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Optimizing innovation in Malaysia: Analyzing cultural, organizational, and strategic factors influencing R&D and patent output

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ABSTRACT

As Malaysia strives to transition from a middle-income manufacturing hub to a high-income, innovation-driven economy, understanding the dynamics influencing research and development (R&D) and patent output is critical. Despite national policies positioning innovation as a cornerstone of economic transformation, a disconnect remains between financial investment and tangible output. This review investigates the factors affecting innovation performance in Malaysia and developing countries. The analysis identifies common themes in key cultural barriers, such as high-power distance and risk aversion, while highlighting the role of employee training and knowledge management in building absorptive capacity. Furthermore, it evaluates strategic approaches, including open innovation and risk management, alongside the pivotal role of government interventions and public-private partnerships. Synthesizing these findings, this study proposes a unified conceptual framework to guide resource-constrained organizations in optimizing resources to enhance innovation output and financial performance.

1. Introduction

Malaysia has embarked on a journey to enhance its global competitiveness by fostering innovation activities. This ambition is evident in the country's approach to stimulating research and development (R&D) and increasing patent output. Key to this effort has been the implementation of several national policies, such as the science, technology and innovation (STI) policy, which emphasizes innovation as a cornerstone of economic transformation. These plans highlight the need for advancements in various sectors to drive economic growth (Bekhet and Latif, 2017). A component of Malaysia's innovation strategy is its emphasis on creating a robust entrepreneurial ecosystem. Business incubation systems have been established to nurture small and medium-scale industries, providing essential support in technology transfer and commercialization (Yunos, 2002).

A crucial aspect of Malaysia's innovation ecosystem is its investment in R&D, which has remained around 1% of the country's gross domestic product (GDP) from 2012 to 2022 (Asraf and Ahmad, 2012; MOSTI, 2025). While this level of expenditure aligns with the average investment in emerging economies, it is still lower than that observed in developed nations, which often exceed 2% of GDP.

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The relatively modest R&D spending highlights the challenges Malaysia faces in scaling up its innovation capabilities.

A critical disconnect remains between investment and tangible output (Dobranski and Bobowski, 2020). Despite concerted efforts to build a robust innovation ecosystem, several challenges continue to hinder the realization of Malaysia's R&D potential. The relatively modest R&D spending highlights the challenges Malaysia faces in scaling up its innovation capabilities (Saleh and Ndubisi, 2006). More importantly, achieving these innovation levels requires more than just policy initiatives or increased funding; it necessitates a deep understanding of the factors that influence innovation outcomes.

While prior research has covered innovation from a technical or macro-economic policy perspective, there is a lack of comprehensive reviews that synthesize the specific interplay between innovation investment and financial performance. For instance, while the lack of technological capability in SMEs is well-documented (Sivageahnam et al., 2015), the underlying success drivers are frequently overlooked in broader economic reviews. Furthermore, Malaysian firms often rely on soft factors, such as employee training, rather than formal R&D investments (Hegde and Shapira, 2007), yet there is a gap in understanding how to translate these soft capabilities into concrete new product developments and patent outputs.

Therefore, this article fills a gap in the literature by guiding organizations with a unified framework. It moves beyond the 'what' of low innovation output to investigate the 'why' and 'how,' specifically by identifying factors that drive innovation and patent output. By synthesizing these factors, this review provides decision-makers with limited resources a holistic roadmap to navigate the innovation landscape, with the end goal of increasing organizations' financial performance.

2. Methodology

The literature search strategy for this study on optimizing innovation in Malaysian institutions and enterprises was designed to ensure a comprehensive, high-quality review of relevant academic literature. The search aimed to identify and synthesize studies on the factors and innovation practices that influence R&D and patent output. To achieve this goal, a systematic approach was adopted, following Randolph (2019), using several reputable academic databases, including Scopus, ScienceDirect, and Google Scholar. These databases were selected for their extensive coverage of multidisciplinary research, high citation rates, and inclusion of peer-reviewed journals pertinent to the fields of innovation management, organizational behavior, cultural studies, and strategic management.

To ensure a targeted and efficient search process, specific keywords and search terms were employed. These included "innovation," "R&D," "patent output," "commercialization factors," "developing countries," "Malaysian enterprises," "public-private partnerships," "technology transfer," and "financial performance." The use of Boolean operators (AND, OR, NOT) was also integrated into the search strategy to further refine results and combine multiple concepts, thereby improving search precision and relevance. For example, the search terms "innovation AND Malaysian enterprises" and "R&D OR patent output AND financial performance" were adopted to capture studies that focusing specifically on the intersection of these themes within the Malaysian context.

Inclusion and exclusion criteria were carefully defined to guide the selection of studies, as shown in Fig. 1. Inclusion criteria focused

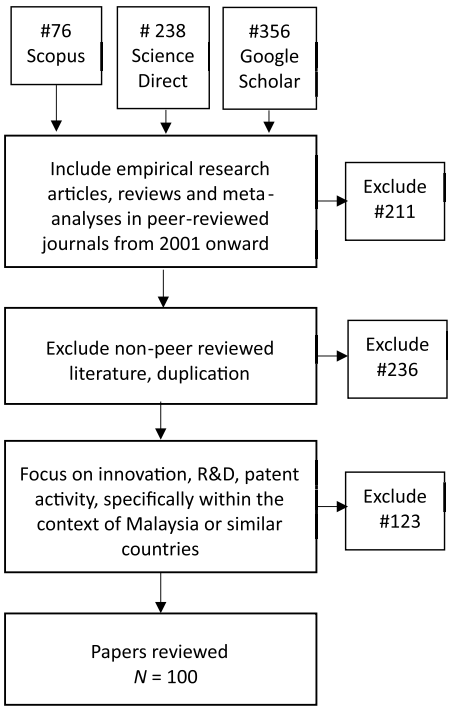

Fig. 1. Flow diagram of the search process for publications in the literature review.

on empirical research articles, reviews, and meta-analyses published in peer-reviewed journals from 2001 onward, when the eight Malaysian plans were launched toward knowledge-

driven output growth, to capture the most relevant and recent developments in the field. Studies had to focus on innovation, R&D, patent activity, or financial performance affecting these processes, specifically within the context of Malaysian institutions or in comparative studies involving similar developing economies. Exclusion criteria eliminated non-peer-reviewed literature. Furthermore, research focusing solely on the technical aspects of R&D without considering organizational, cultural, or strategic factors was excluded to maintain the study's focus on its primary research objectives.

The selected papers were analysed to identify common themes, which subsequently served as the structural foundation of this review. To fully contextualize these findings, it is essential to first identify the innovation models guiding R&D activities. With this in mind, the objective was to identify factors to optimize innovation and patent output.

The analysis identified four pivotal themes that enhance innovation: cultural dynamics, organizational practices, strategic approaches, and government policy. Building on these findings, a novel conceptual framework is proposed.

3. Evolution of innovation models

To understand the current state of innovation in Malaysia, one must first contextualize the theoretical frameworks that guide R&D activities. Innovation theories have evolved, transitioning from simplistic linear models to more dynamic frameworks that capture the complexity of the innovation process. This theoretical evolution is not merely academic; it mirrors the operational reality that Malaysian firms are struggling to adapt to.

3.1. Limitations of linear models

Early innovation theories were dominated by linear concepts, specifically the "technology push" and "market pull" models. These models depict innovation as a straightforward sequence of stages. The linear model suggests a sequence beginning with research, followed by development, then production, and culminating in market introduction. "Technology push" implies that basic science drives innovation, which then finds a market. "Market pull" suggests that market demand dictates technical development.

While these models provide a foundational understanding, this linear perspective has been critiqued for oversimplifying the innovation process and failing to account for the iterative and recursive interactions between various actors, knowledge sources, and environmental factors (Kline and Rosenberg, 2010; Tidd, 2006). In the context of a developing innovation ecosystem like Malaysia's, a reliance on linear models can be detrimental. It leads to a "silo" mentality where R&D departments work in isolation from marketing or production, resulting in inventions that lack commercial viability or market needs that cannot be technologically met. The linear perspective ignores the crucial feedback loops that are essential for correcting course during the development process.

3.2. Shift to dynamic models

Recognizing the deficiencies of linearity, dynamic models have emerged, recognizing innovation as a complex, non-linear process characterised by uncertainty and involving multiple feedback loops and stages of development and diffusion.

The chain-linked model views innovation as an interconnected and dynamic process. It starts with identifying a market need, which drives research, design, and testing, leading to production and marketing. Crucially, this model includes feedback loops between each stage and acknowledges the role of the existing knowledge base. It posits that innovation is not a clean sequence but a messy, iterative process of trial and error (Kline and Rosenberg, 2010).

The integration model considers the interplay among different aspects of innovation, from idea generation to implementation and commercialization. It emphasizes that R&D, manufacturing, and marketing should occur concurrently rather than sequentially to accelerate time-to-market.

As shown in Table 1, more sophisticated models have emerged, recognizing innovation as a complex, non-linear process characterized by uncertainty and involving multiple feedback loops and stages of development and diffusion (Kline and Rosenberg, 2010).

Additionally, the distinction between radical and incremental innovation has become a focal point of contemporary research,

Table 1
Comparative analysis of innovation models.

Innovation model	Mechanism of Action	Strengths	Limitations and Critiques
Linear Model	Straightforward sequence: Research > Development > Production > Marketing.	Simple to understand; clear delineation of roles.	Critiqued for simplicity and lack of feedback loops, it ignores the iterative nature of real-world R&D.
Integration Model	Considers the simultaneous interplay among different aspects of innovation, from idea generation to commercialization.	Faster development times; better alignment of cross-functional teams.	Requires high coordination costs and sophisticated management communication.
Chain-Linked Model	Interconnected dynamic process starting with market need; includes feedback loops between every stage.	Highly realistic; acknowledges the role of the existing knowledge base; allows for correction.	Complex to implement; requires robust open communication channels, often lacking in hierarchical firms.

particularly in high-technology sectors like biopharmaceuticals, where firms must balance the risks and rewards associated with breakthrough versus incremental advancements (Tidd, 2006). This distinction highlights the need for a more nuanced understanding of how different types of innovation strategies can be effectively managed and leveraged to drive growth and competitiveness.

3.3. Application in the Malaysian context

Over the past two decades, research on innovation in developing countries has increased fourfold. However, this growth has been significantly skewed toward middle-income emerging countries, which dictates the field's thematic direction (Lema et al., 2021).

The development of innovation models has been driven by a growing recognition of the critical role played by external factors, such as market conditions, technological advancements, and social contexts, in shaping innovation outcomes. Modern innovation theories emphasize the importance of the later stages of innovation—development, commercialization, and diffusion—as these are crucial for achieving commercial success and sustaining competitive advantage.

In the academic sector, research universities in Malaysia are exploring innovation models that integrate elements from a holistic business perspective, recognizing that traditional, technology-driven approaches may be insufficient to meet the commercialization needs of a rapidly changing global marketplace (Kowang et al., 2014). These adaptations underscore the importance of contextualizing innovation theories within the specific socio-economic and cultural context of Malaysia to enhance their applicability and effectiveness. The transition from linear to dynamic innovation is not merely a procedural change; it requires a cultural shift in how failure, feedback, and collaboration are perceived within Malaysian organizations.

In environments characterized by resource constraints, such as Turkey, the exclusive reliance on internal capabilities is often insufficient; instead, organizations must actively leverage external knowledge channels to bolster their innovation strategies. Findings indicate that while internal R&D provides the necessary absorptive capacity, the strategic acquisition of external technological and market insights is what differentiates successful innovators. Policies that facilitate university-industry collaboration and improve the quality of human capital are essential for strengthening these internal and external knowledge linkages (Kamal et al., 2022; Kleiner-Schafer and Lifner, 2021).

4. Cultural factors

4.1. Cultural barriers to innovation

Culture plays a role in influencing innovation and R&D outcomes within Malaysian institutions and enterprises. The unique cultural landscape in Malaysia, characterized by diversity and a mix of traditional and modern values, presents both opportunities and challenges for fostering an innovative environment.

One of the cultural barriers to innovation identified in the literature is the power distance that prevails in many Malaysian organizations. Power distance refers to the extent to which less powerful members of organizations accept and expect that power is distributed unequally. This hierarchical structure can stifle creativity and innovation by discouraging open communication and the free exchange of ideas, which are essential for collaborative R&D efforts (Rujirawanich et al., 2011). In such environments, employees may feel disempowered to challenge existing norms or propose novel solutions, leading to stagnation in innovation activities (Larsen and Lewis, 2006).

Innovation often bubbles up from the bottom, from the engineers and marketers closest to the product. A high-power distance culture imposes a top-down decision-making process that can filter out or ignore grassroots innovations before they can be tested (Zhang et al., 2023a).

Moreover, the cultural inclination toward uncertainty avoidance in Malaysian organizations further compounds these challenges. Uncertainty avoidance, which refers to the extent to which members of a culture feel threatened by ambiguous or unknown situations, can lead to risk-averse behaviours that hinder innovation. In the context of R&D, where experimentation and the acceptance of failure are crucial to breakthrough innovations, a strong aversion to uncertainty can lead to a preference for incremental improvements over radical innovations (Rujirawanich et al., 2011).

Collectivism, another prominent cultural characteristic in Malaysia, can also serve as a double-edged sword in the context of innovation. On the one hand, collectivist cultures, which emphasize group harmony and consensus, can create supportive environments that facilitate teamwork and collaboration—key drivers of innovation (Asmawi and Mohan, 2011). On the other hand, the strong emphasis on maintaining group harmony can lead to conformity and resistance to change, particularly when new ideas challenge established norms and practices (Deligiannaki and Ali, 2011). This resistance to change can be a barrier to the adoption of innovative practices, especially in organizations where top-down decision-making processes dominate (Rivera-Vazquez et al., 2009).

These cultural barriers underscore the importance of understanding the specific cultural context in which innovation activities occur. The influence of Western cultural values is increasingly evident in Malaysia, leading to a gradual shift in traditional cultural norms (Rujirawanich et al., 2011). As such, organizations must strike a balance between leveraging traditional cultural strengths, such as strong communal ties and collaborative work environments, while also embracing more open, flexible, and innovative practices to remain competitive in a rapidly evolving global market. By addressing these cultural barriers and fostering a supportive organizational culture, Malaysian institutions can enhance their R&D capabilities and drive greater innovation output.

4.2. Fostering a culture of creativity

In diverse cultural settings such as Malaysia, leveraging multicultural interactions can generate novel ideas and solutions when organizations create environments conducive to creativity. This involves striking a balance between individualistic and collectivist cultural values, where the former promotes independence and unique thought, and the latter fosters collaboration and group synergy (Hermida et al., 2019). Encouraging open-mindedness toward different cultural perspectives allows employees to draw from a broader range of experiences and viewpoints, facilitating innovative thinking and problem-solving (Leung et al., 2008).

Fostering creativity requires specific management strategies that align with cultural dynamics. Effective leadership is pivotal in promoting a culture of creativity by adopting styles that support autonomy, risk-taking, and experimentation (Demircioglu and van der Wal, 2022; Wu et al., 2008). Leaders in Malaysian organizations must cultivate a supportive system that encourages knowledge sharing and reduces the fear of failure, which often stifles innovation. By facilitating environments that deemphasize rigid adherence to traditional norms and encourage flexible thinking, leaders can empower employees to explore and develop creative ideas (Hermida et al., 2019).

Absorptive capacity, the ability to absorb external knowledge and apply it, is a critical dynamic capability. Without absorptive capability, technology transfer fails to materialize (Cuevas-Vargas et al., 2023).

Additionally, fostering a culture of creativity in diverse organizations involves the strategic integration of global management practices with local cultural nuances. A case study involving a Norwegian multinational highlighted how adapting U.S.-developed performance management practices to local cultural contexts over time can help subsidiaries gradually accept and integrate these practices, fostering creativity within a culturally sensitive framework (Lunnan et al., 2005). This approach underscores the importance of cultural adaptability and sensitivity in creating innovative and creative organizational cultures. A summary of cultural factors that influence R&D and patent output is shown in Table 2.

5. Organizational factors

5.1. Organizational practices

Organizational innovation practices are critical in shaping R&D and patent output in Malaysian institutions and enterprises. Recent studies have emphasized the importance of a comprehensive approach that combines both technological and organizational innovations to enhance overall innovation performance. One significant finding is that companies in Malaysia exhibit strong organizational and process innovation capabilities but often lack in areas such as new product development, primarily due to their reliance on "soft factors" like employee training, collaborative culture, and knowledge sharing, rather than on formal R&D investments (Hegde and Shapira, 2007). This indicates that while Malaysian firms have robust internal capabilities to improve processes and organizational structures, there is a gap in translating these capabilities into new product innovations.

Malaysian firms often lack access to cutting-edge technologies and skilled human resources, which are critical to driving innovation. Additionally, there is insufficient investment in research, which limits these firms' ability to develop new products or processes that could increase patent output (Dobranski and Bobowski, 2020).

Moreover, firm characteristics, such as size, export orientation, and industry type, play a substantial role in determining the extent of R&D engagement and expenditure. For instance, larger firms and those with a strong export orientation are more likely to invest heavily in R&D to maintain global competitiveness and protect intellectual property through patents (Shafi'i and Ismail, 2015). This is particularly relevant in industries where innovation is critical to maintaining a competitive edge, such as high-tech and manufacturing sectors. These firms are also more likely to adopt open innovation strategies, such as R&D collaborations, outsourcing, and mergers, which enable them to explore new technologies and diversify their innovation portfolios (Cammarano et al., 2017). Such practices not only foster incremental innovations but also pave the way for radical and architectural innovations, thereby enhancing a firm's ability to generate and protect novel inventions through patents.

Organizational innovation practices, encompassing both technological and managerial aspects, are integral to optimizing R&D and

Table 2
Cultural factors that influence R&D and patent output.

Cultural barriers
• Power distance in hierarchical structures discourages open communication and free exchange of ideas. Employees feel disempowered to challenge norms (Larsen and Lewis, 2006; Rujirawanich et al., 2011; Zhang et al., 2023a).
• Cultural inclination toward uncertainty avoidance leads to risk-averse behaviors. Preferences may shift to incremental rather than radical inventions (Rujirawanich et al., 2011).
• Collectivism can lead to conformity and resistance to change. Dissenting ideas may be suppressed to maintain consensus (Deligiannaki and Ali, 2011; Rivera-Vazquez et al., 2009).
Fostering culture of creativity
• Multicultural experiences significantly enhance creativity (Leung et al., 2008). Multicultural interactions lead to the generation of novel ideas (Hermida et al., 2019).
• Leadership is pivotal in promoting a culture of creativity. Must support autonomy, risk-taking, and reduce the fear of failure (Demircioglu and van der Wal, 2022; Wu et al., 2008).
• Absorptive capacity absorbs external knowledge and applies it to the organization (Cuevas-Vargas et al., 2023).
• Integrate global practices with local contexts fosters acceptance and creativity (Lunnan et al., 2005).

patent output in Malaysian institutions and enterprises. By adopting a holistic approach that combines strategic firm characteristics, robust human resource management, and open innovation strategies, Malaysian companies can enhance their innovation capabilities and strengthen their competitive position in the global market.

Vietnam, as an emerging developing country, has proven that investment in R&D positively influences listed companies' revenues, profits, and return on equity. Additionally, companies with higher R&D investment perform better than those with lower R&D investment (Tung and Binh, 2021).

5.2. Human capital and knowledge management

Absorption capacity becomes innovation when training is involved (Sancho-Zamora et al., 2022). Researchers drive R&D, which generates patents, ultimately fuelling the competitive advantage required for high-tech exports. This highlights the role of human capital in simulating the downstream export economy (Bhat and Momaya, 2020; Gurler, 2021; Ersin et al., 2022). India's investment in human capital gives it a competitive edge in information technology, biotechnology, pharmaceuticals, and space research (Krishna, 2022). Even latecomer firms are able to develop their human capital and knowledge base to meet international competition (Chattopadhyay and Bercovitz, 2020; Ray and Ray, 2021).

In the context of Malaysia, human capital significantly and positively affects economic growth. While the short-term impact may be negative, the long-term determination is positive. Similarly, evidence from Turkey highlights the substantial returns to education (Wusiman and Ndzembanteh, 2020). Malaysian family-owned SMEs rely on tacit knowledge of the founding generation, which is insufficient to transform them into dynamic innovation capabilities. Without ways to transform this knowledge, family firms risk stagnation (Yew, 2021).

An analysis of the Russian innovation system reveals that the continued expansion of general higher education yields diminishing returns, whereas a shortage of vocational skilled workers acts as a bottleneck hindering innovation output. Although advanced researchers with doctoral degrees remain the primary drivers of patent activity, the findings suggest that sustainable innovation requires a balanced human capital—one that supports high-level R&D personnel and a skilled technical workforce to implement new technologies (Teslenko et al., 2021).

In China, skilled human capital drives innovation. Further analysis reveals that in metropolitan areas, the general manager's tenure is critical for innovation, whereas in SMEs, the general manager's education level takes precedence (Sun et al., 2020).

Employee training and knowledge management are fundamental components that significantly influence organizational innovation, particularly R&D and patent output. Training is recognized as a key driver of innovation, enabling employees to develop the necessary skills and competencies to contribute to creative and innovative processes within organizations (Tan and Nasurdin, 2011). In the context of Malaysian institutions and enterprises, the role of training becomes even more critical due to the diverse cultural and organizational landscape, which necessitates a tailored approach to skills development. Empirical research has demonstrated that training enhances various dimensions of organizational innovation, including product, process, and administrative innovation (Tan and Nasurdin, 2011). This suggests that well-structured training programs not only improve technical capabilities but also foster a culture of continuous improvement and creativity among employees.

Knowledge management practices are crucial for sustaining innovation within organizations by facilitating the effective dissemination and use of knowledge across levels and departments. Knowledge management is not merely about accumulating knowledge but also about transforming it into actionable insights that drive innovation (Liao and Wu, 2010). The effectiveness of knowledge management is significantly influenced by organizational learning, which acts as a mediator between knowledge management practices and innovation outcomes (Liao and Wu, 2010). This mediating role of organizational learning underscores the importance of fostering a learning-oriented culture where employees are encouraged to share knowledge, learn from failures, and continuously seek new ways to solve problems. Studies have shown that organizations with robust knowledge management practices, supported by comprehensive training programs, are more likely to achieve higher levels of innovation and improved R&D outcomes (Farooq, 2019). These findings underscore the necessity for Malaysian companies to invest in both training and knowledge management to enhance their innovation capabilities and remain competitive in the global market, as summarized in Table 3.

Table 3
Organizational factors that influence R&D and patent output.

Organizational innovation practices in Malaysia
• Malaysia exhibits strong organizational and process innovation capabilities but lacks new product development (Hegde and Shapira, 2007; Dobranski and Bobowski, 2020).
• Larger firms with strong export orientation are more likely to invest in R&D, explore new technologies and diversify innovation portfolios (Cammarano et al., 2017; Shafi'i and Ismail, 2015).
Investment in R&D has a positive influence on the listed company's revenues, profits and return on equity (Tung and Binh, 2021).
Employee training and knowledge management
• Training is a key enabler of innovation (Krishna, 2022; Sancho-Zamora et al., 2022; Tan and Nasurdin, 2011; Wusiman and Ndzembanteh, 2020).
• Increase the number of researchers with doctoral degrees and the vocational workforce in a balanced way to implement new technologies (Teslenko et al., 2021).
• Knowledge management transforms knowledge to drive innovation (Liao and Wu, 2010).
• Knowledge management practices supported by training programs are more likely to achieve higher levels of innovation (Farooq, 2019).

6. Strategic factors

6.1. Open innovation strategies

The strategic orientation of firms, especially their focus on market responsiveness and cost leadership, has been shown to significantly influence both innovation practices and financial performance, particularly in the manufacturing sector (Sivageahnam et al., 2015). In manufacturing, strategic innovation that aligns with innovative operational strategies has been found to significantly affect both operational and market performance, indicating the importance of a well-integrated approach to innovation management (Aghajari and Senin, 2014). These findings underscore the need for Malaysian companies to adopt a sector-specific innovation strategy, balancing immediate operational improvements with longer-term investments in new product development and technological advancements.

Building on the insights regarding the strategic orientation and innovation strategies of Malaysian firms, it is essential to explore the specific mechanisms through which these strategies influence R&D and patent output. The adoption of open innovation practices—such as collaboration with external partners, customers, and academic institutions—has been shown to enhance innovation capabilities by expanding the knowledge base and fostering a culture of continuous learning (Cammarano et al., 2017; Chesbrough, 2004). For Malaysian companies, this approach is particularly relevant given the resource constraints they often face, as it allows them to leverage external expertise and technologies to compensate for limited internal R&D capabilities (Lim and Nagaraj, 2011).

An investigation in Iran revealed that a surge in scientific publications failed to translate into technological innovation or economic growth. This is due to the reliance on the linear model of innovation, which neglects the demand of the industrial sector (HamidiMotlagh et al., 2020). Although large Brazilian firms serve as the primary drivers of domestic innovation, they fall into a low-innovation trap by disengaging from the coalition-building necessary to align government proposals with the productive sector (Chiarini et al., 2020).

A survey indicates that the successful commercialization of academic research is driven by university-industry collaboration and the specific behavior of academicians (Lubango, 2020; Suhaimi et al., 2020). Another study supports the establishment of an open and independent platform to facilitate neutral interaction, promote cross-sector knowledge exchange between industry and academia to spur knowledge transfer, and adopt collaborative data analytics management tools to facilitate efficient information sharing (Balakrishnan and Johar, 2023). Additional studies support the development of interdisciplinary collaboration and the strengthening of knowledge transfer channels between academia and industry (Kruger and Steyn, 2024).

In Turkey, robust institutional frameworks and physical infrastructure are identified as primary drivers of patent output. These mechanisms provide the operational environment for innovation to thrive, effectively lowering barriers to commercialization (Ar et al., 2021).

Saudi Aramco utilizes a triple helix collaboration model to foster innovation, primarily partnering with top-tier academic institutions and industry leaders to co-develop and secure intellectual property. Key academic collaborators include King Fahd University of Petroleum and Minerals, King Abdullah University of Science and Technology, and King Abdulaziz University. Internationally, Saudi Aramco has established strategic ties with institutions such as the China University of Petroleum (Fasi, 2023). The University of Brasilia is a regional model of the triple helix (Borges et al., 2020).

China's leading photovoltaic industry enterprises serve as the primary engines of R&D, relying heavily on internal collaborations driven by investment. The external collaborative network is shifting from localized interactions to cross-regional collaboration (Hu et al., 2024a). In academic networking, collaboration is dominated by top-ranked universities. The industry-university interface is characterized by depth and specialization; businesses actively pursue technological cooperation with academic institutions in their specific domains (Du et al., 2024). Analysis of global innovation networks reveals that China occupies a dominant position, with the United States identified as its foremost collaborative partner (Hu et al., 2024b). For every 1 % increase in renewable energy technology innovation, carbon intensity decreases by 0.051 % (Cheng and Yao, 2021). Foreign investment exerts a significant positive influence on both the quantity and quality among domestic firms within the same industry. This is driven by intensified market competition rather than direct knowledge spillover (Chen et al., 2022). In developed cities, the introduction of external patents acts as a catalyst for innovation. In contrast, underdeveloped cities experience a crowding-out effect when transferring patents outward, which undermines their capacity for innovation (Jin et al., 2022). A city's innovation output is not solely determined by local resources but is significantly enhanced by its embeddedness in broader intercity networks. This structural advantage is significant primarily within industry-industry network (Yao et al., 2020).

6.2. Risk management

Risk management is a critical component of innovation strategy, especially in the context of R&D and patent output. In Malaysian institutions and enterprises, managing the risks associated with innovation activities is essential to ensure the successful commercialization of new technologies and maintain competitiveness in the global market. Effective risk management in innovation involves identifying potential risks early in the development process, assessing their impact on project outcomes, and implementing strategies to mitigate these risks (Chauhan et al., 2018). One of the primary challenges in innovation risk management is balancing the need for creativity and experimentation with the necessity of minimizing potential losses. This balance is particularly crucial in the early stages of new product development (NPD), where uncertainties are high, and decisions made can significantly influence a project's trajectory (Kumar and Allada, 2022). Techniques such as Markov processes and quality function deployment (QFD) have been utilized to assess risks during the early phases of NPD, allowing organizations to make informed decisions while maintaining flexibility in design choices

(Kumar and Allada, 2022).

Furthermore, the adoption of comprehensive risk management frameworks has been shown to enhance decision-making processes and improve the overall success rate of innovation projects. For example, Bayesian networks offer a probabilistic approach to assessing operational risk, focusing on potential reliability failures that could jeopardize product launch success (Filho et al., 2013). By integrating these risk assessment tools within the innovation process, companies can better manage the uncertainties inherent in developing new products and technologies. Additionally, the use of a stage-gate model has proven effective in incorporating risk management into the innovation process by providing structured checkpoints that assess the project's viability and the associated risks at each stage (Bowers and Khorakian, 2013). This approach ensures that risks are continuously monitored and mitigated, thereby enhancing the likelihood of achieving the desired innovation outcomes.

In Malaysian companies, the emphasis on proactive risk management strategies has also led to the development of frameworks tailored to the unique challenges faced by innovation-driven companies. For instance, the enterprise risk management (ERM) model has been adapted to focus on innovation, allowing firms to measure and manage risks in alignment with their strategic objectives (Etges et al., 2017). This alignment is crucial for balancing risk management with the need for flexibility and creativity in innovation projects. A systematic review has identified nine categories of risk events specific to innovation-oriented businesses, ranging from market risks to technological uncertainties, thereby providing a comprehensive framework for risk assessment and management in this context (Etges and Cortimiglia, 2019). A summary of cultural factors that influence R&D and patent output is shown in Table 4.

6.3. *Intellectual property (IP) strategies*

Empirical evidence identifies five critical challenges SMEs face in open innovation: motivating spillovers, the incorporation of external knowledge, IP management, the maximization of internal innovation, and financial constraints. Among these, IP management is particularly significant, while effective IP control secures commercial success, many Malaysian SMEs struggle to manage it properly (Iqbal and Hameed, 2020).

A positive correlation was found between environmental patents and economic growth in the Middle East (Abedi and Moeenian, 2021). In Brazil, patent valuation is performed for academic inventions to facilitate licensing negotiations (Tukoff-Guimaraes et al., 2021). Valuation has a positive influence on the increase in innovation in Indonesia-based startups and SMEs (Muchtar et al., 2023).

A study conducted in India, using patent renewal data as a proxy for value, found that most patents expire prematurely due to non-payment of fees, leaving only a small fraction to reach their full term. This pattern mirrors the trends observed in the US and Europe. The analysis indicates that specific characteristics—namely, patent family size, technological scope and number of inventors—determine a patent's value and longevity (Danish et al., 2020).

Venture capital (VC) and IP strategies work synergistically to drive startup success, particularly when entrepreneurs adopt a comprehensive 'IP portfolio' approach rather than relying on a single form of protection. Startups that manage a diversified portfolio of IP assets, such as those that combine patents and trademarks, achieve significantly higher financial and non-financial innovation performance. VC-backed startups with robust IP portfolios are better positioned to leverage their intangible assets for better market performance (Li et al., 2024).

Latin American companies experienced growth from internal R&D, yet face a negative impact from patent applications (Paula and Rocha, 2021). The number of patent grants is a superior indicator of economic progress compared to patent applications. Quality innovation, represented by successful patent grants, is the true driver of growth, whereas a mere increase in applications often reflects a quantity concern that fails to translate into real economic value due to low commercialization success (Law et al., 2020).

Data from Russia suggests that the disclosure of patent activities in annual reports has a positive effect on market capitalization, particularly for companies in the energy, raw materials and utilities sector that operate internationally (Fedorova et al., 2023). Patenting activities reveal a shift of innovation centres from oil- and gas-rich areas to Moscow, St. Petersburg, and the Republic of Tatarstan. This shift is driven by superior R&D infrastructure in metropolitan areas which offer a high concentration of researchers

Table 4
Strategic factors that influence R&D and patent output.

Open innovation strategies
• Market responsiveness and cost leadership influence both innovation practices and financial performance (Sivageahnam et al., 2015). Strategic innovation that aligns with innovative operational strategies affects both operational and market performance (Aghajari and Senin, 2014).
• Adoption of open innovation practices enhances innovation capabilities (Cammarano et al., 2017; Chesbrough, 2004). Leveraging external expertise and technologies to compensate for limited internal R&D (Lim and Nagaraj, 2011). Successful commercialization of academic research is driven by university-industry collaboration and the specific behavior of academicians (Lubango, 2020; Suhaimi et al., 2020).
Risk management in innovation
• Risk management involves identifying potential risks, assessing their impact and implementing strategies to mitigate these risks (Chauhan et al., 2018).
• Probabilistic approach to assess operational risk (Filho et al., 2013).
• Enterprise risk management model adapted to focus on innovation (Etges et al., 2017). Nine categories of risk events specific to innovation-oriented business (Etges and Cortimiglia, 2019).
Intellectual property (IP) strategies
• A positive correlation was found between patents and economic growth (Abedi and Moeenian, 2021; Fedorova et al., 2023). Patent valuation is performed for academic inventions to facilitate licensing (Tukoff-Guimaraes et al., 2021).
• VC-backed startups with robust IP portfolios are better positioned to leverage their intangible assets for better market performance (Li et al., 2024).
• The number of patent grants is a superior indicator of economic progress compared to patent applications (Law et al., 2020).

(Kryukov and Tokarev, 2022).

7. Policy interventions and government support

7.1. Government policies and financial support

Organizations operating within advanced innovation activities make superior contributions to GDP, employment generation and wage levels (Linder, 2021). Government policies on innovation in Malaysia have been instrumental in fostering an environment conducive to R&D and patent output, with a strong emphasis on enhancing national competitiveness and socio-economic development. Over the years, the Malaysian government has rolled out multiple strategic plans to encourage innovation across various sectors. The Economic Transformation Programme (ETP) is a notable example, which aims to transition the country into an innovation-driven economy by prioritizing high-tech and knowledge-intensive industries (Bekhet and Latif, 2017). Moreover, the government has outlined 12 National Key Economic Areas (NKEAs) and nine priority sectors under the ETP to boost Malaysia's competitive edge globally (Othman, 2013).

Malaysia's innovation strategy involves implementing the Quadruple Helix framework, which promotes collaboration among academia, industry, government, and civil society to enhance innovation outputs and economic development (Othman, 2013). This approach recognizes the importance of multi-stakeholder involvement in driving innovation and has been pivotal in establishing a supportive environment for R&D activities. Additionally, Malaysia's innovation policies have increasingly focused on social innovation, recognizing its potential to address societal challenges and improve public welfare. Initiatives such as microfinancing, social entrepreneurship, and enhancements in public service delivery are examples of social innovation practices that have demonstrated significant socio-economic benefits (Nasir and Subari, 2017).

Government interventions are essential for fostering a culture of innovation, especially in Malaysia, where private sector investment in R&D is limited. By providing funding, establishing supportive regulatory frameworks, and promoting public-private partnerships, the government plays a pivotal role in stimulating innovation activities. These efforts are particularly crucial in overcoming structural barriers that hinder innovation, such as inadequate infrastructure, limited access to capital, and a lack of skilled human resources (Foster and Heeks, 2013).

Several targeted policies have been introduced to address specific challenges and enhance the effectiveness of R&D and patent output. One of the key initiatives is the establishment of innovation funding programs such as the Malaysian Technology Development Corporation (MTDC) and Cradle Fund, which provide financial support to startups and SMEs engaged in innovative activities (Bekhet and Latif, 2017). These programs are designed to bridge the funding gap that often hampers innovation in its early stages, providing vital capital to foster research and technological development.

The impact of these policies is evident in the growing number of patents filed by Malaysian companies, particularly in high-tech sectors. The government's commitment to fostering a knowledge-based economy is further reflected in its efforts to improve the IP framework, aiming to protect innovations and incentivize inventors and businesses to invest in R&D (Nasir and Subari, 2017).

Comparing Malaysia's innovation policies with those of other countries reveals both similarities and distinct strategies that reflect different national priorities and economic contexts.

For instance, the Republic of Korea has invested heavily in innovation-driven policies to transition from a manufacturing-based to a knowledge-based economy. The Republic of Korea's government has implemented robust R&D support mechanisms, including significant public investment in research institutions and targeted funding for key industries such as electronics, biotechnology, and renewable energy (Dayton, 2020). The Republic of Korea's government has also emphasized collaboration between academia, industry, and government, mirroring Malaysia's Quadruple Helix framework (Othman, 2013).

Germany's innovation policy has been successful in promoting R&D and knowledge transfer to SMEs, with government funding accounting for about 10 % of SMEs' R&D expenditure (Belitz et al., 2013). The German government recognizes the importance of research and innovation for economic growth, value creation, and improved quality of life (Achleitner et al., 2008).

In Europe, policy-driven initiatives and direct grants support IP by subsidizing the high costs of R&D and patent filing fees, thereby removing the risk of the innovation process for smaller entities (Sinadinos, 2022).

A study in Turkey discovered that technology parks with Triple Helix shareholders, ownership stakes held by a mix of university, industry and government entities, demonstrated lower patenting performance compared to parks without such mixed shareholders. This suggests that complex shared governance might create inefficiencies or conflicting priorities that hinder the specific metric of patent generation. The findings suggest that while government financial support is highly effective for innovation output, mixed ownership may introduce complexities that dampen performance (Unlu et al., 2023). Research commercialization is hampered by unclear ownership of patents (Temel et al., 2021).

In China, government policy and direct financial interventions play pivotal roles in shaping the innovation landscape, particularly for the high-tech and pharmaceutical sectors. Research indicates that government R&D subsidies serve as a critical catalyst, directly stimulating corporate investment in R&D, which in turn enhances innovation performance (Xu et al., 2021). Furthermore, for SMEs, these financial subsidies significantly boost sustainable patent output, enabling firms to effectively capitalize on their technological advancements (Xu et al., 2020). Targeted mechanisms such as green policies act as catalysts for promoting the wind and solar power sectors (Hayashi, 2020; Liu et al., 2023; Wu et al., 2022). Digital finance serves as a significant catalyst for corporate innovation, directly correlating with a measurable increase in both patent applications and authorizations (Yu et al., 2021; Zhang et al., 2023b).

India's R&D tax credit raised the weighted tax deduction for in-house R&D expenditures for private firms' innovation activities. The analysis reveals that the reform led to a sharp and significant increase in R&D expenditure, R&D intensity and the number of

patent applications (Ivus et al., 2021). Firms increase R&D expenditures to reduce corporate social responsibility activities (Gongopadhyay and Homroy, 2023).

While Malaysia's innovation policies share some common elements with those of other countries—such as the emphasis on public funding, the promotion of collaboration among academia, industry, and government, and support for SMEs—there are also notable differences. For further upgrade its its innovation ecosystem, Malaysia may benefit from adopting more targeted strategies similar to those implemented in Germany while maintaining its commitment to inclusive innovation and socio-economic development (Nasir and Subari, 2017). By learning from these international best practices, Malaysia can continue to refine its innovation policies to better support sustainable economic growth and improve its position in the global innovation landscape.

7.2. Bridging the gap between perception and performance

Bridging the gap between perception and performance in innovation requires understanding the factors that influence both perceived and actual outcomes. A challenge in this context is the misalignment between how innovation strategies are perceived by stakeholders within an organization and how these strategies translate into tangible performance outcomes. Studies have shown that while organizations may perceive themselves as being innovative, this perception does not always correlate with measurable improvements in business metrics such as market share gains (Djellal and Gallouj, 2009). This discrepancy often stems from a lack of strategic alignment and integration between innovation initiatives and broader business objectives.

Furthermore, the concept of "innovation readiness" is pivotal in understanding this gap. Innovation readiness refers to an organization's capacity to effectively implement and leverage innovation strategies to achieve desired outcomes. Studies have shown that

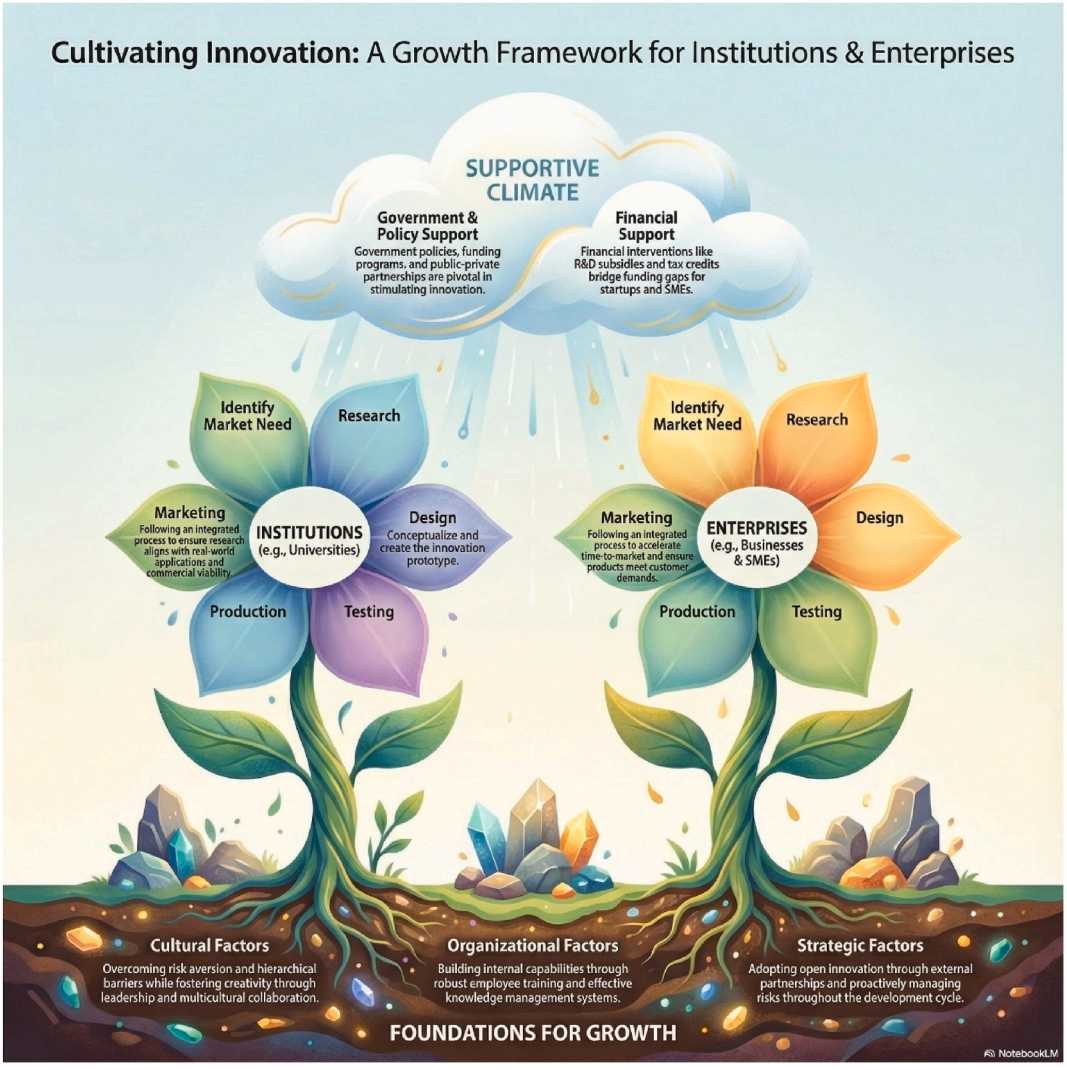

Fig. 2. Factors that optimize R&D and patent output.

organizations with high innovation readiness are more likely to align their innovation strategies with their business goals, resulting in enhanced performance outcomes (Cui et al., 2015).

8. Conceptual framework for optimizing output

To address the innovation deficit, a unified conceptual framework (Fig. 2) is proposed that integrates the cultural, organizational, and strategic factors discussed above. This framework serves as a guide for companies with limited resources to optimize R&D and patent output. Furthermore, the framework posits that these internal initiatives are most effective when nurtured by supportive government policy and financial intervention.

8.1. Growing institutions and enterprises

- In this conceptual framework, institutions such as universities and enterprises (including SMEs) are visualized as distinct flowers. The petals of each flower represent the critical stages of the innovation lifecycle: identifying market needs, research, design, testing, production and marketing.
- These entities rely on a robust foundation of cultural, organizational, and strategic factors for growth, all of which are anchored by and nurtured through government policy and financial support.

8.2. Cultural factors

- Diverse Cultural Mindset: Leveraging Malaysia's multicultural society to foster diverse innovation perspectives. Encourage cross-cultural collaboration and inclusivity in innovation projects.
- Risk Aversion and Entrepreneurial Culture: Address cultural tendencies toward risk aversion by promoting entrepreneurship education and community support to foster a culture that embraces risk-taking and sees failure as a learning opportunity.
- Innovation Leadership: Cultivate leadership that prioritizes innovation at all organizational levels, promotes a culture of intrapreneurship and encourages employees to propose and develop new ideas.

8.3. Organizational factors

- Employee Training: Foster a culture of continuous learning, collaboration, and knowledge sharing. Tailor training programs that focus on developing creative problem-solving skills, innovation management, and technology adoption to ensure that employees are equipped with the latest tools and techniques. It should emphasize cross-functional collaboration, encouraging teams from different departments to work together on innovation projects and leveraging diverse perspectives.

- Knowledge Management Systems: Knowledge management systems should be implemented to capture, store, and disseminate organizational knowledge, enabling employees to access critical information and lessons learned from past innovation efforts. Feedback loops should be incorporated to measure the effectiveness of training initiatives, ensuring alignment with the organization's strategic goals in innovation.

8.4. Strategic factors

- Adoption of Open Innovation Strategies: Foster external collaborations, leverage diverse knowledge sources, and integrate internal and external innovation efforts. Establish strategic partnerships between academia, startups, industry leaders, and government bodies to co-create and share knowledge, technology, and resources. Intellectual property management should be streamlined to protect innovations while encouraging external contributions.
- Risk Management to Drive Innovation: Focus on proactively identifying, assessing, and mitigating risks while fostering a culture that embraces calculated experimentation. Integrate risk management into the innovation process through structured methods such as stage-gate models and risk assessment tools like scenario planning, QFD, or Bayesian networks to evaluate uncertainties at each phase of development.

8.5. Government policies and financial support

- Government Policies: Government interventions are essential for fostering a culture of innovation, functioning through policy frameworks, funding programs and collaborative partnerships.
- Financial Support: R&D subsidies and tax incentives function as critical bridges over funding gaps that impede startups and SMEs.

9. Conclusion

This study highlights the complex interplay of cultural, organizational, and strategic factors that influence R&D and patent output in Malaysian institutions and enterprises. The findings underscore the importance of fostering a culture of creativity and addressing cultural barriers that hinder innovation within R&D institutions. Additionally, the study reveals the critical role of organizational

practices, employee training, and knowledge management in enhancing innovation capabilities. Strategic approaches to innovation and effective risk management are also identified as vital for driving innovation success. The integration of these factors into a cohesive conceptual framework provides a comprehensive understanding of the innovation landscape in Malaysia. Furthermore, the review of government policies and interventions highlights the need to align perceived success factors with actual performance outcomes to enhance innovation output. These insights have significant implications for resource planning for policymakers, researchers, and industry practitioners, offering a pathway to optimize innovation and drive economic growth in Malaysia.

Ethics statement

Not applicable because this work does not involve the use of animal or human subjects.

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

During the preparation of this work, the authors used Gemini to improve the language of the content. Additionally, the authors utilized NotebookLM to generate Fig. 2. After using these services, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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