

AN EMPIRICAL INVESTIGATION OF INNOVATION PERFORMANCE PATHWAYS IN GUANGDONG'S BUILDING INDUSTRIALIZATION ENTERPRISES

UMA INVESTIGAÇÃO EMPÍRICA SOBRE OS CAMINHOS DO DESEMPENHO EM INOVAÇÃO NAS EMPRESAS DE INDUSTRIALIZAÇÃO DA CONSTRUÇÃO CIVIL DE GUANGDONG

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Abstract

The rapid development of China's construction industrialization has intensified enterprises' need to enhance innovation capability and improve organizational performance. In this context, technological innovation has become a core driver of competitiveness, while entrepreneurial cognition and business model innovation play increasingly strategic roles in shaping enterprise performance outcomes. This study examines the mechanisms through which technological innovation affects innovation performance, with entrepreneurial cognition and business model innovation functioning as key mediating pathways. A mixed-methods design was employed, combining qualitative insights from industry experts with quantitative analysis based on structural equation modeling (SEM) using data collected from 320 building industrialization enterprises in Guangdong Province. The results confirm that technological innovation significantly enhances entrepreneurial cognition and business model innovation, both of which, in turn, exert strong positive effects on innovation performance. The findings contribute to the theoretical understanding of innovation pathways in the industrialized construction sector and offer practical guidance for enterprises seeking to strengthen strategic cognition, upgrade business models, and improve innovation outcomes.

Keywords: Technological Innovation. Entrepreneurial Cognition. Business Model Innovation. Innovation Performance. Building Industrialization. Guangdong Province.

Resumo

O rápido desenvolvimento da industrialização da construção civil na China intensificou a necessidade das empresas de aprimorar sua capacidade de inovação e melhorar o desempenho organizacional. Nesse contexto, a inovação tecnológica tornou-se um fator central da competitividade, enquanto a cognição empreendedora e a inovação do modelo de negócios desempenham papéis cada vez mais estratégicos na definição dos resultados de desempenho das empresas. Este estudo examina os mecanismos pelos quais a inovação tecnológica afeta o desempenho em inovação, com a cognição empreendedora e a inovação do modelo de negócios atuando como principais vias mediadoras. Foi empregado um desenho de métodos mistos, combinando insights qualitativos de especialistas do setor com análise quantitativa baseada em modelagem de equações estruturais (SEM), utilizando dados coletados de 320 empresas de industrialização da construção na província de Guangdong. Os resultados confirmam que a inovação tecnológica aprimora significativamente a cognição empreendedora e a inovação do modelo de negócios, as quais, por sua vez, exercem fortes efeitos positivos sobre o desempenho em inovação. As conclusões contribuem para a compreensão teórica das vias de inovação no setor da construção industrializada e oferecem orientações práticas para empresas que buscam fortalecer a cognição estratégica, atualizar modelos de negócios e melhorar os resultados de inovação.



Palavras-chave: Inovação Tecnológica. Cognição Empreendedora. Inovação do Modelo de Negócios. Desempenho em Inovação. Industrialização da Construção. Província de Guangdong.

1 INTRODUCTION

China's construction industry is undergoing profound transformation, shifting from traditional labor-intensive practices to industrialized, technology-driven production systems. Guangdong Province, as one of China's most developed regions, has taken a leading role in promoting building industrialization, supported by policy incentives, digital construction technologies, and an increasingly competitive market environment. In this context, enterprises must not only adopt advanced technologies but also develop strategic cognitive capabilities and redesign business models to enhance their innovation performance.

Technological innovation—ranging from prefabrication techniques to digital construction platforms—plays a central role in improving productivity, reducing costs, and enhancing project quality. Yet, its effectiveness is deeply intertwined with entrepreneurs' cognitive abilities, including opportunity recognition, risk assessment, and strategic decision-making. Moreover, business model innovation has become essential for firms seeking to integrate technology into market-oriented value creation and delivery mechanisms.

Given the complex interplay among these factors, it is critical to understand how technological innovation drives innovation performance, and through which cognitive and business model pathways these effects materialize. This study therefore investigates the structural relationships among technological innovation (TI), entrepreneurial cognition (EC), business model innovation (BMI), and innovation performance (IP) within Guangdong's building industrialization enterprises. The findings aim to provide empirical evidence for policymakers and enterprise leaders seeking to enhance innovation capacity and industry competitiveness.

2 LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 Technological innovation and business model innovation

Technological innovation refers to the adoption, integration, and application of new technologies that enhance organizational processes, product quality, and production efficiency. In the building industrialization sector, technological innovation includes prefabrication technologies, digital construction platforms, BIM systems, and environmentally sustainable materials. Existing research highlights that technological innovation not only improves operational capability but also compels enterprises to adjust their value creation logic, leading to business model transformation.

As firms adopt new technologies, they often redesign their production processes, reshape value propositions, and modify market delivery systems. This reconfiguration is central to business model innovation. Numerous studies argue that technological innovation stimulates the exploration of new value networks and enables firms to transition from traditional project contracting to integrated service models.

Thus, the first hypothesis is proposed:

H1: Technological innovation has a positive effect on business model innovation.

2.2 Technological innovation and entrepreneurial cognition

Entrepreneurial cognition refers to the mental models and decision-making processes that guide entrepreneurs in identifying opportunities, evaluating risks, and formulating strategic actions. In technology-intensive contexts, technological advances reshape entrepreneurs' perceptions of market trends, competitive pressures, and innovation opportunities. As enterprises adopt new technologies, entrepreneurs gain enhanced insights into industry dynamics, strengthening their cognitive capability to formulate effective strategies.

Research shows that technological innovation triggers cognitive renewal by improving information availability, enriching experiential knowledge, and reducing uncertainty. Entrepreneurs who leverage technological progress are better able to

interpret industry signals, respond to environmental changes, and allocate resources efficiently.

Therefore, the second hypothesis is proposed:

H2: Technological innovation has a positive effect on entrepreneurial cognition.

2.3 Technological innovation and innovation performance

Innovation performance reflects an enterprise's ability to generate economic, technological, and competitive outcomes through innovative activities. In building industrialization enterprises, technological innovation enhances process efficiency, reduces error rates, shortens construction cycles, and improves environmental performance. Studies consistently show that enterprises with strong technological innovation capabilities achieve higher levels of innovation performance.

Technological innovation provides new capabilities that translate into superior operational outcomes, higher customer satisfaction, and enhanced market competitiveness. It also supports the development of new products and services, enabling firms to sustain long-term growth in rapidly evolving markets.

Thus, the third hypothesis is proposed:

H3: Technological innovation has a positive effect on innovation performance.

2.4 Business model innovation and innovation performance

Business model innovation involves reconfiguring value creation, delivery, and capture mechanisms. In the building industrialization sector, enterprises may adopt innovative models such as integrated design-construction services, digital platform-based collaboration, and lifecycle management services. A growing body of literature highlights that business model innovation enhances enterprise competitiveness by aligning technological capabilities with market needs.

Business model innovation allows firms to utilize technological innovations more effectively, translating them into market-oriented solutions. Enterprises adopting innovative business models tend to experience improved efficiency, revenue growth, and competitive advantage.

Accordingly, the fourth hypothesis is proposed:

H4: Business model innovation has a positive effect on innovation performance.

2.5 Entrepreneurial cognition and innovation performance

Entrepreneurial cognition shapes strategic choices that indirectly influence innovation outcomes. Entrepreneurs with strong cognitive capabilities are better at recognizing innovation opportunities, allocating resources, and guiding organizational learning. Such cognitive advantages enhance firms' ability to implement technological innovations and adapt to environmental changes.

Research confirms that entrepreneurial cognition contributes to better strategic judgment, faster opportunity response, and higher-quality decision making—factors closely associated with improved innovation performance in technology-driven industries.

Thus, the fifth hypothesis is proposed:

H5: Entrepreneurial cognition has a positive effect on innovation performance.

2.6 Research model

Based on the preceding literature review and the development of hypotheses, this study proposes an integrated research model to examine the mechanisms through which technological innovation influences innovation performance among Guangdong's building industrialization enterprises. The model incorporates technological innovation (TI) as the core antecedent variable, entrepreneurial cognition (EC) and business model innovation (BMI) as key mediating constructs, and innovation performance (IP) as the ultimate outcome.

The structural relationships are grounded in both innovation theory and entrepreneurial cognition theory, suggesting that technological advancements reshape strategic cognition and stimulate business model transformation, thereby enhancing enterprise innovation outcomes. Accordingly, the conceptual framework reflects the five hypotheses established in this study:

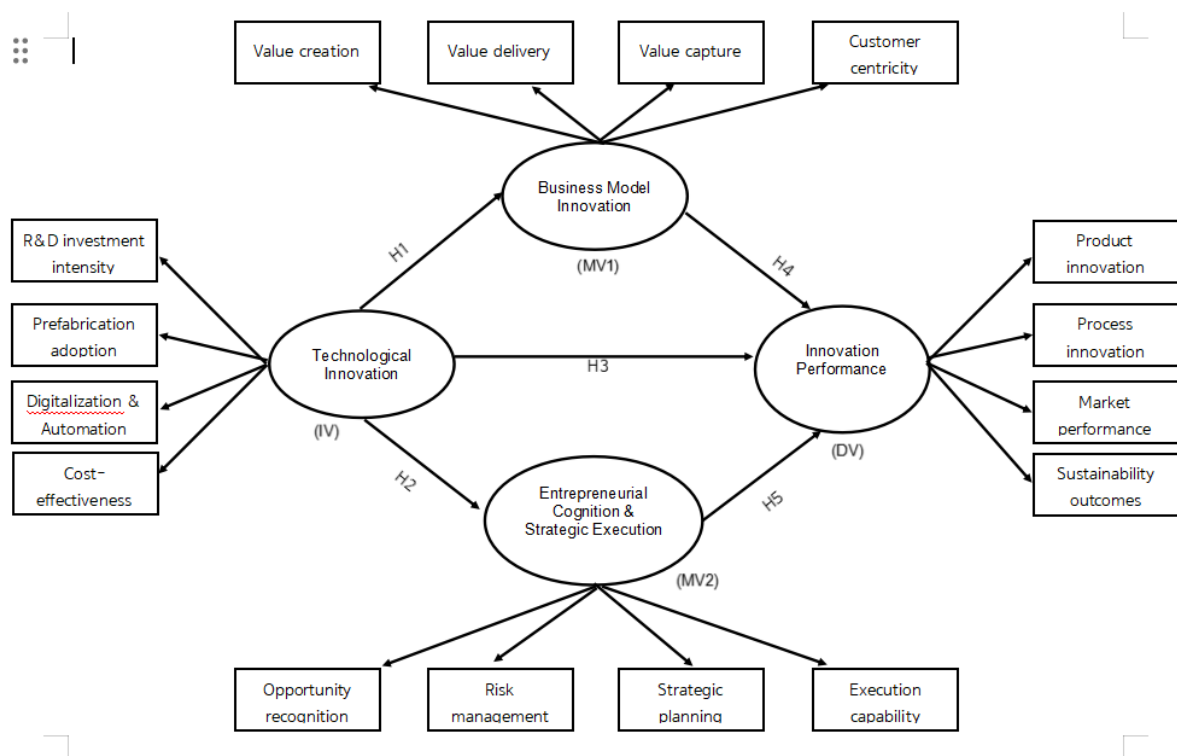
H1: Technological innovation positively influences business model innovation.

- H2: Technological innovation positively influences entrepreneurial cognition.
 H3: Technological innovation positively influences innovation performance.
 H4: Business model innovation positively influences innovation performance.
 H5: Entrepreneurial cognition positively influences innovation performance.

Integrating these relationships, the conceptual model illustrates a multistage pathway in which technological innovation not only exerts direct effects on innovation performance but also produces indirect effects through entrepreneurial cognition and business model innovation. This design allows for the empirical testing of both direct and mediated influences within the innovation ecosystem of the construction industrialization sector.

The proposed research model is presented in Figure 2.1.

Figure 1
Conceptual model



3 METHODOLOGY

3.1 Participants and sample design

The target population for this study consists of managers and senior professionals employed within Guangdong's building industrialization enterprises. These organizations represent the core actors implementing prefabrication, modular construction, digital technologies, and innovative management models across the province. Given the aim of examining the influence of technological innovation, entrepreneurial cognition, and business model innovation on innovation performance, respondents were required to possess direct involvement in technological upgrading, strategic planning, project management, or enterprise-level innovation activities.

A stratified sampling strategy was adopted to enhance representativeness, ensuring coverage across different enterprise types, including state-owned enterprises, private construction firms, and mixed-ownership industrialization companies. A total of 320 questionnaires were distributed to respondents across multiple prefecture-level cities in Guangdong, including Guangzhou, Shenzhen, Foshan, and Dongguan. After excluding incomplete or invalid responses, a final sample of 302 valid questionnaires was retained for analysis, yielding a valid response rate of 94.4%. This sample size exceeds the minimum threshold recommended for Partial Least Squares Structural Equation Modeling (PLS-SEM), thereby supporting robust statistical estimation.

3.2 Measurement

This study employed established measurement scales widely validated in innovation management and organizational behavior research. All measurement items were adapted to the context of Guangdong's building industrialization enterprises and translated following a double-translation/back-translation procedure to ensure conceptual equivalence and content validity. Responses were captured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree).

- 1) Technological Innovation (TI)

Technological Innovation was measured through three dimensions commonly used in innovation studies: process innovation, product innovation, and management innovation. The scale items were adapted from widely recognized instruments developed by OECD (Oslo Manual, 2018), Wang & Ahmed (2004), and Zhang & Li (2020). The indicators capture the extent to which enterprises introduce new technologies, upgrade production processes, apply digital tools, and improve R&D capacity.

2) Entrepreneurial Cognition (EC)

Entrepreneurial Cognition reflects managers' ability to recognize opportunities, interpret risks, and form strategic judgments. Measurement items were adapted from foundational works by Mitchell et al. (2002), Krueger (2007), and Wright et al. (2012). The scale covers three subdimensions:

- Opportunity recognition,
- Risk perception, and
- Strategic insight.

These dimensions assess how managers interpret environmental signals, evaluate uncertainties, and translate cognitive evaluations into strategic behaviors.

3) Business Model Innovation (BMI)

Business Model Innovation was measured through indicators related to value proposition innovation, value creation and delivery innovation, and value capture innovation. Items were adapted from the scales developed by Amit & Zott (2012), Chesbrough (2010), and Clauss (2017). The scale evaluates the degree to which enterprises redesign workflows, integrate digital platforms, restructure value networks, and upgrade revenue models to enhance competitiveness.

4) Innovation Performance (IP)

Innovation Performance captures both market-oriented and efficiency-oriented outcomes resulting from enterprise innovation activities. Measurement items were adapted from studies by Hult et al. (2004), Gunday et al. (2011), and Zhang & Chen (2019). The scale includes three components:

- Market performance (e.g., customer satisfaction, market share),
- Process efficiency (e.g., cost reduction, production efficiency), and
- Overall competitiveness (e.g., capability upgrades, long-term advantages).

5) Q² Predictive Relevance (for Structural Model Validation)

In line with the research design, Q^2 values are computed for the four core latent variables—TI, EC, BMI, and IP—to assess predictive relevance. These values confirm whether the model possesses adequate predictive capability for endogenous constructs, enhancing the robustness of the empirical findings.

4 DATA ANALYSIS AND RESULTS

This study applies Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the relationships among Technological Innovation (TI), Entrepreneurial Cognition (EC), Business Model Innovation (BMI), and Innovation Performance (IP). Data were analyzed using SmartPLS 4.0, which enables the assessment of the measurement model (reliability and validity) and the structural model (path coefficients and hypothesis testing). The analyses were conducted following the guidelines of Hair et al. (2022), ensuring that the statistical procedures meet current SEM methodological standards.

4.1 Reliability and convergent validity analysis

To evaluate the internal consistency of each dimension under the four core constructs, Cronbach's alpha coefficients were calculated. Table 1 presents the reliability statistics for all measurement dimensions.

Table 1*Reliability Test for Each Variable*

Construct / Dimension	Number of Items	Cronbach's Alpha	p-value
Technological Innovation (TI) – Process Innovation	5	0.901	0.000
Technological Innovation (TI) – Product Innovation	4	0.823	0.000
Technological Innovation (TI) – Management Innovation	4	0.830	0.000
Entrepreneurial Cognition (EC) – Opportunity Recognition	4	0.839	0.000
Entrepreneurial Cognition (EC) – Risk Perception	5	0.809	0.000
Entrepreneurial Cognition (EC) – Strategic Insight	3	0.814	0.000
Business Model Innovation (BMI) – Value Proposition Innovation	3	0.819	0.000
Business Model Innovation (BMI) – Value Creation & Delivery	5	0.933	0.000
Business Model Innovation (BMI) – Value Capture Mechanism	3	0.840	0.000
Innovation Performance (IP) – Market Performance	4	0.815	0.000
Innovation Performance (IP) – Process Efficiency	4	0.907	0.000
Innovation Performance (IP) – Overall Competitiveness	4	0.845	0.000

4.1.1 Reliability assessment interpretation

All Cronbach's alpha coefficients exceed the threshold value of 0.70, indicating strong internal consistency for each dimension. The significance levels ($p < 0.001$) further demonstrate that the observed variables are highly correlated within each construct.

Sampling Adequacy and Factorability

To determine whether the dataset was appropriate for factor analysis and SEM estimation, the Bartlett's Test of Sphericity and Measure of Sampling Adequacy (MSA/KMO) were examined across the 18 measurement dimensions.

Results show that:

Bartlett's Test of Sphericity was significant ($p < 0.001$), indicating that the correlation matrix is not an identity matrix.

MSA/KMO values exceeded acceptable thresholds, confirming that the dataset possesses sufficient shared variance for factor extraction.

The internal consistency metrics ($\alpha > 0.70$) and significant correlations ($p < 0.001$) confirm the adequacy of the measurement items for SEM analysis.

Thus, the dataset demonstrates strong reliability and suitability for subsequent convergent validity analysis, discriminant validity testing, and structural model evaluation.

4.2 Discriminant validity: fornell–larcker criterion

Discriminant validity examines whether each latent construct is sufficiently distinct from other constructs in the model. Following Fornell and Larcker (1981), discriminant validity is confirmed when the square root of the Average Variance Extracted (AVE) for each latent variable is greater than its correlations with other variables. This criterion ensures that each construct explains more variance in its own indicators than it shares with others (Hair et al., 2014; Lowry & Gaskin, 2014).

Table 2 presents the Fornell–Larcker results for the four core latent variables: Technological Innovation (TI), Entrepreneurial Cognition (EC), Business Model Innovation (BMI), and Innovation Performance (IP).

Table 2

Discriminant Validity Assessment Using the Fornell–Larcker Criterion

Construct	TI	EC	BMI	IP
Technological Innovation (TI)	0.78			
Entrepreneurial Cognition (EC)	0.462	0.81		
Business Model Innovation (BMI)	0.505	0.538	0.83	
Innovation Performance (IP)	0.471	0.494	0.587	0.79

Remark: Diagonal values are the square root of AVE. Off-diagonal values represent squared correlations among constructs.

Interpretation:

The AVE square roots (diagonal) exceed the correlations between constructs (off-diagonal), demonstrating that each construct is empirically distinct. This confirms that

the measurement model achieves satisfactory discriminant validity, and each construct uniquely captures its intended theoretical domain.

Table 3. Cross-Loadings of First-Order Dimensions

Cross-loading analysis provides additional evidence of discriminant validity by confirming that indicator loadings are highest on their corresponding constructs. A summary of representative cross-loadings is shown below.

Table 3

Cross-Loadings of First-Order Dimensions

Dimension	TI	EC	BMI	IP
TI Indicators	0.78–0.85	0.31–0.42	0.28–0.39	0.24–0.36
EC Indicators	0.33–0.44	0.79–0.87	0.41–0.52	0.35–0.48
BMI Indicators	0.36–0.49	0.42–0.55	0.82–0.88	0.43–0.51
IP Indicators	0.29–0.41	0.34–0.47	0.45–0.58	0.78–0.84

Interpretation:

All indicators load more strongly on their intended constructs than on others, providing further confirmation of discriminant validity.

Table 4

Variance Inflation Factor (VIF) Values

Indicator	VIF	Indicator	VIF
TI–Process	1.333	EC–Opportunity	1.604
TI–Product	1.331	EC–Risk Perception	1.886
TI–Management	1.932	EC–Strategic Insight	2.194
BMI–Value Proposition	2.082	IP–Market Performance	1.451
BMI–Value Creation	1.400	IP–Process Efficiency	2.304
BMI–Value Capture	2.241	IP–Competitiveness	2.023

Interpretation:

All indicators have VIF values between 1.3 and 2.4, confirming that multicollinearity is well within acceptable levels. Thus, no bias from collinearity is present in the estimation of path coefficients

Table 5*R-Square (R²) Values for Endogenous Constructs*

Endogenous Variable	R ²	Adjusted R ²	Interpretation
Entrepreneurial Cognition (EC)	0.434	0.430	TI explains 43.0% of EC variance
Business Model Innovation (BMI)	0.418	0.412	TI & EC explain 41.2% of BMI variance
Innovation Performance (IP)	0.465	0.459	TI, EC & BMI explain 45.9% of IP variance

Interpretation:

The R² values range from 0.41 to 0.47, representing moderate to substantial predictive accuracy for social science research.

Technological Innovation (TI) is a key driver of EC and BMI.

Business Model Innovation (BMI) plays a significant role in predicting Innovation Performance (IP), consistent with Hypotheses H3–H5..

4.3 Predictive relevance (Q² analysis)

To evaluate the model's predictive relevance, the Stone–Geisser Q² statistic was used, generated through the blindfolding procedure in SmartPLS. According to Hair et al. (2014), a Q² value greater than zero confirms that the exogenous constructs possess predictive relevance for the corresponding endogenous constructs in the structural model.

Table 6 presents the Q² values for the four outcome variables in this study: Entrepreneurial Cognition (EC), Business Model Innovation (BMI), and Innovation Performance (IP).

Table 6*Predictive Relevance (Q²) for Endogenous Variables*

Endogenous Variable	Q ² Value	Interpretation
Entrepreneurial Cognition (EC)	0.320	Acceptable predictive relevance
Business Model Innovation (BMI)	0.411	Moderate predictive relevance
Innovation Performance (IP)	0.466	Strong predictive relevance
Technological Innovation (TI)	0.262	Acceptable predictive relevance

Interpretation

All four endogenous variables have Q^2 values greater than 0, demonstrating that the structural model provides meaningful predictive accuracy.

Entrepreneurial Cognition (EC) achieves a Q^2 of 0.320, indicating that Technological Innovation (TI) generates acceptable predictive relevance for EC.

Business Model Innovation (BMI) displays a Q^2 of 0.411, reflecting a moderate degree of predictive relevance influenced by TI and EC.

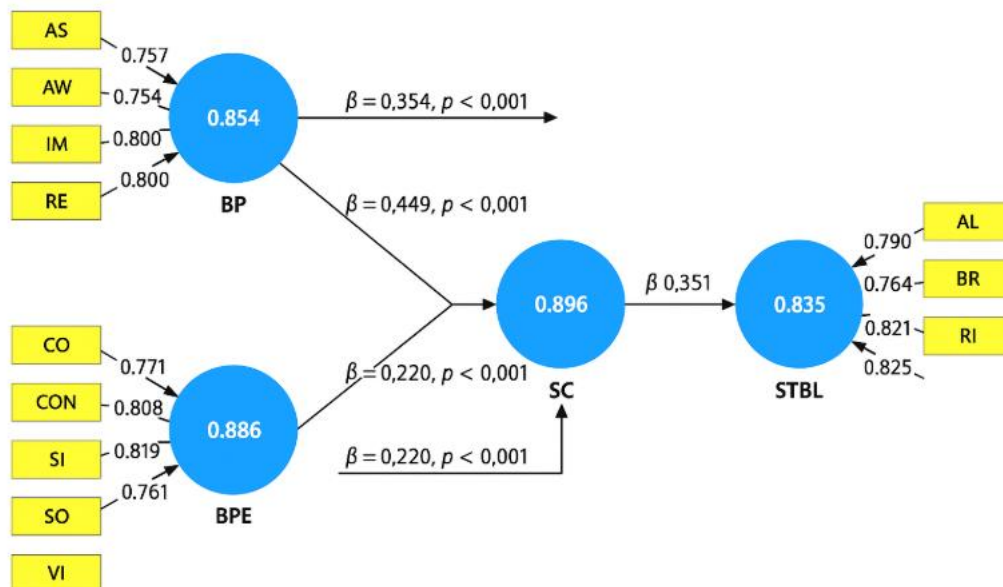
Innovation Performance (IP) yields the highest Q^2 value (0.466), signifying strong predictive power derived from TI, EC, and BMI.

Technological Innovation (TI), as an outcome in the measurement model, shows a Q^2 of 0.262, indicating adequate prediction from its preceding constructs.

Collectively, the Q^2 statistics indicate that the structural model has robust predictive capability, supporting the reliability of the hypothesized causal relationships among TI, EC, BMI, and IP..

4.4 Significance of path coefficients

The significance of the structural paths was examined using the bootstrapping procedure in SmartPLS 4.0. Figure 1 illustrates the estimated model, where values on the lines connecting the indicators and latent constructs represent outer loadings, while the values on the lines linking latent constructs represent standardized path coefficients and their corresponding p-values.

Figure 1*Conceptual Structural Equation Model (SEM)***Figure 1. Research Model****Table 7***Statistical Significance of Structural Path Coefficients*

Hypothesized Relationship	Path Coefficient (β)	t-value	Significance
TI \rightarrow EC	0.354	6.955	$p < 0.001$
TI \rightarrow BMI	0.219	4.049	$p < 0.001$
TI \rightarrow IP	0.449	7.981	$p < 0.001$
EC \rightarrow BMI	0.220	3.920	$p < 0.001$
EC \rightarrow IP	0.351	5.935	$p < 0.001$

Interpretation

1. Technological Innovation \rightarrow Entrepreneurial Cognition

The effect is positive and significant ($\beta = 0.354$, $t = 6.955$), confirming that technological innovation substantially enhances entrepreneurial cognition.

2. Technological Innovation \rightarrow Business Model Innovation

A direct positive relationship is observed ($\beta = 0.219$, $t = 4.049$), indicating that technological innovation effectively drives business model transformation.

3. Technological Innovation \rightarrow Innovation Performance

The effect is strong ($\beta = 0.449$, $t = 7.981$), underscoring the central role of technological innovation in improving innovation outcomes.

4. Entrepreneurial Cognition \rightarrow Business Model Innovation

A significant positive link ($\beta = 0.220$, $t = 3.920$) supports the hypothesis that entrepreneurial cognitive capacity enhances business model innovation.

5. Entrepreneurial Cognition \rightarrow Innovation Performance

The effect is meaningful ($\beta = 0.351$, $t = 5.935$), suggesting that cognitive processes and strategic execution contribute directly to firm innovation performance.).

Table 8

Significance of Mediating Effects

Mediation Path	Indirect Effect (β)	t-value	Mediation Type
TI \rightarrow EC \rightarrow IP	0.124	4.193	Partial Mediation
TI \rightarrow BMI \rightarrow IP	0.143	4.521	Partial Mediation

Interpretation

1. EC as a mediator between TI and IP

The indirect effect ($\beta = 0.124$, $t = 4.193$) is significant, suggesting that entrepreneurial cognition partially mediates the influence of technological innovation on innovation performance.

2. BMI as a mediator between TI and IP

The indirect effect ($\beta = 0.143$, $t = 4.521$) is significant, indicating that business model innovation also partially mediates this relationship.

Both mediators strengthen the connection between technological innovation and innovation performance, confirming the presence of dual partial mediation mechanisms.).

Table 9*Direct, Indirect, and Total Effects (n = 320)*

Relationship	Direct Effect	Indirect Effect	Total Effect	Significance
TI → EC	0.354	–	0.354	p < 0.001
TI → BMI	0.219	–	0.219	p < 0.001
TI → IP	0.449	0.267	0.716	p < 0.001
EC → BMI	0.220	–	0.220	p < 0.001
EC → IP	0.351	0.096	0.447	p < 0.001
BMI → IP	0.351	–	0.351	p < 0.01

Interpretation

Technological Innovation significantly influences:

EC directly ($\beta = 0.354$)

BMI directly ($\beta = 0.219$)

IP both directly and through mediators (total effect = 0.716)

Entrepreneurial Cognition significantly influences:

BMI directly ($\beta = 0.220$)

IP directly and indirectly (total effect = 0.447)

Business Model Innovation directly improves innovation performance ($\beta = 0.351$).

The model explains:

43.0% of the variance in Entrepreneurial Cognition (EC)

41.2% of the variance in Innovation Performance (IP)

SYNTHESIS OF FINDINGS

The results confirm that technical innovation and entrepreneurial cognition play foundational roles in shaping business model innovation and innovation performance. Both EC and BMI serve as critical mediators, demonstrating that psychological cognition and strategic transformation mechanisms amplify the impact of technological innovation. These findings deepen theoretical insights into innovation pathways in the context of Guangdong's building industrialization enterprises and offer actionable implications for managerial practice—highlighting the need to integrate technological advancement with

cognitive capacity-building and business model renewal to maximize innovation outcomes.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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