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The nexus of artificial intelligence, frugal innovation and business model innovation to nurture internationalization: A survey of SME's readiness

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ABSTRACT

This study uses transaction cost economics theory to explain the interplay of artificial intelligence readiness, frugal innovation, and business model innovation to achieve SMEs' internationalization objectives. A survey is conducted among SMEs using cluster sampling to determine their readiness for artificial intelligence adoption. The results are analyzed using Smart PLS 4.1 software. The study explored the mediating role of business model innovation and artificial intelligence's moderating role in promoting business model innovation and SMEs' internationalization, respectively. Finally, the authors performed a necessary conditions analysis to identify the necessary conditions for SME internationalisation. The study has contextual implications for stakeholders and policymakers of an oil-rich nation.

1. Introduction

Small and medium-sized businesses (SMEs) are pressured to pursue sophisticated growth strategies to increase competitiveness and adapt to changing social and technological environments (Lew et al., 2023b). SMEs internationalization, as defined within the framework of transaction cost theory, pertains to the strategic expansion of SMEs into global markets, driven by the principles of transaction cost economics (Williamson, 1979). Transaction cost theory posits that SMEs would engage in international expansion when the advantages of entering foreign markets surpass the expenses linked to conducting transactions across national boundaries (Singh et al., 2022; Saridakis et al., 2019). Conventional business models, a lack of digital process innovation, and fewer cost-effective innovations are possible challenges for SMEs to go global (see, e.g., (Denicolai et al., 2021)).

The existing body of literature about SMEs' internationalisation issues sheds light on various barriers and intricacies that SMEs confront when attempting to extend their activities outside national boundaries, including the Middle East/North Africa (MENA) region, including Oman (Younis and Elbanna, 2022; Kumar et al., 2023). Typical obstacles SMEs face include restricted availability of financial resources, inadequate innovation capacities, limited capacity to provide tailored business

models, and the incapacity to embrace cutting-edge technology such as artificial intelligence. SMEs operating in MENA nations, such as Oman, encounter a downturn in their local markets (Alayo et al., 2021; Saleem and Ashfaq, 2023). Consequently, they are motivated to expand internationally by establishing retail outlets such as shopping malls, grocery shops, fuel stations, packaging firms, and milk and dairy facilities overseas, drawing upon their successful domestic endeavours (Younis and Elbanna, 2022). Due to the weak local demand, they are compelled to expand internationally to seek new clientele in overseas markets. In addition to this, the ongoing digital revolution necessitates that SMEs operating in Gulf nations actively engage in technical innovation, such as the use of artificial intelligence (AI) (Saleem et al., 2023; Upadhyay et al., 2023). For smaller enterprises to participate in the global digitized market and establish connected business networks to cater to global clients with individualized products, SMEs should be prepared to adopt digital processes and business model innovation as business processes become more digital (Sjödin et al., 2021). Scholars are interested in investigating the preparedness of SMEs growing in the MENA area to tackle these intricate problems and explore how digitalization, cost-effective innovation, and customised digital business model innovations have the potential to facilitate internationalization for SMEs in oil-rich states operating in MENA (Younis and Elbanna, 2022).

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Scholars have emphasized the importance of frugal innovation in SMEs' expansion, as it allows them to effectively compete on a global scale by offering affordable, high-quality products tailored to meet the demands of emerging markets (Hossain et al., 2016; Shehzad et al., 2022, 2023b). Frugal innovation prioritizes simplicity, affordability, and flexibility over sophisticated technology and expensive expenses (Hossain, 2020; Waseel et al., 2023). This strategy allows SMEs to overcome limitations in resources and enter new markets with little financial expenditure (Hossain, 2018; Shehzad et al., 2023a). Other studies suggest that SMEs may strategically use local resources and gain insights into distinct market needs in order to develop goods and services that effectively connect with international customers (Shehzad et al., 2023a,b, 2022). This frugal approach reduces both production and operating expenses, allowing SMEs to expand on a global scale without requiring significant financial resources (Singh et al., 2022; AlMulhim, 2021; Alayo et al., 2021). However, in the Middle Eastern context, particularly in Oman, limited contextual research necessitates further investigation (Hossain, 2018; Hossain et al., 2016; Shehzad et al., 2022).

Several literature gaps can be identified for the internationalisation of SMEs (Singh et al., 2022). The first is the contextual research gap. Oil-rich economies like Oman are still mostly dependent on natural resources (Younis and Elbanna, 2022). Governments in these economies are interested in exploring how SMEs could be motivated to adopt cost-effective innovation to achieve internationalisation (Dost et al., 2019; Dost and Umrani, 2024). Secondly, lately, artificial intelligence (AI) is gaining capabilities to radically transform not only larger firms but also SMEs to create, deliver, and capture customer value to access the international market (Sjödin et al., 2021). AI-enabled business applications may reshape SMEs' business and break the technical bottlenecks that SMEs and their employees face (Denicolai et al., 2021). However, according to some studies, employees of SMEs may see AI adoption as a barrier due to a lack of awareness about AI capabilities, concerns about job displacement, and the perceived complexity of AI implementation (Mikalef et al., 2019; Hossain, 2022; Shehzad et al., 2022). Thus, there is a need to explore the AI-based cost-effective solution for the business paradigm shift for Omani SMEs (Asemokha et al., 2019; Shehzad et al., 2023a). Thirdly, there is a lack of contextual studies in oil-dependent economies. Most research on SME internationalisation has been conducted in Western economies, with little attention paid to Gulf societies, and does not track data related to SMEs over time. So, this study can help better understand how AI adoption and frugal innovation are happening among SMEs in emerging economies to address further calls for research (Dabić et al., 2022). Lastly, integrating different theoretical perspectives from the domains of technology and international business needs to integrate multiple theoretical perspectives to provide a more comprehensive understanding of the drivers of the internationalisation of SMEs in Gulf economies.

Given the above significance and research gaps, the research is expected to answer the critical research question, i.e., how do artificial intelligence adoption, frugal innovation, and business model innovation help SMEs follow international growth? Accordingly, the key objective of this study is to explain the interactive effect of AI adoption on the relationships between frugal innovation, business model innovation, and the internationalization of SMEs.

The key contributions of this research study are multiple. Theoretically, we expanded on transition cost economies to present a conceptual framework that explains how business model innovation is the missing link between cost-effective innovation and achieving internationalisation objectives. Second, we explored the necessary conditions for the internationalisation of SMEs in an oil-rich economy. Thirdly, we explored the readiness of SMEs to adopt AI to add value to internationalisation. Finally, we combined partial least squares structural equation modelling (PLS-SEM) with multiple necessary conditions analysis (NCA) to produce a unique methodology for rigorous analysis and applied research for policymakers (Richter et al., 2020; Cheah et al., 2023).

The rest of the article is organised into four classical sections, starting from the literature review and hypotheses development section. The second part of the study is dedicated to developing a rigorous methodology to test the conceptual framework. Thirdly, the authors present results by combining PLS-SEM with NCA. Finally, a discussion, conclusion and practical and theoretical implications are presented, and future research is recommended to address the current study's limitations.

2. Theoretical Underpinnings and Literature

Transaction Cost Economics (TCE) is a theory that examines the costs associated with an international exchange of goods and services, including the costs of negotiating, monitoring, and enforcing contracts (Williamson, 1979). TCE focuses on minimizing the stated transaction costs by utilizing a variety of SMEs' strategies, including technology, cost-effective innovation, and innovation in their business model's value proposition (Akter et al., 2022). TCE is ideally suited for examining the relationship between frugal innovation, business model innovation, SME internationalization, and AI adoption, in order to assess SMEs' readiness for global expansion. First and foremost, TCE prioritizes reducing the costs involved in market transactions, which is in line with frugal innovation (FI) strategy of the SMEs (Singh et al., 2022). FI specifically targets transaction cost issues by reducing manufacturing and operating expenses, thereby enhancing competitiveness (Dost et al., 2019; Dost and Umrani, 2024; Williamson, 1979). Second, business model innovation (BMI) acts as an intermediary by converting these cost-effective breakthroughs into feasible commercial strategies to go global for SMEs (Lew et al., 2023a; Schneckenberg et al., 2022). Third, adopting AI could potentially bring about technical progress that would effectively reduce transaction costs through process automation, decision-making enhancement, and market response improvement (Sjödin et al., 2021; Saleem et al., 2023; Akter et al., 2022; Schneckenberg et al., 2022).

2.1. Framework development

2.1.1. Frugal innovation and SME internationalisation

The theory of transaction cost economics (TCE) offers a helpful conceptual framework for comprehending the ways in which innovation may support the internationalization of small and medium-sized enterprises (SMEs) by mitigating the many transaction costs linked to market entry and operation in foreign countries (Saridakis et al., 2019). Frugal innovation (FI) is the creation of simple, cost-effective, and easily accessible goods and services with few resources (Hossain, 2022; Shehzad et al., 2023b). TCE states that SMEs strive to reduce transaction costs, including expenses related to information retrieval, contract negotiation, and agreement monitoring and enforcement (Williamson, 1979). Several key factors may be emphasized while analyzing the correlation between frugal innovation and the internationalization of small and medium-sized enterprises (SMEs) using the framework of TCE. For example, financial inclusion (FI) may assist in decreasing the initial expenses associated with entering a new market for small and medium-sized enterprises (SMEs) aiming to expand internationally (Akter et al., 2022) and help oil-rich economies like Oman to be less dependent on oil export (Abdelfattah et al., 2023). By producing straightforward products and services at fair prices, this is possible. As a result, SMEs can overcome obstacles to entering foreign markets where customers may have restricted buying capacity. Prior research has shown substantial evidence supporting a positive correlation between the innovation of cost-effective goods and the process of internationalization undertaken by SMEs (Singh et al., 2022; Saridakis et al., 2019; Shehzad et al., 2023a) including family-owned SMEs going global for business expansion (Alayo et al., 2021). Consequently, we have postulated the following relationship:

H1: In family-owned SMEs, frugal innovation positively affects internationalisation.

2.1.2. Artificial Intelligence as Moderator between FI and SME Internationalization

(TCE) theory suggests that it may be especially advantageous for SMEs entering new markets where there may be a significant degree of information asymmetry (Aker et al., 2022; Williamson, 1979). This is because information asymmetry enables more transparent communication of value propositions and simplifies comprehending the product or service offered. In light of this, using technology may be the most effective means of enhancing the connection between frugal innovation and the accomplishment of internationalization goals (Alayo et al., 2021; Mikalef et al., 2019). Consequently, family-owned SMEs use the capabilities of artificial intelligence and big data, which gives them an advantage when they possess more or better information than their competitors operating in the MENA region including UAE and Qatar (Hossain, 2022; Reypens et al., 2021). In light of this, we have proposed the following hypothesis:

H2: In family-owned SMEs, AI adoption positively moderates the relationship between frugal innovation and internationalisation.

2.1.3. Frugal innovation and business model innovation

Transaction cost economics emphasizes BMI by optimizing transaction costs to operate in the international market (Williamson, 1979; Schneckenberg et al., 2022). BMI reduces these expenses by rethinking how an SME could develop and distribute value to the customers (Lew et al., 2023a). With BMI customised for the international market, any SME may simplify processes, eliminate information asymmetry, and reduce transaction risks. TCE emphasizes BMI as a strategic requirement for an SME seeking efficiency, uncertainty reduction, and value creation in the international competitive marketplaces, including family-owned SMEs (Asemokha et al., 2019; Singh et al., 2022). Frugal innovation and BMI are intricately linked and may serve as the primary strategy for SMEs to expand globally (Dabić et al., 2022; Saridakis et al., 2019). TCE offers significant insights into how sustainable innovations generate value for international customers, enhance operational efficiency, and attain a competitive advantage over local players to generate revenue while going global (Schneckenberg et al., 2022). Family-owned SMEs in oil-rich economy have the potential to succeed in highly competitive global marketplaces by adopting frugal principles and rethinking their business models (Alayo et al., 2021; Singh et al., 2022), which would help the Omani government to less dependent on oil and mineral exports. This may FI driven strategy be achieved by efficiently managing transaction costs and strategically using their distinctive capabilities, resources, and experiences learned locally before moving globally (Hossain et al., 2016). This study suggests a positive relationship between FI and BMI, as explained by transaction cost theory. The concept of FI, which prioritizes simplicity, affordability, and accessibility, effectively decreases the expenses related to commercial transactions Hossain (2020), (2018). Through optimising processes, goods, or services, FI reduces the expenses associated with searching for information, negotiating, and coordinating, enhancing enterprises' efficiency in innovating their business models (Sjödin et al., 2021; Hossain et al., 2016). FI can catalyse business model innovation in family-owned SMEs, motivating them to critically reassess their operational procedures and cost structures while going global (Singh et al., 2022; Dost et al., 2019; Dost and Umrani, 2024). Consequently, we have postulated the following relation.

H3: In family-owned SMEs, frugal innovation positively affects business model innovation.

2.1.4. Artificial Intelligence as Moderator between FI and BMI

Artificial intelligence (AI) acts as a moderator between frugal innovation and business model innovation (Lew et al., 2023a; Schneckenberg et al., 2022), especially with regard to the idea of information asymmetry that is outlined in transaction cost theory (Williamson, 1979). A reduction in information asymmetry may be achieved by the implementation of AI along with FI. In addition, artificial intelligence helps to

control this connection by improving information processing skills, making it easier to make decisions based on facts, and lowering the level of uncertainty. Family SMEs can better comprehend international market dynamics, preferences of digital and global customers via the use of analytics and predictive modeling powered by artificial intelligence and big data analytical capabilities (Ciampi et al., 2021; Mikalef et al., 2019; Sjödin et al., 2021). This helps firms mitigate information asymmetry (Aker et al., 2022; Saleem et al., 2023). This facilitates the ability of SMEs to adjust and better match their strategy with the realities of the global market, which in turn results in a digitally customized business model to provide a distinctive value proposition to global customers (Waseel et al., 2023; Hossain et al., 2016). So we can safely postulate that artificial intelligence moderates between frugal innovation and business model innovation, such that the interaction of FI and AI positively impacts BMI for family-owned SMEs (Dost and Umrani, 2024; Hossain et al., 2016; Shehzad et al., 2023b). It does this by enhancing information processing skills, which in turn reduces transaction costs and enables businesses operating in the MENA region, including Oman, to reinvent their business models more strategically for the firm's international appearance through technology adopting (Sjödin et al., 2021; Denicolai et al., 2021). Consequently, we have postulated the following relationship:

H4 In family-owned SMEs, AI adoption positively moderates the relationship between frugal innovation and business model innovation.

2.1.5. BMI and SME internationalisation

The influence of BMI on the internationalization of SMEs can also be examined via the framework of TCE (Schneckenberg et al., 2022). For example, BMI may assist SMEs operating in oil-rich economies like Oman in reducing the expenses related to entering and doing business in global markets. Arab Family SMEs may reduce transaction costs, such as information search, negotiation, and coordination with international partners, by using innovative and digital business model that simplify operations, improve efficiency, and maximize resource allocation (Alayo et al., 2021). BMI can also enhance the establishment of strategic partnerships and alliances, helping SMEs get more efficient access to international markets. According to TCE, SMEs form partnerships with international counterparts to use the advantages of complementary resources and competencies while simultaneously minimizing transaction costs (Williamson, 1979). Arab family-owned SMEs may overcome obstacles to entering foreign markets and develop a strong presence by using innovative business models that promote cooperation with local partners or distributors while preparing to operate in international markets (Williamson, 1979; Schneckenberg et al., 2022). The significance of adaptability in addressing changes in market dynamics is underscored by transaction cost theory (Schneckenberg et al., 2022). SMEs can potentially improve their flexibility by using innovative business models that may effectively address cultural, regulatory, and competitive disparities in global marketplaces (Sjödin et al., 2021; Schneckenberg et al., 2022). This strategic approach can help mitigate transaction risks. Ultimately, BMI helps Arab SMEs to enhance the efficiency of resource allocation and firms can diversify their businesses from oil and gas to other industries (Abdelfattah et al., 2023). The notion of transaction costs places significant emphasis on the need to align investments with assets and digital systems that are relevant to the transaction (Williamson, 1979). The use of BMI enables SMEs to strategically allocate their resources towards activities that provide the greatest returns, while simultaneously reducing transaction costs. This approach enhances the success of the internationalization efforts of Arab family-owned SMEs. Consequently, we have postulated the following relationship:

H5: In family-owned SMEs, business model innovation positively affects internationalisation.

2.1.6. Business Model Innovation as a Mediator

Using frugal principles (Hossain, 2022), Arab family-owned SMEs

may also enhance their operational efficiency and competitiveness to reach worldwide targets using unique BMI well aligned with digital requirements for international online customers (Lew et al., 2023a; Saleem et al., 2023). Talabat an online delivery company is good example for that which is operating in Oman successfully after COVID-19. Frugal innovation promotes flexibility and demands that SMEs adopt digital business models, allowing them to adjust to changes needed for international market circumstances (Saridakis et al., 2019; Dost and Umrani, 2024). This, in turn, facilitates their worldwide expansion plan. TCE emphasises the significance of transaction-specific investments and the ability to reallocate resources while going international (Aker et al., 2022). By implementing innovative business models, SMEs may enhance their ability to meet the changing demands of worldwide customers, global market trends, and regulatory environments (Ciampi et al., 2021). The capacity to adapt decreases the likelihood of transaction failures and strengthens SMEs owned by families in dynamic international business settings (Alayo et al., 2021; Asemokha et al., 2019; Saleem and Ashfaq, 2023). The use of frugal innovation in business model development has the potential to foster the establishment of a durable competitive advantage for SMEs controlled by families (Alayo et al., 2021). By implementing innovative business models, these SMEs may distinguish themselves from local rivals operating in global markets (Sjödin et al., 2021; Alayo et al., 2021). So increasing their chances of capturing a larger portion of the worldwide market. In addition, Arab family-owned SMEs have the potential to enhance their connections with consumers, suppliers, and other relevant parties via the use of frugal principles through digitally enabled BMI (Sjödin et al., 2021). This, in turn, may enhance firm's competitive standing within the global and regional market of the Middle East. Consequently, we have postulated the following mediating relationship:

H6: In family-owned SMEs, business model innovation mediates the relationship between frugal innovation and internationalisation Fig. 1.

3. Methodology

According to Oman's National Centre for Statistics and Information (NCSI) *, 81,460 SMEs were registered across eleven Omani states, locally known as 'Governorates'. NCSI reported that until July 2022, 33.6 % of Omani SMEs were in Muscat, 15.39 % in North Al Batinah, 11 % in Al Dakhiliyah, 10.5 % in Dhofar, and 7.3 % in South Al Batinah. The remaining SMEs were registered in South Al Sharqiyah Governorate, Al Dhahirah, Al Buraimi Al Wusta, and Musandam, respectively.

The primary rationale for choosing firms from these Omani cities is their status as commercial hubs for Arab family-owned SMEs, ensuring that the sample accurately represents Oman's economic landscape. This increases the significance of the research but may limit its applicability, necessitating caution when extending the results to firms operating in other oil-rich nations, including Saudi Arabia, Bahrain, the UAE, Qatar, and others.

We used cluster sampling due to its traits of a maximum

representation of the sampling frame, low cost, and better response rates to overcome the deficiency of convenience sampling issues as adopted in the latest Omani context (Abdelfattah et al., 2023). We made five clusters as per the top five percentages of governorates in Oman disbursed across five geographic locations: Muscat, North Al Batinah, Al Dakhiliyah, Dhofar, South Al Batinah, and others.

Older studies suggest that we chose to test this moderated mediation using Smart PLS for data analysis due to its ability to handle complex models, small sample sizes, and non-normally distributed data (Cheah et al., 2023). SMART PLS 4.03: The structural equation modeling approach greatly benefited this study by maximizing the explained variance of dependents, i.e., the internationalization of SMEs in our case (Sarstedt et al., 2014). Smart PLS effectively handled our four constructs with controls. The study's hypotheses are well-suited to the robust analysis, thus prioritizing the variance explanation, making it the best candidate for this analysis (Cheah et al., 2023; Sarstedt et al., 2014).

The data were obtained using electronic channels, namely via Google Forms and social media platforms such as Facebook and WhatsApp. Additionally, emails were employed to enhance the dissemination of the questionnaire. The survey instrument is partitioned into two distinct sections to capture the demographics of the company and measure the latent constructs. The first section captured firm size, industrial sector, and domestic versus international company type. The second section of the scale comprises the 20 items used to represent the primary study variables. Our sample size was large, i.e., greater than 10,000. Therefore, as reported in a previous study (Baruch, 1999), we relied on two criterion to get a true representation of the SME population. First, we ensured the number of responses should exceed 100 (20 items x 5 responses). Second, we ensure that a larger sample's response rate remains above 10 %. 400 translated questionnaires were sent, with the expectation of obtaining around 10 % of a larger population across five clusters. During the first phase, 90 replies were received, 80 of which were highly engaged respondents. In response to the low response rate, further data collection was conducted, and email reminders were sent. This intervention significantly increased the response rate, reaching 44.25 % with total of 177 usable responses from SMEs.

A translated version of the scale in Arabic was used to ensure an appropriate response. Consequently, procedures were implemented to guarantee the excellence, accuracy, and appropriateness of the Arabic language in creating the relevant scale for this study (Chidlow et al., 2014). Initially, we used a proficient multilingual expert with vast expertise in teaching business courses using Arabic to verify the translations; then we used the reverse translation technique to address any inconsistencies or errors in the translated questionnaire, using Google translate as a second measure to ensure the excellence, accuracy, and appropriateness of the tool translated into the Arabic language by translating the questionnaire back into its original Arabic language. Finally, a pilot study on 15 students was done using the Arabic-translated tool with workers of SMEs pursuing an MBA program at Sohar University. Any apprehensions about comprehension, clarity,

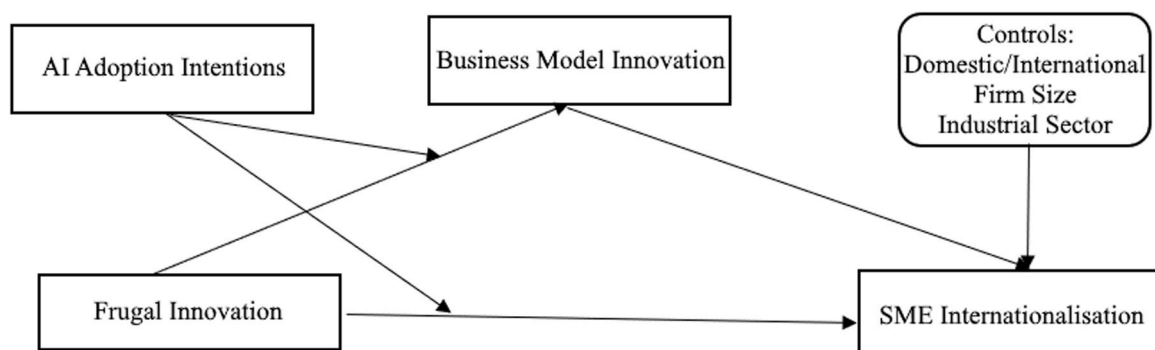


Fig. 1. Conceptual.

or cultural suitability were addressed throughout that phase in communication with local translation experts.

3.1. Measurements

This research consisted of four latent variables: frugal innovation as the independent variable, readiness to adopt artificial intelligence as the moderating variable, business model innovation as the mediating variable, and SME internationalization as the dependent variable. The measuring scales are derived from previous investigations and are found to be valid and reliable.

The nine-item scale for business model innovation was adopted from previous studies (Spieth and Schneider, 2016) to capture value creation, value proposition, and value capture with three items each, which scholars lately tested in a reputed journal by collecting data from UK-based SMEs (Lew et al., 2023b). The five-item scale of frugal innovation was adopted from a previous study measuring key dimensions, i.e., functionality, ecosystem, and cost-effectiveness of the company's product or service. The scale has recently been tested on SMEs of one of the Gulf states, the Kingdom of Saudi Arabia (AlMulhim, 2021). The scale for the readiness to adopt artificial intelligence consisted of three items and was adopted from a study (Upadhyay et al., 2023). Finally, the internationalisation scope of SMEs consists of three items adopted from the latest study (Lew et al., 2023b). The study used three control variables to follow previous studies, namely firm size, industrial sector, and domestic versus international company type (Clauss, 2017; Upadhyay et al., 2023; Lew et al., 2023b; AlMulhim, 2021).

4. Results

4.1. Descriptive Analysis

Referring to Table 1, four types of SMEs are operating in production (40 %), construction (12 %), retail (40 %), and services (8 %). Most of the SMEs are locally owned by Omanis (57 %). There were Micro (23 %), Small (52 %), Medium (25 %). Most of the SMEs who responded were operating in Muscat (34 %) and North Al Batinah (23 %). Employees reported that they had been affiliated with SMEs for a long and demonstrated high organizational commitment. 20 % of employees reported less than a year, 25 % reported 1–5 years of working experience

Table 1
Demographics.

Variable	Sample (n=177)	Percentage
Industry Sector		
Production	71	40 %
Construction	22	12 %
Retail	70	40 %
Services	14	8 %
Firm Type		
Local	101	57 %
International	70	40 %
Prefer not to say	6	3 %
Size of SMEs		
Micro (up to 10 employees)	40	23 %
Small (11–50 employees)	92	52 %
Medium (51–250 employees)	45	25 %
Region		
Muscat	60	34 %
North Al Batinah	40	23 %
Al Dakhiliyah	40	23 %
Dhofar	20	11 %
South Al Batinah	15	8 %
Other	2	1 %
Experience with SME		
Less than a year	35	20 %
1–5 years	45	25 %
6–10 years	70	40 %
11 or more years	21	12 %

with current SMEs, 40 % reported 6–10 years of experience, and 12 % staff was affiliated with current SMEs 11 or above years.

Please consult the Table 2. The average variance extracted (AVE) for the four distinct constructs ranged from 0.686 to 0.723. Furthermore, the factor loading above the criterion of 0.700 ensures the convergent validity of each item for each of the four constructions (i.e., AIA, BMI, FI, SME Internationalization). The appendix pasted after references contains the scale items for all four constructs.

Table 3 presents the discrimination validity analysis. All four of our study's constructs (AIA, BMI, FI and SME Int) have demonstrated internal consistency; values are within acceptable limits.

4.2. Significance and relevance of the path coefficients

4.2.1. Direct paths

In this study, we examined the direct effect of frugal innovation (FI) on SME internationalization on business model innovation(BMI) and BMI's impact on SME internationalization. Bootstrapping is a technique that involves the creation of sub-samples by randomly selecting observations from the main sample with replacements. In accordance with scholarly recommendations, a substantial number of bootstrap sub-samples (i.e. 10,000) were conducted to evaluate our hypothesis. The results showed (See Table 4) that there existed statistical evidence of a significant positive effect of adopting frugal innovation on the internationalization of SMEs (H1 $\beta= 0.180$, $t=1.878$, $p < 0.05$) and (H3: $\beta=0.473$, $t=2.150$, $p < 0.01$). Similarly, BMI's impact on SME internationalization was statistically significant (H5: $\beta=0.473$, $t=2.150$, $p < 0.01$). Thus, our direct hypotheses are substantiated (H1, H3 and H5).

4.2.2. Moderating and mediation paths

The authors used the product indicator approach in SmartPLS 4.1 to examine artificial intelligence's (AIA) moderating impact on two paths (H2 and H4). In this study, we examined the moderating effect of AIA PM on the relationships between FI and SME internationalization (H2) and FI and BMI (H4). The results showed (See Table 4) that there existed statistically insignificant evidence moderating effect of the readiness to use artificial intelligence on the relationship of FI and SME internationalization; thus, the moderating hypothesis is not substantiated (H2 $\beta= 0.053$, $t=1.878$, NS). However, the moderating role of AI is substantiated on the path from FI to BMI (H4: $\beta=0.147$, $t=2.806$, $p < 0.05$), highlighting the significance of willingness to adopt AI along with frugal innovation strengthens the business model innovation efforts of SMEs. However, directly using AI without BMI is not supportive of promoting the internationalization of SMEs.

Table 2
Standardized loadings, AVE, CR and Alpha.

Description	Items	Estimate	AVE	Alpha	CR
AI Adoption Readiness (Moderator)	AIAI1	0.849	0.717	0.804	0.883
	AIAI2	0.914			
	AIAI3	0.772			
Business Model Innovation (Mediator)	BMI1	0.807	0.695	0.944	0.953
	BMI2	0.916			
	BMI3	0.902			
	BMI4	0.884			
	BMI5	0.835			
	BMI6	0.825			
	BMI7	0.800			
	BMI8	0.812			
	BMI9	0.701			
Frugal Innovation (Independent)	FI1	0.842	0.686	0.886	0.916
	FI2	0.762			
	FI3	0.861			
	FI4	0.837			
	FI5	0.837			
SME Internationalization Scope (Dependant)	INT1	0.825	0.723	0.808	0.886
	INT2	0.884			
	INT3	0.841			

Table 3
Discriminant validity.

		1	2	3	4	5	6	7
1	AIA	1.000						
2	BMI	0.665	1.000					
3	FI	0.815	0.771	1.000				
4	Firm Size	0.068	0.084	0.032	1.000			
5	Firm Type	0.149	0.197	0.158	0.009	1.000		
6	Industry	0.121	0.077	0.07	0.137	0.122	1.000	
7	SME Internationalization	0.585	0.652	0.622	0.142	0.132	0.079	1.000

Table 4
Hypothesis testing and propositions for future research.

Hypotheses	β	S.E	t-value	p-value
H1 FI \rightarrow SME-Internalization	0.180	0.096	1.878	0.030
H2 AIA x FI \rightarrow SME-Internalization	0.053	0.025	1.150	0.160
H3 FI \rightarrow BMI	0.473	0.087	5.468	0.000
H4 AIA x FI \rightarrow BMI	0.147	0.052	2.806	0.003
H5 BMI \rightarrow SME-Internalization	0.361	0.093	3.882	0.000
H6 FI \rightarrow BMI \rightarrow SME-Internalization	0.171	0.048	3.552	0.000
Controls				
Industry - \rightarrow SME-Internalization	0.086	0.062	1.394	0.082
Firm Type - \rightarrow SME-Internalization	0.039	0.167	0.236	0.407
Firm Size - \rightarrow SME-Internalization	0.062	0.067	0.932	0.176
Other Pathways				
P1 AIA \rightarrow SME-Internalization	-0.156	0.078	1.994	0.023
P2 AIA \rightarrow BMI	-0.194	0.083	2.324	0.010
P3 AIA \rightarrow BMI \rightarrow SME-Internalization	-0.070	0.039	1.819	0.034
P4 AIA x FI \rightarrow BMI \rightarrow SME-Internalization	0.059	0.025	2.150	0.016

Finally, our study tested the mediating role of business model innovation between frugal innovation and the internationalisation of SMEs (H6). The mediating role of BMI is substantiated between FI and the internationalization of SMEs (H6: $\beta=0.171$, $t=3.552$, $p < 0.001$), recommending that SMEs' internationalisation efforts should be successful through frugal innovation if SMEs consider business model innovation, seriously.

4.3. Necessary condition analysis

Authors have performed a Multiple Necessary Condition Analysis MNCA Analysis and combined it with PLS-SEM as prescribed by studies to explore the necessary conditions for the internationalization of SMEs and business model innovation (Richter et al., 2020). The present analysis facilitated the assessment of the statistical significance of the effect size of necessity obtained by a permutation test. This factor should be considered while formulating a necessity hypothesis. (Dul, 2016). We used bootstrapping at 10000 for a permutation test.

Refer to Tables 5 and 6. SEM analysis explains that most of the paths are significant. For instance, we can observe that FI, BMI, and AI play roles in SME internationalization and business model innovation. However, some variables and their interactions are necessary conditions for SME internationalisation (e.g. FI and BMI), but AI alone is not a necessary condition variable for SME internationalisation. Rather, AI has a negative impact if an SME decides to go global without frugal innovation. Following the bottleneck Table 6 for SME internationalization, we can conclude that to achieve 80 % of the internationalisation (i.e. the value of on a scale of 1–7), frugal innovation must have at least a value of 2.200, and BMI should have at least a value of 2.667. While AI adoption is not a necessary condition for SME- internationalization,. For business model innovation, we can conclude that to achieve 80 % of business model innovation (i.e. the value of on a scale of 1–7), the frugal innovation must have at least a value of 3.968, While AI adoption is a necessary condition only if the SME want to achieve 100 % of business model innovation with at least a value of 5.654 for frugal innovation and

Table 5
Multiple Necessary Condition Analysis.

Scenario	Beta	PLS-Sem Results p-value		Beta	NCA Results p-value	
FI \rightarrow SME-Internalization	0.180	0.032	SD	0.093	0.000	NC
BMI \rightarrow SME-Internalization	0.361	0.000	SD	0.107	0.000	NC
FI \rightarrow BMI	0.473	0.000	SD	0.211	0.000	NC
AIA x FI \rightarrow SME-Internalization	–	0.430	ID	0.161	0.001	NC
AIA x FI \rightarrow BMI	0.147	0.003	SD	0.368	0.000	NC
AIA \rightarrow SME-Internalization	–	0.025	ID/	0.001	0.000	NNC
AIA \rightarrow BMI	-0.194	0.011	ID/ND	0.009	0.490	NNC

Note: SD: Significant determinant; ID: Insignificant determinant; NGD: Negative determinant; NC: Necessary condition; NNC: Not a necessary condition

Table 6
Bottleneck Table for SME Internationalization and BMI.

Percentile	SME Int	AIA	BMI	FI	BMI	AIA	FI
0.00 %	1.000	NN	NN	NN	1.222	NN	NN
20.00 %	2.200	NN	NN	NN	2.378	NN	NN
40.00 %	3.400	NN	NN	NN	3.533	NN	NN
60.00 %	4.600	NN	1.889	NN	4.689	NN	2.283
80.00 %	5.800	NN	2.667	2.200	5.844	NN	3.968
100.00 %	7.000	NN	3.111	3.400	7.000	1.667	5.654

a value of 1.667 for AI adoption.

5. Discussion

The present study examines how and under which boundary conditions frugal innovation (FI) positively impact the internationalization process for small and medium-sized firms (SMEs). Additionally, it seeks to explain the impacts of business model innovation (BMI) on the internationalization of SMEs. In addition, we analyzed the moderating role of artificial intelligence (AI). The results demonstrated a positive effect of adopting frugal innovation on the internationalization of SMEs, which is consistent with previous studies; see, for instance, (Younis and Elbanna, 2022; Sjödin et al., 2021). Similarly, the impact of BMI on the international expansion of SMEs was shown to be positive and significant (Asemokha et al., 2019). This study also aimed to examine the moderating impact of AI as the second key objective. The results showed limited evidence to suggest that the readiness of SMEs to use AI influences the relationship between frugal innovation (FI) and the expansion of SMEs into international markets, which is contrary to pervius studies (Saleem et al., 2023; Upadhyay et al., 2023). The reasons for this could be the context of Middle Eastern SMEs where the resistance to adopting the latest skills and technical knowledge is normal (Younis and Elbanna, 2022). The role of artificial intelligence (AI) in governing the correlation between FI and BMI is substantiated, underscoring the significance of both the inclination to adopt AI and

cost-effective innovation in augmenting the endeavours of SMEs in advancing their business model innovation, confirming previous findings (Asemokha et al., 2019). Nevertheless, using AI without business model innovation fails to facilitate the internationalisation process for SMEs. The results indicate a level of concurrence with previous studies (Clauss, 2017; Sjödin et al., 2021). Our research examined how business model innovation acts as a mediator between frugal innovation and the internationalization of SMEs for the first time using Omani SMEs. We suggest that if SMEs prioritize business model innovation, their internationalization efforts should be effective via frugal innovation.

5.1. Theoretical implications

From a theoretical perspective, our study's objective is to enhance comprehension of crucial elements pertinent to examining the internationalization of SMEs and their preparedness for using artificial intelligence from using transaction cost perspective. Specifically, we examined the advantages of evaluating frugal innovation as a catalyst for determining the future development trajectory of the SME's internationalization. Furthermore, we enhance the existing knowledge on the internationalization of SMEs by elucidating the interconnections between internationalization, preparedness for AI, and business model innovation (Kumar et al., 2024; Zeshan et al., 2023). We demonstrated the advantages of concentrating on a particular kind of digitalization in SMEs: artificial intelligence. This contribution enhances our comprehension of digitalization at a more detailed level. We argue that the liability of smallness may account for the fact that SMEs attain worldwide success by focusing on agile business models and adopting artificial intelligence (AI) despite their low resources. SMEs investing in AI without changing their business model may not end up in a successful internationalization. The path to SME's internationalisation goes through BMI, which is also conditional to the level of readiness to adopt AI.

5.2. Practical implications for stakeholders

According to the Nessacary Condition Analysis (NCA), stakeholders, investors, and policymakers in oil-rich countries such as Oman and other middle-eastern countries should understand that successful SME internationalization requires a combination of frugal innovation and business model innovation to target international markets. This implies that policymakers should foster an environment that is conducive to cost-effective and resource-efficient innovations, a concept known as frugal innovation. Policymakers should provide frameworks that enable both cost-effective innovation and the creation of strong business models for SMEs. This would help SMEs expand their global market presence while reducing their reliance on oil exports.

Small and medium-sized enterprises (SMEs) ought to acknowledge the synergistic relationship between frugal innovation (FI) and business model innovation (BMI) and deliberately include both methodologies into their operational frameworks while expanding globally. This may include cultivating a culture that promotes cost-effective and sustainable innovation, allocating scarce resources towards cross-functional cooperation, and ensuring that innovation initiatives align with the broader company goals. The research's findings indicate that AI is not necessary for SME internationalization. This study indicates that the effect of AI adoption on moderating this relationship is not statistically significant. However, the strategic deployment of AI may promote FI efforts and improve competitiveness in global markets for SMEs. SMEs should evaluate their preparedness to adopt AI technologies and allocate resources towards developing internal skills or using external expertise to use AI's potential for sustainable and cost-effective innovation. Finally, SMEs should exercise caution when using AI technology without simultaneously modifying their business model. In light of the possible negative consequences associated with fragmented frugal innovation endeavours, it is essential for SMEs to emphasize a well-rounded AI

adoption strategy across multiple departments and processes that integrate technology progress with strategic adjustments to their agile business models as per customer needs. This may include doing thorough evaluations of innovation requirements to satisfy consumer expectations, promoting cooperation across different functions (social media marketing and supply chain, capturing online orders), and continuously refining business models to maintain adaptability in global market contexts.

Arab family-owned SMEs may use these measures to incorporate AI and frugal innovation into their business models. First, SMEs need to determine their core needs. This is possible by assessing SME issues and areas where AI and frugal innovation might provide value. Prioritize cost reduction, efficiency, and customer happiness. Second, Arab SMEs can creatively use existing resources from oil-related businesses to create cost-effective solutions. For instance, reuse technology and procedures to save money. Third-party firms can initiate small-scale AI pilot initiatives to examine their feasibility and efficacy, which they can then gradually improve and scale up using trial results. Fourth, AI-driven staff training is critical; equipping human resources with the right skills helps them integrate and use new tools. It is possible that the industry could fund a new tech graduate studying AI in Oman. Following these steps, Omani SMEs may integrate AI with frugal innovation for sustainable development and competitive advantage.

5.3. Limitations and future research

The first limitation of this study is that we have used cluster sampling, which is subject to some methodological limitations (Aga et al., 2023). For example, the similarity between clusters and the correlation between variables within the same cluster can cause a higher sampling error. If clusters do not emerge naturally, it may lead to inefficiency, and the accuracy of the findings heavily depends on precise cluster definitions. The second limitation of the study is that we have used the SMEs data based on their readiness instead of collecting data from the real firms adopting artificial intelligence with the purpose of helping the industry consider the role of AI for internationalization. Thirdly, multiple theoretical lenses were missing to develop our hypotheses.

The study has limitations. Accordingly, future research is recommended. When analyzing the study's findings, researchers should consider certain aspects that might restrict the conclusions that can be drawn. Future research could proceed in various directions. Theoretically and empirically, one should expand the analysis to examine other national Gulf contexts like the UAE and Saudi Arabia to produce comparative studies. Scholars can study how artificial intelligence adoption and digital transformation lead to internationalization through frugal innovation using the lens of the classical Uppsala model (Aftab et al., 2024; Coviello et al., 2017). A formal investigation can be conducted, including other factors and boundary conditions that could contribute to the internationalization of SMEs, e.g., turbulent environment, scarcity of technical local workforce, knowledge, and pace of digital transformation (Dost and Umrani, 2024; Saleem et al., 2023; Dost et al., 2019). A mixed-method study exploring a holistic understanding of the internationalization processes of SMEs in MENA should also be encouraged (Cheah et al., 2023; Saleem et al., 2020). Table 4 this study has uniquely postulated the negative role of AI adoption on SME internationalisation. The reason discussed in the previous studies is that the quality of technical human resources in oil-rich economies is a big question mark. Thus, exploratory studies are needed to compare the readiness of local and expat tech workers to adopt machine learning and artificial intelligence in business processes (Ciampi et al., 2021; Kumar et al., 2023; Mustafa et al., 2022). Lastly, the need to study how quickly the firms in the Middle East are adopting machine learning approaches to attract international customers is yet to be studied using qualitative design (Obaid, 2023; Dost and Umrani, 2024).

5.4. Conclusion

In summary, the correlation between frugal innovation, business model innovation, and the involvement of artificial intelligence in the internationalization of SMEs highlights the intricate dynamics of innovation inside these entities. The study conducted indicates that frugal innovation and BMI are mutually reinforcing strategies, and the strategic incorporation of AI may further augment their synergistic association. Nevertheless, our research also presents empirical evidence and asks future research to test the assumption that why alone AI is not an essential prerequisite for the internationalization of SMEs. Conversely, we see that the use of AI without simultaneous BMI initiatives might have adverse consequences on internationalization results. This emphasizes the significance of embracing a comprehensive strategy for innovation and globalization, in which technical progress is deliberately synchronized with wider business model adjustments.

Ethical Approval

Ethical approval for this article was obtained from the relevant departments at Sohar University, Oman.

Statement of Informed Consent

Informed consent was obtained via a cover letter. Researchers agreed to hide the identities of the respondents.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

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Ethical Statement for Solid State Ionics

Hereby, I Irfan Saleem consciously assure that for this manuscript the following is fulfilled:

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- 3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
- 4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
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CRedit authorship contribution statement

Najla Salim Said Al Breiki: Funding acquisition, Data curation. **Irfan Saleem:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Muzaffar Asad:** Writing – review & editing, Methodology, Data curation.

Declaration of Generative AI and AI-assisted technologies in the writing process

While preparing this work, the authors used Grammarly and QuillBot to improve the language and readability of the written content, as the authors are non-native English speakers. Moreover, ChatGPT was used to identify possible theories related to this study before choosing a suitable underpinning theory. After using these tools/services, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

Declaration of Competing Interest

The authors affirm that no conflicts of interest are associated with its publication.

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Appendix A. Appendix: Scale Items

Frugal Innovation

- Resource optimization and cost-effectiveness are key focuses in product/service development in my firm.
- We frequently explore creative ways to re-purpose existing resources for new product/service offerings.
- Training and development programs are available to encourage frugal thinking and innovative problem-solving among our employees.
- Successfully introducing innovative products/services that cater to price-sensitive customers is a noteworthy achievement for us.
- Simplifying processes and reducing unnecessary complexities are priorities within our firm.

AI Adoption

- Our firm is planning to adopt AI.
- Our firm will adopt AI for all my requirements.
- I think that our firm will adopt AI.

Business Model Innovation

- Our business model offers new combinations of products, services and information.
- Our business model constantly attracts new collaboration partners.
- Our business model constantly attracts new customer segments

- Our business model bonds participants together in novel ways
- Our business model always links participants to transactions in novel ways.
- We frequently introduce new ideas and innovations into our business model.
- We constantly utilise new opportunities arising from the integration of external partners into value-creation activities.
- Whenever needed, we frequently introduce new operational processes and significantly modify existing ones in our business model.
- Overall, our business model is a novel internationalization scope

Internationalization scope of SMEs

- We entered different foreign markets
- Our majority of revenues come from diverse foreign export markets
- Our export markets are very diverse

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