao villages. Han and Lee (2011) investigated the positive impact of technology transfer induced by international trade on the development of underdeveloped economies, focusing on licensing technology and fostering business development (Chege *et al*., 2019). These procedures involve generating new technology, evaluation, venture capital, financial backing, joint ventures, spin-offs, technology licenses, spin-ins, and business growth. Technical complexity, owner's pedagogical skills, recipient's learning capacity, and complex relationships collectively influence technology transfer (Lee *et al*., 2018).

Evaluating a technology transfer project's impact is complex, especially for intangible benefits. A balanced scorecard, considering market, financial, technological, and organizational perspectives, provides a strategic solution (Jagoda *et al*., 2010). Strategic public policies can enhance agribusiness capacities, facilitate knowledge dissemination, and support research and development. Innovation sources and user networks significantly influence technology transfer dynamics and the adoption of new ideas by potential customers (Lee *et al*., 2018). This research uses Barry Bozeman contingent effectiveness model of technology transfer, as this model particularly suited to this study because it directly addresses the five key dimensions critical to effective technology transfer, including transfer mechanisms, provider

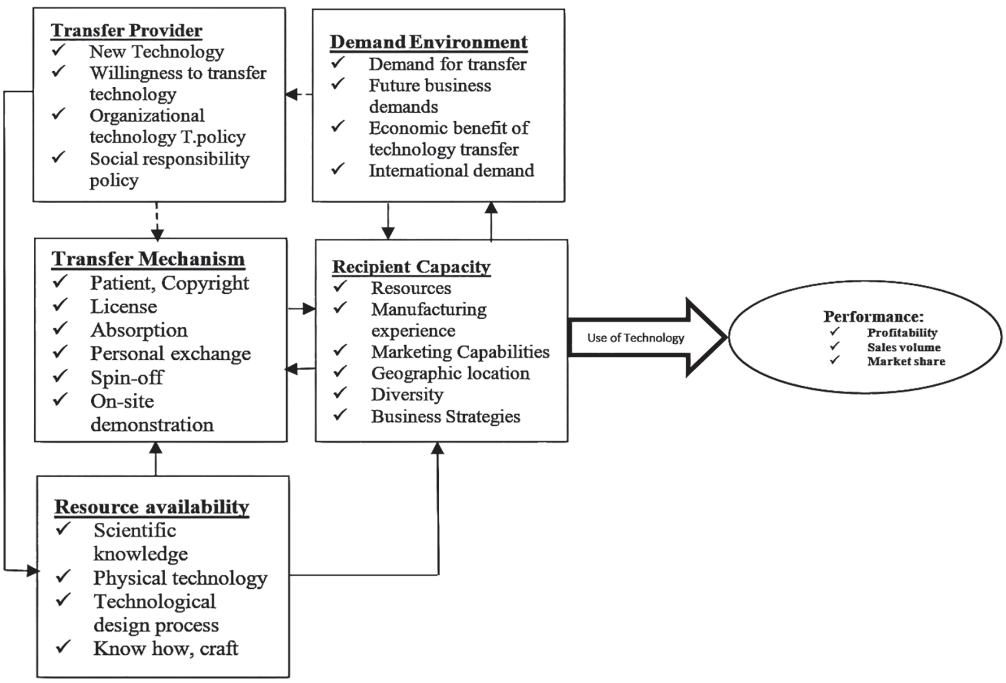


**Fig. 2.** Proposed model of technology transfer (Bozeman *et al*., 2015).

characteristics, demand environment, resource availability, and recipient absorptive capacity which are all essential in understanding the challenges faced by agribusiness in Pakistan (Bozeman *et al*., 2015), as depicted in Fig. 2. Unlike alternative models, such as the linear model of innovation or open innovation model, Bozeman's framework accounts for the complex and context-specific factors unique to developing countries, such as limited resources, diverse infrastructure, and sector-specific needs (Chesbrough, 2003; Godin, 2006). This makes it the most fitting theoretical framework for analyzing technology transfer in the context of Pakistan's rural agribusiness sector (Chege and Wang, 2020b; Sazali *et al*., 2009).

### *2.2. Determinants impacting the process of technology transfer*

#### *2.2.1. Transfer providers*

The technology transfer involves a donor disseminating knowledge and a recipient assimilating and utilizing the shared technology (Da Silva *et al*., 2019). The technology transfer process, despite its simplicity, is notably complex (Maskus, 2004). Given its intricate nature, This study delves into fundamental concepts and barriers of technology transfer, including provider and recipient capacity and the demand environment (Gunsel *et al*., 2019; Baranson, 1970). Technology transfer providers play a vital role in exchanging scientific knowledge and innovative technologies, influencing the effectiveness of the transfer process (Bozeman, 2000). Technology transfer entities include government agencies, NGOs, universities, community based organizations and research institutions, offering direct access to research services and results (Gauchan *et al*., 2003). Research associations, chambers of commerce, technology agencies, and centers collaborate to introduce modern technology into the transfer process, relying on the expertise of the transferor's team and the efforts of the importing firm's employees. Based on existing literature, the study proposes the following:

*H1: Transfer providers positively influence the performance of agribusinesses.*

#### *2.2.2. Transfer mechanism/channels*

Technology transfer is a flexible and collaborative process designed to share skills and knowledge between organizations through various contact mechanisms (Guan *et al*., 2006). Scholars categorize the transfer of technology into vertical and horizontal classifications (Autio and Laamanen, 1995; Grosse, 1996). Horizontal technology transfer occurs within the same stage of the innovation process or between similar phases in one or more organizations, while vertical technology transfer involves moving technology between different stages of the innovation process (Jafari *et al*., 2014). Horizontal technology transfer faces challenges due to diverse specializations among individuals involved and language barriers between recipients and provider's staff. Leveraging insights from existing literature, the study presents the following propositions.

*H2: Transfer channels positively influence the performance of agribusiness.*

#### *2.2.3. Demand environment*

The demand environment is essential for promoting innovation and accelerating technology transfer by providing new ideas that enhance business growth (Omato and Kithinji, 2013). The demand for technology can be categorized as either market-push or market-pull (Dalpé *et al*., 1992). The demand environment's impact on technological innovation influences technology transfer decisions for economic sectors, reflecting conflicting perspectives on recipients' capacity and willingness to adopt technology (Chege and Wang, 2020a). Additionally, the market demand stimulates innovative initiatives, resulting in heightened levels of innovation (Pikkarainen *et al*., 2012). Small-scale farmers in rural regions face challenges like erratic rainfall patterns, limited market access, insufficient value-adding facilities, untrained workers, and inadequate infrastructure (Shange, 2014). To succeed in a globally competitive market, businesses must leverage new technology transfer opportunities to gain market shares and meet customer needs (Noori, 1987). Based on literature, the study presents the following propositions.

*H3: Demand Environment has a positive impact on Agribusiness Performance.*

*2.2.4. Resource availability*

Organizational resources, including tangible and intangible assets like physical assets, technology, information, and managerial skills, play a crucial role in supporting innovative activities and technology transfer. Firms must effectively manage their limited resources, such as market position, technological information, intangible assets, and human capital, aligning innovative initiatives with organizational goals. The resource-based perspective views these resources as capabilities and essential building blocks for establishing a competitive edge and fostering growth within the firm (Park and Lee, 2011). Firms need help when implementing technology transfer, if they require additional resources that are both costly and challenging to reproduce within a specific time frame (Serry, 1998). Survival in agribusiness relies not only on overcoming hurdles and securing finances but also on the successful implementation of technology transfer, strongly linked to positive results. Based on literature, the study presents the following propositions:

*H4: Resource availability of technology transfer positively influences the SMEs' performance.*

*2.2.5. Recipient absorptive capacity*

Recipient absorptive capacity involves the firm's proficiency in recognizing, acquiring, assimilating, and applying transferred technology, requiring technical capabilities for selecting and integrating the technology within the business (Odagiri, 2003). Recipient's absorptive capacity is important for successful technology transfer (Stock *et al*., 2001; Whangthomkum *et al*., 2006). However, limited research has explored the impact of absorptive capacity on technology transfer, especially within individual firms (Lin *et al*., 2002; Whangthomkum *et al*., 2006). Absorptive capacity is the proficiency in applying newly acquired technological knowledge from external sources (Li, 2011). A recipient with strong absorptive capacity can effectively utilize transferred technology, fostering innovation and business growth (Tsai and Wang, 2008). Scholars commonly measure absorptive capacity using company size and R&D intensity (Battistella *et al*., 2016; Hervas-Oliver *et al*., 2012). However, there's a lack of analysis on the owners' capacity to effectively embrace and adopt new technologies. Based on the literature, the study presents the following propositions:

*H5: The recipient's absorptive capacity to adopt transferred technology improves agriculture business performance.*

## 3. Data and Method

*3.1. Respondents' biodata*

This study employed a quantitative approach using a semi-structured questionnaire developed based on prior theoretical work (Zikmund *et al*., 2010; Jankowicz, 2011). To ensure validity, the survey's framework and variables were reviewed through consultations with agricultural practitioners and academic experts. After revisions, the finalized questionnaire was administered to participants. The survey was conducted between January and March 2024, with 158 questionnaires distributed. A total of 113 responses were received, yielding a 71.5% response rate. After quality screening, 107 valid responses were retained for analysis, resulting in a 75% usable response rate (Jankowicz, 2011). Table 1 presents the respondents' biodata. The majority (74.77%) were male, and 47.66% were aged 31–36 years. Nearly 48% of participants had secondary education, which influences how respondents interpret the questionnaire and their absorptive capacity for technology transfer.

**Table 1**
Sample profile.

| Item | Classification | Frequency | Percentage |
|---|---|---|---|
| Age | 18–25 years | 14 | 13.08 |
| | 26–30 years | 21 | 19.63 |
| | 31–36 years | 51 | 47.66 |
| | Above 37 years | 21 | 19.63 |
| Gender | Male | 80 | 74.77 |
| | Female | 27 | 25.23 |
| Experience | 1–2 years | 23 | 21.50 |
| | 3–4 years | 27 | 25.23 |
| | 5–6 years | 57 | 53.27 |
| Education level | Bachelors | 15 | 14.02 |
| | Diploma | 12 | 11.21 |
| | Secondary certificate | 51 | 47.66 |
| | Primary certificate | 29 | 27.10 |
| Employees | 1–5 | 53 | 49.53 |
| | 6–10 | 36 | 33.64 |
| | Above 10 | 18 | 16.82 |
| Business category/ | Livestock/daily farming | 83 | 77.57 |
| sector | animal feeds/Crop | 24 | 22.43 |

*3.2. Methods of agribusiness technology transfer*

The methods of technology transfer identified by survey respondents are summarized in Table 2. These findings affirm earlier observations (Chege and Wang, 2020a; Okello and Ireri, 2017). Farmers' technology usage fosters knowledge exchange, particularly through mobile devices, enabling access to agricultural expertise from different sources.

*3.3. Sampling and research instruments*

This research adopt a quantitative approach, focusing on evaluating managers in agribusiness enterprises in Punjab, Pakistan, given the region's agricultural significance (Azam and Shafique, 2017).

**Table 2**
Methods of technology transfer in agribusiness.

| Approach to the technology transfer process | Mean | SD |
|---|---|---|
| **Mass media** | | |
| Mobile phone | 2.683 | 1.567 |
| TV program | 2.938 | 1.690 |
| Newspaper/magazine | 1.551 | 1.132 |
| Radio | 3.412 | 1.651 |
| **Social media** | | |
| WhatsApp/ Facebook/TikTok | 1.753 | 1.235 |
| **Institutional exhibition/conference** | | |
| Agricultural seminars | 3.467 | 1.471 |
| Demonstration farms | 4.610 | 0.993 |
| University exhibitions | 2.324 | 1.432 |
| Ministry of agriculture extension services | 3.631 | 1.511 |
| NGOs | 2.361 | 1.511 |
| **Inter-farmer collaborations** | | |
| Farmer-to-farmer | 4.487 | 1.769 |

N = 107, The Mean is determined on a five-point-Likert-scale

Agriculture dominates Pakistan's economy, involving crop cultivation, livestock, fish farming, and beekeeping. Punjab, the most populous province, leads in national agricultural production, employing 48% of the population and contributing 19% to GDP. The majority of Pakistan's exports are agricultural, with Punjab contributing 60% (Government of Punjab, 2022). Punjab, the second-largest province in Pakistan, covers 25.9% of the total landmass (20.63 million hectares). Of this, 72% is open for cultivation, with 53% actively cultivated annually. Another 9% is fallow, and 8% is classified as culturable waste, remaining uncultivated for over three years (Government of Punjab, 2022). The second characteristic is that Punjab is an arid to semi-arid region, mainly flat, benefiting from the presence of five rivers that contribute significantly to agricultural productivity (Environment & Department, 2017). The research employed random sampling to select around 260 properly registered and licensed agribusiness enterprises operated by young individuals, ensuring the representativeness and adequacy of the sample for statistical analysis (Dattalo, 2008; Marshall *et al*., 2013). However, the required sample size may vary based on the statistical analysis, and the literature reflects diverse perspectives, even when employing the same analytical tools. According to Chege and Wang (2020a) and Williams (2007), a sample size ranging from 10% to 30% is deemed satisfactory when the population consists of more than 30 elements. In line with this criterion, a sample comprising 158 firms were selected based on the formula proposed by Israel (2012).

*3.4. Variable measurement*

The measurement framework for key variables was tailored to the study's context by refining established constructs from existing literature. The framework for measuring key variables was customized to fit the specific context of this study, refining established constructs from the literature to align with the research's unique goals and operational needs. The constructs related to transfer providers were adapted from prior works (Battistella *et al*., 2016; Chege and Wang, 2020a). Modifications to the constructs concerning the transfer mechanism were made based on earlier studies (Bozeman, 2000; Chege and Wang, 2020a; Han and Lee, 2011). Furthermore, the constructs for resource availability were updated and adapted based on the work of Almarri and Gardiner (2014), Chege and Wang (2020a), and Jabar and Soosay (2010). The construction of recipient absorptive capacity was drawn from earlier studies conducted by Azagra-Caro *et al*. (2006), Buratti and Penco (2001), Chege and Wang (2020a) and Jabar and Soosay (2010). Demand environment variables were derived from the works of Chege and Wang (2020a), Jasinski (2009) and Omato and Kithinji (2013); and firm performance measures were influenced by previous research by Chege and Wang (2020a), and Mohd Sam and Hoshino (2013).

**Table 3**
Measurement items.

| Construct | Item | Source |
|---|---|---|
| Transfer Provider (TP) | TP 1<br>TP 2<br>TP 3<br>TP 4 | (Chege and Wang, 2020a) |
| Resource Availability (RA) | RA 1<br>RA 2<br>RA 3<br>RA 4<br>RA 5 | (Almarri and Gardiner, 2014; Chege and Wang, 2020a; Jabar and Soosay, 2010) |
| Demand Environment (DE) | DE 1<br>DE 2<br>DE 3<br>DE 4 | (Chege and Wang, 2020a; Jasinski, 2009) |
| Recipient Absorptive Capacity (RAC) | RAC 1<br>RAC 2<br>RAC 3<br>RAC 4<br>RAC 5 | (Azagra-Caro *et al*., 2006; Buratti and Penco, 2001; Chege and Wang, 2020a; Jabar and Soosay, 2010) |
| Forms of Transfer Mechanism (FTM) | FTM 1<br>FTM 2<br>FTM 3<br>FTM 4<br>FTM 5 | (Bozeman, 2000; Chege and Wang, 2020b; Han and Lee, 2011) |
| Firm Performance (FP) | FP 1<br>**FP 2**<br>**FP 3** | (Chege and Wang, 2020a; Mohd Sam and Hoshino, 2013) |

*3.5. Analytical methods*

This research utilized Structural Equation Modeling (SEM) and fuzzy-set Qualitative Comparative Analysis (fsQCA) for data analysis. SEM was initially employed to test hypotheses concerning the effects of the transfer provider, transfer mechanism, resource availability, demand environment, and recipient absorptive capacity on firm performance in Pakistan's agricultural sector. Building on the recommendations by Woodside (2013), the study also implemented a contrarian case analysis to uncover asymmetric situations and identify contrasting patterns. This method aims to reveal distinct configurations of these independent variables and their impact on firm performance. The study recognizes that traditional quantitative methods, such as multiple regression, have limitations in accounting for complex variable interactions (Shalev, 2007). To address these limitations, the research integrates fsQCA alongside conventional statistical methods to identify causal configurations and solution pathways that influence firm performance outcomes within the agricultural sector.

*3.6. Calibration*

The analysis utilizes a two-step fsQCA framework to assess causal relationships. Initially, the method assigns membership scores from 0.0 (representing complete non-membership) to 1.0 (complete membership), allowing for a detailed mapping of semi-qualitative datasets. This scaling approach aligns with the study's mixed-data structure, where precise categorization of cases is critical. Second, fsQCA derives logical combinations of antecedent conditions (e.g., resource availability, absorptive capacity) that collectively suffice to explain variations in firm performance. These Boolean configurations reveal distinct pathways terminated "sufficient solutions" — through which agricultural enterprises achieve performance outcomes. For variable calibration, the methodology adheres to the standardized transformation protocols established in recent fsQCA literature (Pappas and Woodside, 2021). The study operationalizes Likert-scale responses into fuzzy-set values using a three-anchor calibration system. Specifically, the highest Likert score (5) is assigned to have a full membership value of 0.95, while the lowest score (1) corresponds to full non-membership (0.05). A neutral response (score = 3) serves as the crossover threshold (0.50), delineating the transition between membership states. Solutions are retained only when surpassing a consistency threshold of 0.90, ensuring robust causal inference.

Following the mentioned calibration procedure (Ragin, 2009), the outcome variable 'firm performance' was calibrated as 'fs_ firm performance'. The condition variable 'transfer providers' was calibrated as 'fs_ transfer providers', 'transfer mechanisms' was calibrated as 'fs_ transfer mechanisms', 'resource availability' was calibrated as 'fs_ resource availability', and 'demand environment' was calibrated as 'fs_ demand environment' and 'recipient absorptive capacity' was calibrated as 'fs_ recipient absorptive capacity'.

*3.7. Integrated methodology*

By merging SEM with fsQCA, the analysis uncovers both linear relationships and complex causal pathways shaping agricultural firm performance in Pakistan. This dual framework clarifies how the interplay of transfer providers, transfer mechanisms, resource availability, demand environment dynamics, and recipient absorptive capacity collectively drive rural development outcomes. The SEM-fsQCA synergy enhances methodological rigor, offering granular insights into both standalone and combinatorial effects of these factors.

## 4. Results

*4.1. Common method bias*

To evaluate potential common method bias, the study conducted Harman's Single-Factor Test. The analysis showed that the average squared method factor loadings of 25 items (0.392) were lower than the average squared substantive construct loadings (0.602). These results (Annexure 1) confirm that common method variance was not a critical threat to the validity of the dataset.

*4.2. Reliability and validity*

The analysis first assessed instrument reliability by examining convergent and discriminant validity. Construct validity was evaluated through Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) measure, which quantifies sampling adequacy for all variables. As recommended by methodological standards (Özdamar, 2002), the KMO index exceeded the minimum threshold of 0.6, confirming suitability for factor analysis. Results confirmed the suitability of the data for factor analysis, with both tests meeting statistical thresholds (see Table 4).

**Table 4**
KMO bartlett's test.

| | |
|---|---|
| Kaiser–Mayer–Olkin measures of sampling adequacy | 0.784 |
| Bartlett's Test of Sphericity | |
| Approx. chi-square | 4303.931 |
| df | 425 |
| Sig | 0.000 |

Note: A Sig-value less than < 0.05 in Bartlett's Test indicates that factor analysis is appropriate for this data.

The analysis revealed a cumulative explained variance of 66.58%, which exceeded the widely accepted threshold of 60% (Özdamar, 2002), thereby meeting the criteria for robust dimensionality or factor retention in the dataset. Bartlett's Test of Sphericity produced a statistically significant result chi-square 4,303.931 and significant p (0.000) < 0.05, confirming that the variables exhibit substantial correlations, thereby validating their suitability for subsequent multivariate analysis. The all-item factor loading of each scale exceeds 0.5 (Hair *et al*., 1998). All factors had loadings above 0.6, confirming convergent validity. The analysis of the data indicates that the measurements exhibited satisfactory convergent validity. According to Fornell and Larcker (1981), the composite reliability of the measurements should meet or exceed a threshold of 0.6. The findings revealed that all latent variables achieved composite reliability values within the range of 0.83 to 0.88, meeting or exceeding the required threshold. Furthermore, the consistency of the constructs was evaluated through Cronbach's alpha (α) to assess the internal reliability of the measurement scales. According to the Cronbach's alpha test, the overall reliability scores ranged from 0.76 to 0.89 (refer to Table 5), which exceeds the minimum acceptable threshold of 0.7 as proposed by Nunnally (1978). A Cronbach's alpha value of 0.7 or higher is generally considered indicative of a reliable scale, as stated by O'Leary-Kelly and Vokurka (1998). The alpha values for the six constructs varied from 0.76 to 0.89, confirming that all the constructs displayed robust reliability. In addition, convergent and discriminant validity were examined by calculating the average variance extracted (AVE). As per Bagozzi *et al*. (1988) the minimum AVE threshold is 0.5. In this study, the AVE values for all measurements ranged from 0.51 to 0.66, exceeding the recommended threshold. This indicates that the study achieved adequate levels of both convergent and discriminant validity.

**Table 5**
Factor loadings, average variance extracted (AVE), eigenvalues, and composite reliability (CR) for construct measures.

| S.NO | Variable constructs Measures (Cronbach's alpha) | Factor loading | Eigenvalue | AVE | CR |
|---|---|---|---|---|---|
| | **A. TRANSFER PROVIDER (α = .872)** | | 12.912 | 0.576 | 0.871 |
| 1. | Collaboration and linkages facilitate the transfer. | 0.832 | | | |
| 2. | The personnel are ready and culturally aligned for technology transfer. | 0.939 | | | |
| 3. | The providers possess sufficient resources for technology transfer. | 0.737 | | | |
| 4. | The transfer personnel have scientific and technological expertise. | 0.876 | | | |
| | **B. FORMS OF TRANSFER MECHANISM (α = .898)** | | 6.112 | 0.665 | 0.883 |
| 1. | Technology transfer occurs through training and coaching. | 0.776 | | | |
| 2. | Technology transfer predominantly utilizes mass media channels. | 0.799 | | | |
| 3. | The transfer provider employs onsite demonstration and incubation. | 0.876 | | | |
| 4. | Technology transfer requires patents, copyright, licensing, and collaborations. | 0.810 | | | |
| 5. | Chosen transfer methods enhance innovation and adaptation in firm. | 0.878 | | | |
| | **C. RECIPIENT ABSORPTIVE CAPACITY (α = .879)** | | 1.298 | 0.513 | 0.843 |
| 1. | Technology applications are designed to be user-friendly. | 0.867 | | | |
| 2. | Our business is competitively equipped to adopt new technology. | 0.763 | | | |
| 3. | Regular training sessions are conducted for new technology's adoption. | 0.712 | | | |
| 4. | Is adopting new technology easy, regardless of new functionality? | 0.725 | | | |
| 5. | I am experienced and familiar with using new technology. | 0.734 | | | |
| | **D. DEMAND ENVIRONMENT (α = .892)** | | 1.326 | 0.661 | 0.831 |
| 1. | The government policy promote TT. | 0.722 | | | |
| 2. | Technology transfer has economic benefits for our business. | 0.717 | | | |
| 3. | Supplier and customers demand influence TT decision. | 0.835 | | | |
| 4. | Stiff competition in agribusiness sector that necessitates TT. | 0.765 | | | |
| | **E. RESOURCE AVAILABILITY (α = .832)** | | 1.172 | 0.563 | 0.887 |
| 1. | Lack of capital to implement TT limits firm performance. | 0.700 | | | |
| 2. | Collaborations provide access to more TT resources. | 0.811 | | | |
| 3. | Government support for agricultural TT. | 0.765 | | | |
| 4. | Collaborated with university and research institutions to boost TT. | 0.778 | | | |
| | **F. FIRM PERFORMANCE (α = .765)** | | 1.243 | 0.645 | 0.831 |
| 1. | Increased profitability. | 0.888 | | | |
| 2. | Sales volumes. | 0.754 | | | |
| 3. | Increased market access and expansion. | 0.725 | | | |

*4.3. Hypothesis testing*

The SEM approach was utilized to investigate the relationships between the constructions proposed in the study. The SEM analysis was conducted using AMOS version 24, which simultaneously evaluated the goodness-of-fit indices. The results demonstrated a strong model fit, as indicated by the following statistical measures: Chi-square/df = 1.153, CFI = 0.983, TLI = 0.989, IFI = 0.986, GFI = 0.931, RMSEA = 0.020, and SRMR = 0.047 (see Table 6). These values collectively support the robustness of the model. Hu and Bentler (1999) and Yuan *et al*. (2016) emphasized that RMSEA, TLI, and CFI are critical indices for assessing model fit. In line with this, the study proposed and tested five hypothesized paths to evaluate the structural relationships within the model.

**Table 6**
Model fit.

| Goodness of fit indices | Constructs |
|---|---|
| $X^2$ /degree of freedom | 1.153 |
| CFI (comparative fit index) | 0.983 |
| TLT (Tusker–Lewis fit index) | 0.989 |
| IFI (incremental fit index) | 0.986 |
| RMSEA (root mean square error) | 0.200 |
| GFI (goodness fit index) | 0.931 |
| SRMR (root mean square residual) | 0.47 |

Fig. 3 presents a SEM that illustrates the relationships between key factors affecting agribusiness performance, such as Transfer Provider (TP), Resource Availability (RA), Demand Environment (DE), Form of transfer mechanisms (FTM) and Recipient Absorptive Capacity (RAC). The arrows represent the relationships between these variables, with path coefficients showing the strength of these connections. This model helps explain how different factors contribute to or hinder the successful impact of technology transfer on agribusiness outcomes. The results revealed that all hypothesized paths were statistically significant ($p < 0.05$), except for H5 (Recipient Absorptive Capacity → Firm Performance), which did not show a significant relationship. A SEM model reveals that key factors TP, FTM, RA, and DE all directly and positively affect firm performance, with the exception of RAC. The entire paths in this model were significant at $p < 0.05$ TPs directly influence the performance of agribusinesses. The statistical results show that TPs have a positive effect on agribusiness performance. Therefore, this hypothesis (H1) is accepted at $p < 0.05$. The effectiveness of technology transfer relies heavily on the capabilities of the technology provider and the appropriate dissemination of technical knowledge and expertise through methods such as on-site demonstrations, workshops, and exhibitions.

The study shows that transfer channels directly contribute to the performance of agribusinesses. The results indicate that TM play a pivotal role in enabling the smooth movement of technology and resources, which in turn boosts agribusiness performance. This hypothesis (H2) is validated by statistical results, with significance at $p < 0.05$. The DE contributes to fostering innovation and speeds up technology transfer by offering insights that support business development and growth. Technology demand can be classified into two categories: market-push and market-pull, which both influence technology transfer decisions in economic sectors. Statistical findings confirm that a conducive DE has a significant

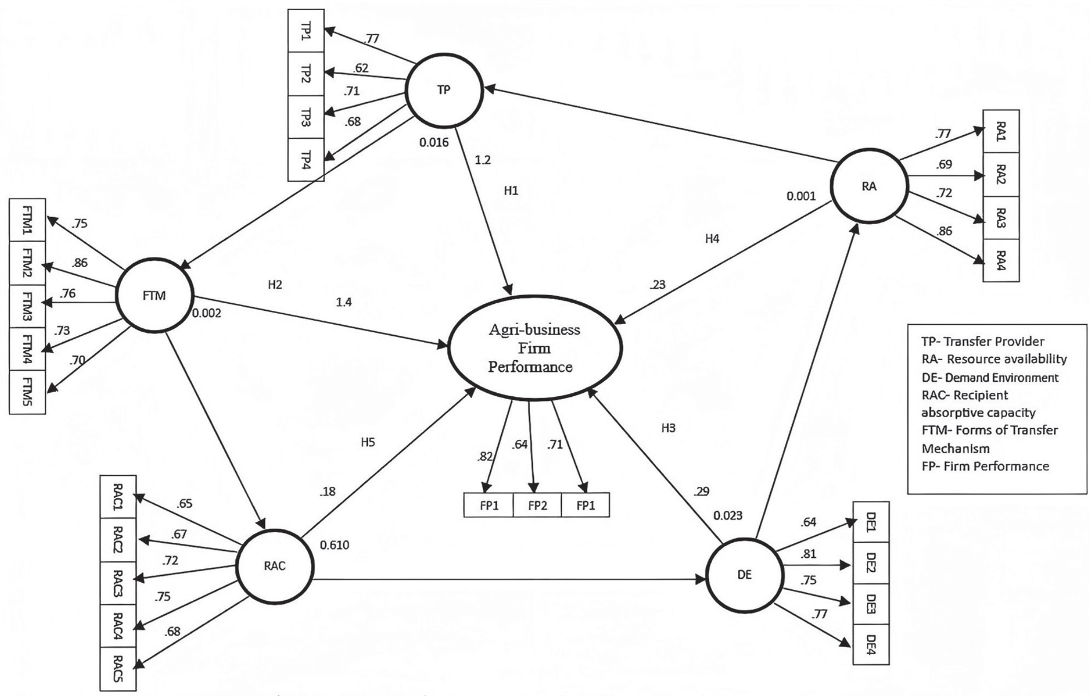


**Fig. 3.** Degree of relationship between variables.

positive impact on technology transfer, thereby improving agribusiness performance. This hypothesis (H3) is accepted at $p < 0.05$. Furthermore, findings exposed to those organizational resources, including physical assets, technology, and human capital, play a pivotal role in supporting innovative activities and facilitating technology transfer. The study highlights that adequate resource availability significantly enhances the successful implementation of technology transfer, resulting in improved agribusiness performance. Therefore, this hypothesis (H4) is validated at $p < 0.05$. RAC, which includes the ability to recognize, acquire, assimilate, and apply transferred technology, is crucial for successful technology transfer. However, statistical findings reveal that the RAC does not have a statistically significant positive effect on agribusiness performance ($p > 0.05$). Therefore, this hypothesis (H5) is not accepted. The findings collectively indicate that TP, TM, RA and DE have a direct and positive impact on the performance of agribusinesses. These factors significantly stimulate improvements in technology transfer and overall operational efficiency. Table 7 shows the standard path estimates and p-values of the SEM model.

**Table 7**
Standard estimation of the main model.

| Hypothesis | Path | Estimate | SE | CR | p-value | Results |
|---|---|---|---|---|---|---|
| H1 | Transfer Provider → Firm Performance | 0.331 | 0.72 | 4.495 | 0.0160 | supported |
| H2 | Transfer Mechanism → Firm Performance | 0.268 | 0.69 | 3.592 | 0.0020 | supported |
| H3 | Demand Environment → Firm Performance | 0.412 | 0.56 | 5.489 | 0.0230 | supported |
| H4 | Resource Availability → Firm Performance | 0.396 | 0.765 | 5.414 | 0.0015 | supported |
| H5 | Recipient Absorbative Capacity → Firm Performance | 0.098 | 0.52 | 1.872 | 0.0610 | Rejected |

Note: A significance level of $p < 0.05$ was used to assess statistical significance.

*4.4. Fuzzy-set qualitative comparative analysis*

The study applies first SEM analysis, using FP as the dependent variable and TP, TM, RA, DE and RAC as the independent variables. Following the recommendations of Woodside (2013), this study employs contrarian case analysis to identify potential asymmetric relationships. The study also highlights that traditional quantitative methods are often limited in their ability to capture the intricate interactions between variables, as noted by Osabutey and Jin (2016). To address these limitations, the study complements statistical analysis with configurational approaches by employing fsQCA. This method is used to examine the interconnections among the factors under study. Unlike traditional multiple regression analysis, fsQCA utilizes fuzzy logic and Boolean logic (Pappas *et al.*, 2016), making it more effective for identifying asymmetric relationships and complex scenarios (Woodside, 2013).

First, the study performed a necessary condition analysis. If the consistency score exceeded the cutoff of 0.9, a condition or a combination of conditions were considered as "necessary" (Navarro *et al.*, 2016). Table 8 shows the results of necessary condition analysis for the presence of agri-business performance. It is found that DE, TE, recipient capacity (RC) and resource availability (RA) are necessary conditions for agricultural business performance.

**Table 8**
Analysis of necessary conditions for agricultural business performance.

| | **Consistency** | **Consistency** |
|---|---|---|
| fs_transfer_provider | 0.828 | 0.838 |
| ~fs_transfer_provider | 0.372 | 0.870 |
| fs_demand_environment | 0.940 | 0.812 |
| ~fs_demand_environment | 0.526 | 0.806 |
| fs_transfer_mechanism | 0.926 | 0.806 |
| ~fs_transfer_mechanism | 0.378 | 0.875 |
| fs_recipient_capacity | 0.923 | 0.885 |
| ~fs_recipient_capacity | 0.398 | 0.865 |
| fs_resource_availability | 0.927 | 0.880 |
| ~fs_resource_availability | 0.386 | 0.880 |

Note: ~ indicates the absence of the condition.

Table 9 presents the cross-tabulation of percentile groups for technology transfer and firm performance, highlighting the presence of contrarian cases. These cases contradict the main effect between technology transfer and firm performance. The data showcases unique patterns that warrant further analysis, providing insights into how varying levels of technology transfer impact firm performance across different percentile groupings. Table 9 reports a quintile analysis of technology transfer and firm performance. Table 9 also highlights 18 cases with high technology transfer but low firm performance and 15 cases with low technology transfer but high firm performance (18 + 15 = 33 cases, representing 30% of the total sample, as 33/107 = 30%). Following the call for innovative approaches to analyzing such datasets (Woodside, 2013), this study utilizes fsQCA.

The software FsQCA 2.5 generates three types of solutions for identifying sufficient configurations that lead to firm performance: a complex solution, an intermediate solution, and a parsimonious solution. In this study, both the complex solution and the intermediate solution produced the same results. Table 10 provides the solutions related to the causal relationships among the five factors: TP, DE, TM, RC and RA to firm performance. Filled solid (black) circles denote the presence of a condition, unfilled (white) circles signify the negation of causal conditions, and blank cells indicate the absence of a condition. This analysis highlights the configurational pathways through which these factors contribute to variations in firm performance.

**Table 9**
Cross-tabulation of percentile groups for technology transfer and firm performance.

| Count | | percentile grouping of technology transfer | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Total |
| percentile grouping of firm performance | 1 | 4 | 2 | 1 | 4 | 7 | 18 |
| | 2 | 3 | 5 | 3 | 7 | 2 | 20 |
| | 3 | 8 | 6 | 4 | 7 | 2 | 27 |
| | 4 | 4 | 3 | 7 | 3 | 7 | 24 |
| | 5 | 5 | 3 | 2 | 4 | 4 | 18 |
| | | 24 | 19 | 17 | 25 | 22 | 107 |

Note: Two No of cases generated

Solutions 1 and 2 in Table 9 present two distinct pathways leading to high firm performance with sufficient consistency (≥0.90) and high coverage (0.65). These solutions demonstrate how combinations of factors such as TP, DE, TM, RC and RA contribute to achieving superior firm performance outcomes. Solution 1 states that professionals recognize that the presence of a strong TP, an effective TM, high RC and good RA, along with the presence of DE (a core condition), are members of the set of high firm performance. This finding is in line with previous studies highlighting the role of knowledge transfer impact on the shared knowledge and outsourcing performance (Blumenberg *et al.*, 2009). This solution achieves a consistency of 92%, meaning it reliably leads to high performance in the majority of cases. It provides a unique contribution of 8% to the explanation of firm performance. Solution 2 indicates that the joint presence of a strong DE, an effective TM and high RA, and with core condition of RC achieves a consistency of 93% and are members of the set of high firm performance. This finding aligns with previous studies, such as the ones by Martin and Salomon (2003) and Pueyo *et al.* (2011), these combined factors are essential for driving high performance in organizations, emphasizing the need for a comprehensive approach to technology transfer. This configuration proves to be highly dependable in explaining high levels of firm performance and accounts for 22% of the cases. The study's findings identify two distinct pathways that lead to superior performance. The first pathway emphasizes the crucial role of a set of positive factors combining a strong TP, an effective TM, high RC and sufficient RA, in addition to the core condition of DE, all of which are essential for achieving high firm performance. The second pathway highlights the combination of a robust DE, an effective TM and RA, alongside the core condition of RC. Both configurations serve as sufficient conditions for high firm performance, demonstrating the complex nature of technology transfer and its impact on firm success.

The parsimonious solutions reveal two key pathways, with an overall solution coverage of 0.68 and a consistency of 0.93. These findings highlight that the presence of TM, RA, and DE are fundamental conditions for achieving high firm performance. On the other hand, factors such as TR and TC, which are not consistently present in the parsimonious solutions, are considered secondary or peripheral conditions (Fiss, 2011). Further analysis of firm performance negation showed no significant configurations, indicating that the absence of certain factors does not automatically lead to poor outcomes. Crucially, TA and TM emerge as essential conditions, appearing consistently across all identified solutions. This reinforces the importance of these factors in driving firm performance and enhancing the success of technology transfer initiatives.

**Table 10**
Configurational solutions for technology transfer and firm performance.

| Solution | Transfer provider | Demand environment | Transfer mechanism | Recipient capacity | Resource availability | Raw coverage | Unique coverage | Consistency | Solution coverage | Solution consistency |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ● | ○ | ● | ● | ● | 0.48 | 0.08 | 0.92 | 0.68 | 0.93 |
| 2 | | ● | ● | ○ | ● | 0.57 | 0.22 | 0.93 | | |

Note: ● Filled circles denote conditions that exceed the threshold levels, while ○ unfilled circles represent negative conditions. Large circles indicate core conditions, and small circles represent peripheral conditions. Blank cells signify conditions that are not considered

*4.5. Robustness testing*

A robust test was performed by increasing the consistency threshold from 0.8 to 0.85. The results showed no significant changes in the number of configurations, their components, or the consistency and coverage fit parameters. The reliability of current study was enhanced (Huang and Xie, 2021).

## 5. Discussion

Technology transfer has the potential to drive innovation and spur economic growth, but its success hinges on several key factors. These include the quality of the technology being transferred, the strength of existing infrastructure, and the institutional support available to foster innovation (Bozeman, 2000; Chege and Wang, 2020b; Guan *et al.*, 2006). This study investigates the impact of technology transfer on agriculture within a developing country context, applying a model that incorporates critical factors such as DE, RA, RC and TP. The findings highlight the positive effects of technology transfer on the performance of agribusiness, with statistically significant results showing that effective transfer mechanisms and competent providers are essential. The study underlines the importance of technology transfer in assisting farmers to improve their yields and overcome challenges. It also emphasizes that farmers must understand the relevance of the transferred technology in the context of their own economic situation, experience, and available alternatives.

The results of this study provide substantial evidence underscoring the importance of key factors in determining the performance of agribusinesses. Utilizing SEM, it was established that factors such as TP, TM, RA and DE have significant positive impacts on firm performance. However, RAC did not show a statistically significant correlation ($p > 0.05$) with firm performance, suggesting its influence may be context dependent. These findings highlight the crucial role of effective technology transfer in improving the operational efficiency of the agricultural sector.

While this study primarily focuses on small agricultural businesses, it is important to recognize that there may be potential differences in the impact of technology transfer when comparing small businesses with medium and large agricultural businesses. Large agricultural businesses, with more resources and established infrastructures, might experience different dynamics regarding technology transfer. These businesses could already have in-house R&D capabilities, making the need for external transfer providers or mechanisms less significant. Furthermore, medium and large businesses may possess higher absorptive capacity, potentially leading to greater success in applying transferred technologies. However, the focus of this study remains on small agribusinesses, and further research is needed to explore these potential differences in depth.

TPs were found to be critical drivers of agribusiness performance. Their ability to transfer technical knowledge, often through on-site demonstrations, workshops, and training, plays a significant role in performance outcomes. These activities help to facilitate the successful implementation of new technologies, thereby enhancing productivity and operational efficiency. This supports Hypothesis (H1), which was validated with strong statistical significance ($p < 0.05$). Similar findings were reported in the study by (Günsel, 2015), which examined the impact of technology transfer on SME performance.

Furthermore, the study emphasizes the importance of TM in enhancing firm performance. Efficient mechanisms for the flow of technology and resources are critical to ensure seamless knowledge transfer across organizational boundaries. This supports Hypothesis (H2), showing that strong transfer mechanisms are integral to agribusiness success ($p < 0.05$).

The DE was another significant factor influencing firm performance. A favorable market-driven demand environment creates a pull effect that encourages businesses to adopt new technologies, fostering innovation and business growth. This study confirms the role of demand-driven technology transfer in improving agribusiness performance, thus validating Hypothesis (H3) ($p < 0.05$).

RA emerged as an essential factor for firm performance. The study underscores that access to adequate physical resources, technological infrastructure, and skilled human capital is necessary for successful technology transfer and implementation. This aligns with Hypothesis (H4), emphasizing the pivotal role of resources in enhancing performance outcomes ($p < 0.05$).

Interestingly, RAC, which refers to the ability to recognize, assimilate, and apply new technology, did not have a statistically significant impact on firm performance ($p > 0.05$). While absorptive capacity is crucial for successful technology transfer, its effect may depend on other factors. One possible reason for the lack of impact could be that small agribusinesses, despite having the capacity to absorb new technologies, might lack the necessary resources (financial, technological, or human) to implement them effectively. Additionally, the compatibility of the technology with the existing infrastructure and skills of the businesses could also limit the ability to apply it successfully. Moreover, external factors like market conditions and government policies might have a more substantial influence on firm performance, overshadowing the role of absorptive capacity. Therefore, Hypothesis (H5) was not supported, suggesting that future research should explore the conditions under which absorptive capacity becomes a significant factor in technology transfer success, considering aspects such as resource availability and external factors.

The fsQCA analysis revealed that specific combinations of factors, including RA, DE and TM, are crucial for high firm performance in agribusinesses. These core conditions appeared consistently in the configurations, leading to superior performance outcomes. For example, Solution 1 showed that a substantial TM, RC, RA, and the absence of DE led to high performance. Similarly, Solution 2 indicated that a strong DE, effective TMs, and sufficient RA in combination result in improved performance outcomes, even without strong recipient capacity. Both solutions displayed high consistency (≥0.90) and sufficient coverage (≥0.65), validating their reliability in explaining agribusiness performance.

Table 7, which provides the cross-tabulation of percentile groups for technology transfer and firm performance, sheds light on the complex relationships between these variables. It revealed 18 cases with high technology transfer but low firm performance and 15 cases with low technology transfer but high firm performance, constituting approximately 30% of the sample. These findings indicate that while technology transfer improves performance, other factors—such as a robust DE, RA, or effective TMs—can significantly influence the results. On the other hand, high levels of technology transfer without sufficient supporting conditions like RA or market demand may fail to improve performance. This highlights the complexity of the technology transfer process and the need to consider multiple interconnected factors when assessing its impact on agribusiness outcomes.

The study underscores the necessity of focusing on core and peripheral factors in technology transfer. Core conditions such as RA, DE and TMs are essential for achieving high firm performance. In contrast, peripheral factors like TP and RAC may play supplementary roles, depending on the context. Future research should further investigate how external factors such as government policies, institutional support, and market conditions affect the effectiveness of these configurations in driving agribusiness performance.

## 6. Conclusion

### *6.1. Theoretical implications*

This study contributes to the analysis of technology transfer, particularly within the context of agribusiness in rural Pakistan. It expands the current understanding of how key technology transfer components—TP, TM, RA and DE—directly influence firm performance. While previous research has identified various factors impacting technology transfer, inconsistencies remain in understanding the interconnections between these components and their collective role in improving agribusiness outcomes (Awang *et al*., 2016; Chege and Wang, 2020a). This study bridges this gap by using both SEM and fsQCA, deepening insights into the pathways leading to high firm performance through effective technology transfer.

As this study primarily focuses on small agricultural businesses, future research should address the differences in the impact of technology transfer for medium and large agricultural businesses. Large businesses with more resources and infrastructure may experience different effects, especially in terms of absorptive capacity and the need for external TPs. Research that compares these different sizes of businesses will provide a more comprehensive understanding of the technology transfer process and its effects across various scales.

The findings underscore the complex interrelationships between these components and their collective impact on the operational efficiency of agribusinesses. Notably, while RAC does not directly influence performance in a statistically significant way, other contextual factors—such as infrastructure, market conditions, and organizational readiness—may mediate its effects. This enriches existing literature by emphasizing the need for a multifaceted approach to managing technology transfer components and suggests that future research should explore these mediating factors more thoroughly.

Additionally, the integration of SEM with fsQCA provides a novel methodological approach to understanding the configurational pathways that lead to high firm performance. Unlike studies that examine individual components of technology transfer separately, this study advocates for a holistic view of how these components interact to influence agribusiness success. The study's contribution lies in its ability to uncover distinct pathways to successful technology transfer, offering a more comprehensive perspective on the complexities of technology adoption, particularly in developing economies.

*6.2. Managerial implications*

The findings of this study offer several crucial managerial insights for agribusiness managers and policymakers. First, the study emphasizes the importance of strengthening technology TMs within agribusinesses. Agribusiness managers should ensure that TPs possess the necessary expertise and resources to conduct effective training, workshops, and demonstrations, as these are essential for the successful adoption of new technologies. Furthermore, mechanisms such as on-site demonstrations, mass media campaigns, and collaborations with universities and research institutions should be prioritized. These initiatives can facilitate the smooth exchange of knowledge and resources between transfer providers and agribusiness firms.

Another key implication highlighted by the study is the critical role of RA—availability of resources like financial, human, and technological—in facilitating effective technology transfer. Managers must ensure that their firms have adequate resources to successfully adopt and implement new technologies. This may involve investing in necessary infrastructure, providing training, and developing human capital to build internal capabilities within the organization. In addition, creating a supportive DE is crucial for encouraging innovation and technology adoption. Both market-pull and market-push forces are essential in stimulating the adoption of new technologies. Policymakers should aim to foster a favorable environment by offering incentives such as subsidies, tax breaks, or other market-driven initiatives that encourage businesses to adopt innovative technologies.

The study also identifies two distinct pathways to achieving high agribusiness performance through technology transfer. The first pathway underscores the importance of having strong TMs and adequate RA as sufficient conditions for high performance. The second pathway highlights the need for a supportive DE, effective TMs, and sufficient RA. These pathways emphasize the necessity of a strategic, integrated approach to technology transfer that combines these critical elements. By addressing these factors, agribusinesses can position themselves for sustainable growth and enhanced competitiveness in the increasingly dynamic agricultural sector.

*6.3. Limitations and future research directions*

While this study provides valuable contributions to understanding technology transfer and its impact on agribusiness performance, it has certain limitations that must be addressed in future research. One of the primary limitations is that the study focuses specifically on agribusinesses in Pakistan, which may limit the generalizability of the findings to other sectors or geographical contexts. Given the diverse economic, cultural, and institutional factors in developing countries, future research should explore the role of technology transfer in other developing nations or industries to provide broader insights into the factors that drive firm performance through technology adoption.

Another limitation is the study's limited scope in accounting for external factors that may also significantly influence technology transfer outcomes. While the study emphasizes the importance of TMs and RA, it does not fully consider the role of government policy incentives, institutional frameworks, or broader market dynamics. Future research should incorporate these external factors and investigate how they interact with internal conditions, such as RA and TMs, to affect technology transfer success.

Furthermore, while this study examines the role of RAC in technology transfer, it finds that absorptive capacity does not exhibit a direct significant effect on firm performance. However, its indirect influence may be more pronounced under different contextual conditions. Future studies should explore under what conditions absorptive capacity becomes a critical factor in the success of technology transfer, especially in sectors or regions with varying levels of technological readiness, infrastructure, or institutional support. This would offer deeper insight into how firms in different contexts can leverage their absorptive capacity to enhance the benefits of technology transfer. In addition, while this study primarily focuses on the short-term effects of technology transfer on agribusiness performance, it would be valuable for future research to explore the long-term impacts, such as innovation, market competitiveness, and agricultural sustainability. These factors are essential for the sustained success and growth of agribusinesses and including them in future models will provide a more comprehensive understanding of the long-term benefits of technology transfer in the agricultural sector.

## Conflicts of interest

The authors declare no conflict of interest.

## References

Adegbola, P., & Gardebroek, C., 2007. The effect of information sources on technology adoption and modification decisions. *Agricultural economics*, 37(1), 55–65.

Ahmad, M., & Iqbal, M., 2004. Science and Technology Based Agriculture Vision of Pakistan and Prospects of Growth.

Aker, J. C., 2011. Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agricultural economics*, 42(6), 631–647.

Almarri, K., & Gardiner, P., 2014. Application of resource-based view to project management research: supporters and opponents. *Procedia-Social and Behavioral Sciences*, 119, 437–445.

Aslam, M., 2016. Agricultural productivity current scenario, constraints and future prospects in Pakistan. *Sarhad Journal of Agriculture*, 32(4), 289–303.

Autio, E., & Laamanen, T., 1995. Measurement and evaluation of technology transfer: review of technology transfer mechanisms and indicators. *International Journal of Technology Management*, 10(7-8), 643–664.

Awan, A. G., & Aslam, A., 2015. Impact of agriculture productivity on economic growth: A case study of Pakistan. *Global Journal of Management and Social Sciences*, 1(1), 57–71.

Awang, A. H., Hashim, K., & Ramli, Z., *et al*., 2016. The effects of technology transfer, good agriculture practices on the productivity of independent palm oil smallholders. *Journal of Economic and Management Perspectives*, 10(4), 300–304.

Azagra-Caro, J. M., Archontakis, F., & Gutierrez Gracia, A., *et al*., 2006. Faculty support for the objectives of university–industry relations versus degree of R&D cooperation: The importance of regional absorptive capacity. *Research Policy*, 35(1), 37–55.

Azam, A., & Shafique, M., 2017. Agriculture in Pakistan and its impact on economy. A review. *International Journal of Advanced Science and Technology*, 103, 47–60.

Azumah, S. B., Donkoh, S. A., & Awuni, J. A., 2018. The perceived effectiveness of agricultural technology transfer methods: Evidence from rice farmers in Northern Ghana. *Cogent Food and Agriculture*, 4(1), 1503798.

Bagozzi, R., Baumgartner, J., & Yi, Y., 1988. An investigation into the role of volitions as intervening variables in the atitude-behavior relationship unpublished working paper. *The University of Michigan*.

Bandiera, O., & Rasul, I., 2006. Social networks and technology adoption in northern Mozambique. *The economic journal*, 116(514), 869–902.

Baranson, J., 1970. Technology transfer through the international firm. *The American Economic Review*, 60(2), 435–440.

Battistella, C., De Toni, A. F., & Pillon, R., 2016. Inter-organisational technology/knowledge transfer: a framework from critical literature review. *The Journal of Technology Transfer*, 41, 1195–1234.

Bhutto, A. W., & Bazmi, A. A., 2007. Sustainable agriculture and eradication of rural poverty in Pakistan. Paper presented at

the Natural Resources Forum.
Blumenberg, S., Wagner, H. T., & Beimborn, D., 2009. Knowledge transfer processes in IT outsourcing relationships and their impact on shared knowledge and outsourcing performance. *International Journal of Information Management*, 29(5), 342–352.
Bozeman, B., 2000. Technology transfer and public policy: a review of research and theory. *Research Policy*, 29(4–5), 627–655.
Bozeman, B., Rimes, H., & Youtie, J., 2015. The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy*, 44(1), 34–49.
Buratti, N., & Penco, L., 2001. Assisted technology transfer to SMEs: lessons from an exemplary case. *Technovation*, 21(1), 35–43.
Case, A., 1992. Neighborhood influence and technological change. *Regional science and urban economics*, 22(3), 491–508.
Chege, S. M., & Wang, D., 2020a. The impact of technology transfer on agribusiness performance in Kenya. *Technology analysis & strategic management*, 32(3), 332–348.
Chege, S. M., & Wang, D., 2020b. The influence of technology innovation on SME performance through environmental sustainability practices in Kenya. *Technology in Society*, 60, 101210.
Chege, S. M., Wang, D., & Suntu, S. L., *et al*., 2019. Influence of technology transfer on performance and sustainability of standard gauge railway in developing countries. *Technology in Society*, 56, 79–92.
Chesbrough, H. W., 2003. Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.
Cinar, O., Altuntas, S., & Alan, M. A., 2021. Technology transfer and its impact on innovation and firm performance: empirical evidence from Turkish export companies. *Kybernetes*, 50(7), 2179–2207.
Da Silva, V. L., Kovaleski, J. L., & Pagani, R. N., 2019. Technology transfer in the supply chain oriented to industry 4.0: a literature review. *Technology analysis and strategic management*, 31(5), 546–562.
Dalpé, R., DeBresson, C., & Hu, X. P., 1992. The public sector as first user of innovations. *Research Policy*, 21(3), 251–263.
Dattalo, P., 2008. Determining sample size: Balancing power, precision, and practicality. Pocket Guide to Social Work Re.
Elahi, E., Abid, M., & Zhang, L., *et al*., 2018. Agricultural advisory and financial services; farm level access, outreach and impact in a mixed cropping district of Punjab, Pakistan. *Land use policy*, 71, 249–260.
Punjab Climate Change Policy 2017. Retrieved from https://epd.punjab.gov.pk/system/files/PCCP%20Draft%20%28internatl%29_0.pdf.
Farhadikhah, Z., & Husseini, S. M. H., 2015. A review of methods and models of technology transfer. *International Letters of Social and Humanistic Sciences*, 62, 173–181.
Fiss, P. C., 2011. Building better causal theories: A fuzzy set approach to typologies in organization research. *Academy of management journal*, 54(2), 393–420.
Fornell, C., & Larcker, D. F., 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 18(1), 39–50.
Gauchan, D., Joshi, M., & Biggs, S., 2003. A strategy for strengthening participatory technology development in agricultural and natural resources innovations systems: the case of Nepal. *International Journal of Technology Management & Sustainable Development*, 2(1), 39–52.
Gibson, M., 2005. Technology transfer introduction and objectives. *Technology Transfer*, 1–12.
Godin, B., 2006. The linear model of innovation: The historical construction of an analytical framework. *Science, Technology, & Human Values*, 31(6), 639–667.
Government of Punjab, 2022. Agriculture department. Retrieved from https://www.agripunjab.gov.pk/overview.
Grosse, R., 1996. International technology transfer in services. *Journal of international business studies*, 27, 781–800.
Guan, J. C., Mok, C. K., & Yam, R. C., *et al*., 2006. Technology transfer and innovation performance: Evidence from Chinese firms. *Technological Forecasting and Social Change*, 73(6), 666–678.
Günsel, A., 2015. Research on effectiveness of technology transfer from a knowledge based perspective. *Procedia-Social and Behavioral Sciences*, 207, 777–785.
Gunsel, A., Dodourova, M., & Ergun, A. T., *et al*., 2019. Research on effectiveness of technology transfer in technology alliances: evidence from Turkish SMEs.
Hair, J., Anderson, R., & Tatham, R., *et al*., 1998. Multivariate Date Analysis. Prentice-Hall, Englewood Cliffs, NJ.
Han, J. S., & Lee, S. Y. T., 2011. The Impact of Technology Transfer on a Firm's Market Value in Korea.
Hervas-Oliver, J. L., Albors-Garrigos, J., & Baixauli, J. J., 2012. Beyond R&D activities: the determinants of firms' absorptive capacity explaining the access to scientific institutes in low–medium-tech contexts. *Economics of Innovation and New Technology*, 21(1), 55–81.

Hu, L. T., & Bentler, P. M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, 6(1), 1–55.

Huang, R., & Xie, C. W., 2021. Pressure, state and response: configurational analysis of antecedents of hotel employees' career prospect perceptions following the COVID-19 pandemic crisis.

Israel, G. D., 2012. Sampling the evidence of extension program impact: Citeseer.

Jabar, J., & Soosay, C., 2010. An assessment of technology transfer in Malaysian manufacturers and the impact on performance and innovativeness. Paper presented at the 2010 IEEE International Conference on Management of Innovation & Technology.

Jafari, M., Akhavan, P., & Rafiei, A., 2014. Technology transfer effectiveness in knowledge-based centers providing a model based on knowledge management. *International Journal of Scientific Knowledge*, 4(7).

Jagoda, K., Maheshwari, B., & Lonseth, R., 2010. Key issues in managing technology transfer projects: Experiences from a Canadian SME. *Management Decision*, 48(3), 366–382.

Jankowicz, D., 2011. Research Methods for Business and Management.

Jasinski, A. H., 2009. Barriers for technology transfer: the case of a country in transition. *Journal of Technology Management in China*, 4(2), 119–131.

Joensuu-Salo, S., Sorama, K., & Viljamaa, A., *et al*., 2018. Firm performance among internationalized SMEs: The interplay of market orientation, marketing capability and digitalization. *Administrative sciences*, 8(3), 31.

Khan, I., Lei, H., & Khan, A., *et al*., 2021. Yield gap analysis of major food crops in Pakistan: prospects for food security. *Environmental Science and Pollution Research*, 28, 7994–8011.

Khan, M. J., Abbas, A., & Naeem, M., *et al*., 2013. Current issues and future prospects of dairy sector in Pakistan. *Science, Technology, and Development*, 32(2), 126–139.

Kumar, S., Luthra, S., & Haleem, A., *et al*., 2015. Identification and evaluation of critical factors to technology transfer using AHP approach. *International Strategic Management Review*, 3(1–2), 24–42.

Lee, S., Kim, B. S., & Kim, Y., *et al*., 2018. The framework for factors affecting technology transfer for suppliers and buyers of technology in Korea. *Technology analysis & strategic management*, 30(2), 172–185.

Li, X., 2011. Sources of external technology, absorptive capacity, and innovation capability in Chinese state-owned high-tech enterprises. *World Development*, 39(7), 1240–1248.

Lin, C., Tan, B., & Chang, S., 2002. The critical factors for technology absorptive capacity. *Industrial Management & Data Systems*, 102(6), 300–308.

Lu Yao, & Peng Yun., 2018. An Action Research on the Impact of Agricultural Technology Transfer on Yao Villages in Laos. *Journal of Guangxi University for Nationalities (Philosophy and Social Science Edition)*.

Marshall, B., Cardon, P., & Poddar, A., *et al*., 2013. Does sample size matter in qualitative research?: A review of qualitative interviews in IS research. *Journal of computer information systems*, 54(1), 11–22.

Martin, X., & Salomon, R., 2003. Knowledge transfer capacity and its implications for the theory of the multinational corporation. *Journal of international business studies*, 34, 356–373.

Maskus, K. E., 2004. Encouraging international technology transfer (Vol. 7). *Intellectual Property Rights and Sustainable Development.*

Mgendi, G., Shiping, M., & Xiang, C., 2019. A review of agricultural technology transfer in Africa: Lessons from Japan and China case projects in Tanzania and Kenya. *Sustainability*, 11(23), 6598.

Ministry of Commerce, 2022. Trade Development Authority of Pakistan.

MNFSR, 2023. Governmet of Pakistan. Retrieved from https://mnfsr.gov.pk/.

Mohd Sam, M. F., & Hoshino, Y., 2013. Sales growth, profitability and performance: empirical study of Japanese ICT industries with three Asean Countries. *Interdisciplinary Journal of Contemporary Research in Business*, 4(11).

Muturi, P. M., Gesimba, P. O., & Kithinji, M. A., 2013. Analysis of factors influencing transfer of technology among micro and small enterprises in Kenya. *International Journal of Business and Social Science*, 4(17).

Nakano, Y., Tsusaka, T. W., & Aida, T., *et al*., 2018. Is farmer-to-farmer extension effective? The impact of training on technology adoption and rice farming productivity in Tanzania. *World Development*, 105, 336–351.

Navarro, S., Llinares, C., & Garzon, D., 2016. Exploring the relationship between co-creation and satisfaction using QCA. *Journal of Business Research*, 69(4), 1336–1339.

Noori, H., 1987. Benefits arising from new technology adoption: small vs. large firms. *Journal of Small Business & Entrepreneurship*, 5(1), 8–16.

Nunnally, J. C., 1978. Psychometric theory. McGraw-Hill, New York. In Lance, CE, Butts, MM, and Michaels, LA (2006). The sources of four commonly reported cut-off criteria: what did they really say? *Organisational Research Methods*, 9(2), 202-220.

O'Leary-Kelly, S. W., & Vokurka, R. J., 1998. The empirical assessment of construct validity. *Journal of operations management*, 16(4), 387–405.

Odagiri, H., 2003. Transaction costs and capabilities as determinants of the R&D boundaries of the firm: a case study of the ten largest pharmaceutical firms in Japan. *Managerial and Decision Economics*, 24(2–3), 187–211.

Okello, D., & Ireri, D., 2017. Socio-economic factors influencing use of ICT tools by rural agri-entrepreneurs in Kenya. *The International Journal of Humanities & Social Studies*, 5(9), 302–307.

Omato, G., & Kithinji, M., 2013. Analysis of factors influencing transfer of technology in Kenya. *International Journal of Business and Social Science*, 4(17), 171–179.

Osabutey, E. L., & Jin, Z., 2016. Factors influencing technology and knowledge transfer: Configurational recipes for Sub-Saharan Africa. *Journal of Business Research*, 69(11), 5390-5395.

Otto Garcia., 2003. A review of milk production in Pakistan with particular emphasis on small scale producers.

Özdamar, K., 2002. Paket programlar ile istatiksel veri analizi: SPSS-MINITAB (Çok değişkenli analizler). Kaan Kitabevi.

Pakistan Agricultural Research Council (PARC), 2021. Retrieved from https://www.parc.gov.pk/Detail/ODFlNmNmYzctYmZlNy00M2M0LTlhYzAtODcxMjM2Mzk1ZmI0.

Pappas, I. O., Kourouthanassis, P. E., & Giannakos, M. N., *et al*., 2016. Explaining online shopping behavior with fsQCA: The role of cognitive and affective perceptions. *Journal of Business Research*, 69(2), 794–803.

Pappas, I. O., & Woodside, A. G., 2021. Fuzzy-set Qualitative Comparative Analysis (fsQCA): Guidelines for research practice in Information Systems and marketing. *International Journal of Information Management*, 58, 102310.

Park, S. H., & Lee, Y. G., 2011. Perspectives on technology transfer strategies of Korean companies in point of resource and capability based view. *Journal of technology management & innovation*, 6(1), 161–184.

Pakistan Agricultural Technology Transfer Activity (PATTA), 2018. Retrieved from https://cnfa.org/program/pakistan-agricultural-technology-transfer-activity/.

Pikkarainen, M., Korkala, M., & Biot, O., *et al*., 2012. Focusing innovation in market pull and technology push environment. Paper presented at the ISPIM Conference Proceedings.

Pueyo, A., García, R., & Mendiluce, M., *et al*., 2011. The role of technology transfer for the development of a local wind component industry in Chile. *Energy policy*, 39(7), 4274–4283.

Ragin, C. C., 2009. Redesigning Social Inquiry: Fuzzy Sets and Beyond. University of Chicago Press.

Rehman, A., Jingdong, L., & Khatoon, R., *et al*., 2016. Modern agricultural technology adoption its importance, role and usage for the improvement of agriculture. *Life Science Journal*, 14(2), 70–74.

Saen, R. F., 2006. A decision model for selecting technology suppliers in the presence of nondiscretionary factors. *Applied mathematics and computation*, 181(2), 1609–1615.

Sazali, A., Haslinda, A., & Jegak, U., *et al*., 2009. Evolution and development of technology transfer models and the influence of knowledge-based view and organizational learning on technology transfer. *Research Journal of International Studies*, 12, 79–91.

Serry, M., 1998. Medium-sized technology-based firms: An exploratory study. *Journal of small business management*, 36, 1.

Shahid, R., 2023. Digital revolution in Pakistan's agriculture sector: some key principles.

Shalev, M., 2007. Limits and alternatives to multiple regression in comparative research. Capitalisms Compared (pp. 261–308): Emerald Group Publishing Limited.

Shange, N., 2014. Analysis of the challenges and opportunities for smallholder farmer value chain integration in the Western Cape: A public and private sector organisation perspective. *Agricultural economics*, 1–61.

Sherazi, S. K., Iqbal, M. Z., & Asif, M., *et al*., 2013. Obstacles to small and medium enterprises in Pakistan. Principal component analysis approach. *Middle-East journal of scientific research*, 13(10), 1325–1334.

Stock, G. N., Greis, N. P., & Fischer, W. A., 2001. Absorptive capacity and new product development. *The Journal of High Technology Management Research*, 12(1), 77–91.

Takahashi, K., Muraoka, R., & Otsuka, K., 2020. Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural economics*, 51(1), 31–45.

Tsai, K. H., & Wang, J. C., 2008. External technology acquisition and firm performance: A longitudinal study. *Journal of Business Venturing*, 23(1), 91–112.

Whangthomkum, N., Igel, B., & Speece, M., 2006. An empirical study of the relationship between absorptive capacity and technology transfer effectiveness. *International Journal of Technology Transfer and Commercialisation*, 5(1–2), 31–55.

Williams, C., 2007. Research methods. *Journal of Business & Economics Research (JBER)*, 5(3).

Woodside, A. G., 2013. Moving beyond multiple regression analysis to algorithms: Calling for adoption of a paradigm shift from symmetric to asymmetric thinking in data analysis and crafting theory. *Journal of business research*, 66(4), 463-472.

World Bank Report., 2017. World Bank Annual Report 2017 (English). Retrieved from http://documents.worldbank.org/curated/en/143021506909711004/World-Bank-Annual-Report-2017.

World Bank Group, 2017. G20 NOTE: Technology and Jobs in the Developing World Washington, DC: Jobs Group of the World Bank.

Yuan, K. H., Chan, W., & Marcoulides, G. A., *et al*., 2016. Assessing structural equation models by equivalence testing with adjusted fit indexes. *Structural equation modeling: a multidisciplinary journal*, 23(3), 319–330.

Zikmund, W. G., Babin, A. J., & Carr, J. C., 2010. Business Research Methods, Eighth Edition.