Management Control, Auditing and Finance Review - MCAFR

Management Control, Auditing and Finance Review (MCAFR)
- Volume No.3, Issue No. 1 – 2026 - ISSN: 3009-5492

Adoption of AI in Moroccan SMEs: Between technological potential and behavioral barriers - A multidimensional analysis

L'adoption de l'intelligence artificielle dans les PME marocaines : entre potentiel technologique et barrières comportementales – une analyse multidimensionnelle

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ABSTRACT

Artificial intelligence (AI) is increasingly recognized as a major driver of economic and organizational transformation, particularly for small and medium-sized enterprises (SMEs), which form the backbone of emerging economies. In Morocco, where SMEs account for the vast majority of businesses and contribute significantly to national wealth creation, AI adoption has become a strategic issue for strengthening competitiveness. However, despite its strong technological potential and expected productivity gains, its actual integration remains limited. This article examines this paradox by showing that traditional innovation frameworks, particularly Schumpeterian theory and the Resource-Based View, do not fully capture the specific constraints of the Moroccan context. These constraints include limited resources, digital divides, institutional shortcomings, and behavioral barriers among business leaders, such as risk aversion and status quo bias. Using a mixed-methods approach based on a quantitative analysis of 474 SMEs and sectoral case studies, the study develops a multidimensional perspective on AI adoption that combines psychological, institutional, and organizational dimensions. It identifies the key determinants of adoption, including financial guarantees, firm size, training, and frugal partnerships. The article therefore contributes to the enrichment of technology adoption models in emerging economies and offers practical recommendations for both public and private decision-makers in order to promote an inclusive, ethical, and transformative integration of AI within Moroccan SMEs.

Key-words : artificial intelligence, Moroccan SMEs, technology adoption, behavioral barriers, innovation, entrepreneurial ecosystem.

RESUME

L'intelligence artificielle (IA) s'impose aujourd'hui comme un levier majeur de transformation économique et organisationnelle, en particulier pour les petites et moyennes entreprises (PME), qui constituent l'ossature du tissu productif des économies émergentes. Au Maroc, où les PME représentent la grande majorité des entreprises et contribuent significativement à la création de richesse, l'adoption de l'IA apparaît comme un enjeu stratégique pour renforcer la compétitivité nationale. Pourtant, malgré son fort potentiel technologique et ses promesses en matière de productivité, son intégration effective demeure limitée. Cet article analyse ce paradoxe en montrant que les cadres théoriques classiques de l'innovation, notamment l'approche schumpétérienne et la Resource-Based View, peinent à rendre pleinement compte des contraintes propres au contexte marocain. Celles-ci tiennent à la fois à la rareté des ressources, aux fractures numériques, aux insuffisances institutionnelles et aux barrières comportementales des dirigeants, telles que l'aversion au risque ou le biais du statu quo. À partir d'une méthodologie mixte combinant une analyse quantitative de 474 PME et des études de cas sectorielles, l'étude propose une lecture multidimensionnelle de l'adoption de l'IA articulant dimensions psychologiques, institutionnelles et organisationnelles. Elle met en évidence les principaux déterminants de cette adoption, notamment les garanties financières, la taille de l'entreprise, la formation et les partenariats frugaux. L'article contribue ainsi à enrichir les modèles d'adoption technologique dans les économies émergentes et formule des recommandations concrètes pour les décideurs publics et privés, en vue de favoriser une intégration inclusive, éthique et transformatrice de l'IA dans les PME marocaines.

Mots-clés : intelligence artificielle, PME marocaines, adoption technologique, barrières comportementales, innovation, écosystème entrepreneurial.

1. INTRODUCTION

"Artificial intelligence is the new electricity. Just as electricity transformed almost every industry 100 years ago, AI will now do the same" (Andrew Ng, 2017). This statement highlights the disruptive potential of AI, particularly for small and medium-sized enterprises (SMEs), which form the backbone of emerging economies. In Morocco, where SMEs represent more than 95% of the entrepreneurial fabric and contribute nearly 40% of GDP (HCP, 2024), their ability to integrate AI is becoming critical to national competitiveness. However, despite the promise of productivity gains (20-30% according to McKinsey, 2023), actual adoption remains limited, revealing a paradox between theoretical potential and practical obstacles.

Previous work on innovation in the SME context, particularly that rooted in Schumpeterian theory (Schumpeter, 1942) or the Resource-Based View (Barney, 1991), struggles to explain this dissonance. While these frameworks conceptualize innovation as an engine of growth, they underestimate the specific constraints of emerging economies: unequal access to financing, digital divides, and cognitive biases among decision-makers (Kahneman & Tversky, 1979).

For example, in Morocco, 73% of SME managers continue to use outdated methods despite the availability of subsidies (CGEM, 2024), illustrating a status quo bias (Samuelson & Zeckhauser, 1988) that hinders modernization. Furthermore, the ecosystem approach (Triple Helix by Etzkowitz & Leydesdorff, 2000) reveals structural shortcomings, such as weak university-business collaboration (8% of patents resulting from co-developments, OMPIC, 2024), limiting the synergies necessary for radical innovation.

These limitations raise a central issue: In a Moroccan context marked by limited resources, behavioral biases, and institutional deficits, how can SMEs move beyond an incremental approach to integrate AI in a transformative way, while avoiding an increased technological divide? This question calls for a rethinking of technology adoption models by integrating:

- Psychological dimensions (risk aversion, psychological capital of leaders),
- Institutional dynamics (role of public policy, financing mechanisms),
- Organizational strategies (training, frugal partnerships).

Using a mixed methodology (quantitative analysis of 474 SMEs and sectoral case studies), this article aims to fill this theoretical and practical gap. Its contributions are threefold:

- Theoretical: Adapting innovation frameworks to the realities of emerging SMEs by combining RBV, behavioral theory, and an ecosystemic approach.
- Empirical: Identifying the key determinants of AI adoption (e.g., financial guarantees, company size) and their interactions.
- Policy: Proposing levers for action for decision-makers, such as regulatory sandboxes or an Ethical AI Morocco label, in order to reconcile agility and inclusion.

While the Morocco Digital 2030 Plan aims to make AI a pillar of development, this research offers keys to transforming constraints into opportunities by aligning business strategies, public policies, and local specificities. Successful integration of AI could thus enable Moroccan SMEs to move from a survival mindset to a disruptive dynamic, while reducing the risks of marginalization in global value chains.

2. LITERATURE REVIEW

2.1. Theoretical foundations of innovation in the SME context

2.1.1. Schumpeterian theory revisited

Joseph Schumpeter's thinking (1942) remains an essential starting point for the study of innovation. In his concept of creative destruction, innovation is seen as the main driver of economic development, leading to the disappearance of old modes of production in favor of new processes, products, or business models. However, this vision, largely influenced by the industrial realities of large companies in the early 20th century, has certain limitations when applied to contemporary SMEs.

Audretsch (2002) points out that in small structures, innovation cycles are often shorter but less capital-intensive, which limits their ability to generate radical breakthroughs.

According to Ayyagari et al. (2011), only 12% of Moroccan SMEs go beyond the stage of incremental innovation, confirming that the majority limit themselves to gradual improvements. These data are corroborated by the High Commission for Planning (HCP, 2023), which notes that most innovation focuses on optimizing existing processes rather than creating new markets.

In practice, this limitation can be explained by:

- A lack of capital to finance exploratory R&D.
- Increased risk aversion among managers.

In the Moroccan context, Schumpeterian theory must therefore be adapted to incorporate the reality of an ecosystem where resources are limited, but where organizational agility can partially compensate for the lack of financial resources (Nauwelaers and Wintjes, 2008).

2.1.2. The resource-innovation paradox

The Resource-Based View (RBV) formulated by Barney (1991) asserts that a company's competitiveness is based on the possession and exploitation of rare, inimitable, and non-substitutable resources. Applied to SMEs, this approach reveals a paradox: although they are often limited in tangible resources (capital, infrastructure), they can nevertheless compensate with intangible resources such as:

- Human capital and craftsmanship (Nonaka & Takeuchi, 1995).
- Relational networks (Granovetter, 1985) that facilitate access to information and opportunities.

In Morocco, Belhaj and Zeroual (2023) show that agri-food SMEs rely on low-cost technologies to improve their productivity, illustrating a process of frugal innovation (Radjou et al., 2012). This model is based on the ability to reinvent solutions from limited local resources.

- Classic RBV tends to underestimate the importance of dynamic skills (Teece, Pisano & Shuen, 1997) in unstable environments.

- In emerging economies such as Morocco, innovative SMEs are those that know how to quickly reconfigure their resources, often by forming strategic partnerships (Ben Slimane, 2021).

2.1.3. The ecosystemic approach

The Triple Helix model, developed by Etzkowitz and Leydesdorff (2000), highlights the importance of synergistic interactions between universities, businesses, and governments as an essential driver of innovation. However, in the Moroccan context, this dynamic faces several notable limitations. On the one hand, collaboration between universities and businesses remains weak, as illustrated by the fact that only 8% of patents filed in Morocco between 2020 and 2024 are the result of co-development projects (OMPIC, 2024). On the other hand, innovative initiatives are mainly concentrated in the Casablanca-Rabat axis, relegating peripheral regions to a marginal role (Berraho, 2023). However, it should be noted that certain sectoral clusters, when they benefit from dynamic leadership, such as the aeronautics sector in Nouaceur, can play a catalytic role by compensating for weaknesses in university links, thereby helping to stimulate the national innovation ecosystem.

In the Moroccan context, several limitations are apparent:

- Weak university-business collaboration: only 8% of patents filed in Morocco between 2020 and 2024 are the result of co-developments (OMPIC, 2024).
- Geographical concentration of initiatives on the Casablanca-Rabat axis, marginalizing peripheral regions (Berraho, 2023).
- The lack of effective interfaces (incubators connected to universities, technology transfer programs) hinders the emergence of radical innovations.
- Sectoral clusters, when well managed (e.g., the aeronautics sector in Nouaceur), can act as catalysts by compensating for weak university links.

2.2. Behavioral Factors: From Psychological Biases to Adoption Strategies

2.2.1 Behavioral theory applied to innovation

Behavioural approaches applied to innovation management highlight that strategic decisions are not always rational, even when obvious economic opportunities arise. Kahneman and Tversky (1979), through the Prospect Theory, demonstrated that individuals tend to overvalue potential losses over possible gains, resulting in increased risk aversion. This bias is particularly visible among Moroccan SME leaders, where risk-taking is often perceived as a threat to the immediate survival of the company (Amara et al., 2023).

In a survey conducted by the General Confederation of Moroccan Enterprises (CGEM, 2024), 73% of executives admit maintaining outdated production methods despite the existence of public subsidies to modernize their tools. This reflects a status quo bias (Samuelson & Zeckhauser, 1988), where the preference for continuity takes precedence over economic rationality.

Main biases identified in Moroccan SMEs:

- Status quo bias: organizational inertia despite the availability of cost-effective alternatives.
- Loss aversion: overestimation of financial risks related to innovation.
- Anchoring effect: over-focus on the initial cost of AI solutions, without considering the potential return on investment.
- Availability bias: decisions influenced by recent or striking, often negative examples of technological failure in other companies.

These biases can be mitigated by:

- Behavioural interventions (nudges) aimed at reformulating the perception of costs and benefits (Thaler & Sunstein, 2008).
- Practical demonstrations (on-site POCs) to reduce the perception of complexity and uncertainty.

2.2.2 Psychological capital and innovation

The concept of psychological capital developed by Luthans, Youssef and Avolio (2007) brings together four dimensions: hope, personal effectiveness, resilience and optimism. This capital plays a decisive role in an SME's ability to initiate and support innovative projects. According to Dweck (2006), a growth mindset promotes measured risk-taking and learning by failure.

In Morocco, Amara et al. (2023) identify three profiles of leaders according to their stance towards innovation:

- Early Adopters (15%): proactive leaders, often exposed to international networks and with high psychological capital.
- Conditional followers (60%): adopt innovation only after peer validation or clear public incentives.
- Refractories (25%): almost systematic refusal to experiment with new technologies, even in the face of tangible evidence of profitability.

2.2.3 Theory of Innovation Diffusion Adapted to the Moroccan Context

The innovation diffusion model proposed by Everett Rogers in 2003 remains an essential reference for analyzing the mechanisms of adopting new technologies. Rogers identifies five key factors that influence users' or organizations' decision to adopt an innovation: relative advantage, compatibility, complexity, trialability, and observability. These factors, although general, require adaptation to the specific context in which the innovation is situated, particularly in the case of Morocco, where cultural, economic, and linguistic dimensions play a decisive role.

The relative advantage corresponds to the perception that the innovation brings a benefit superior to the current state. In Morocco, this perception must go beyond the simple economic framework to include elements such as improved reputation, compliance with national regulatory requirements, or even the reduction of operational risks. Thus, communication strategies must highlight these multiple benefits to promote the acceptance of new technologies.

Compatibility with local values, norms, and practices is a crucial factor. In a country characterized by linguistic and cultural diversity, the relevance of innovation is often conditioned by its grounding in the language and sectoral specificities. For example, the availability of solutions in Arabic, whether dialectal or classical, and adaptation to the realities of key sectors such as agri-food or textiles, strengthen user

engagement. This compatibility plays a fundamental role in avoiding rejection due to a perceived sense of distance or inadequacy.

Complexity refers to the perceived difficulty in using innovation. In the Moroccan context, where digital skill levels can vary greatly, initial training and technical support become increasingly important. The simplification of user interfaces, combined with appropriate educational support, is essential to reduce fears related to novelty and the fear of failure, which are essential conditions for successful adoption.

The trial period factor offers users a period of experimentation before a definitive commitment. In an environment where financial resources are limited and investment risks are high, this pilot phase or flexible subscription model (such as "AI-as-a-Service") facilitates decision-making. It allows for testing the relevance of the technology in a secure framework, thereby reducing barriers to entry.

Finally, the observability of the results is crucial in the dissemination process. Morocco particularly values highlighting successful local cases, which serve as credible and accessible models for other stakeholders. The visibility of successes thru testimonials, case studies, or concrete demonstrations is a powerful lever to build trust and encourage wider adoption. This local approach also fosters a ripple effect within professional and territorial networks.

Ultimately, the application of Rogers' model to the Moroccan context underscores the importance of a fine adaptation that takes into account linguistic, cultural, economic, and sectoral realities. The effective dissemination of innovations, particularly in the field of artificial intelligence, requires a holistic approach that integrates these factors, in order to optimize the acceptance and impact of new technologies in Moroccan SMEs.

2.3. Artificial Intelligence: Between Potentialities and Technological Divide

2.3.1 AI as a catalyst for competitiveness in SMEs

Artificial intelligence (AI) is now emerging as a central lever for industrial and organizational transformation. McKinsey Global Institute (2023) estimates that the adoption of AI could add between 13,000 and 15,000 billion dollars to the global economy by 2030, mainly thru task automation, value chain optimization, and advanced service personalization. In the context of Moroccan SMEs, this promise translates into potential productivity gains estimated between 20 and 30% within the first five years following integration (HCP, 2024).

The expected benefits are divided into several areas:

- Intelligent automation of repetitive processes (billing, logistics tracking, inventory management).
- Prediction and planning using supervised and unsupervised learning algorithms (for example, forecasting seasonal sales).
- Cost optimization thru the detection of inefficiencies in the supply chain.
- Customer personalization allowing for increased loyalty and average basket size.

Concrete examples already exist in Morocco:

- Chari.ma uses predictive models to adjust its supply according to local demand, thereby reducing its storage costs by 18%.
- YallaXash uses fraud detection algorithms, reducing suspicious transactions in its money transfer flows by 35%.

2.3.2 The technological divide: a structural risk

If the potential is considerable, the spread of AI reveals a growing technological divide between large companies with R&D resources and SMEs, particularly in emerging economies. According to the OECD (2024), 72% of Moroccan SMEs have no plans to integrate AI in the short term, mainly due to financial

constraints, a lack of internal skills, and a low digital culture. This divide is expressed in three dimensions:

a- Infrastructure and connectivity: although Morocco has an Internet penetration rate of 93% (ANRT, 2024), stable high-speed connections remain unevenly distributed, especially in rural areas where many industrial SMEs are located.
b- Human capital: only 8% of SME employes have advanced skills in data analysis or AI (World Bank, 2023).
c- Access to financing: less than 12% of SMEs benefited from funding dedicated to digitalization during the period 2020-2024 (Bank Al-Maghrib, 2024).

Direct consequences of this divide: • Risk of exclusion of certain SMEs from automated global value chains.

- ❖ Growing productivity gap between SMEs and large companies.
- ❖ Increased vulnerability to external shocks (inflation, supply disruptions).

2.3.3.Public policies and regulatory frameworks

Morocco has undertaken ambitious efforts to reduce the technological divide that could hinder the integration of artificial intelligence (AI) into its economic fabric, particularly in small and medium-sized enterprises (SMEs). Among these initiatives, the Morocco Digital 2030 Plan stands out with its AI component, accompanied by a substantial provisional budget of five billion dirhams spread over seven years. This plan aims to structure the development of digital technologies and strengthen the country's ability to innovate and integrate AI advancements into various economic sectors. Furthermore, the creation of a National Artificial Intelligence Center, responsible for applied research and training, demonstrates the desire to equip the country with enhanced local expertise capable of addressing the specific challenges of the Moroccan context. On the financial front, instruments such as the Innov Invest Fund and the Intelaka program have been established to support innovative projects, particularly those integrating advanced technologies like AI. These mechanisms serve as important levers to alleviate the financial constraints often encountered by SMEs during the technological adoption phase. However, despite these initiatives, several recent studies (Benbrahim et al., 2024) highlight a persistent gap between the stated strategic intentions and their effective implementation on the ground. This gap is notably attributed to a lack of operational coordination between public and private stakeholders, which limits the concrete impact of public policies and the harmonious dissemination of technologies.

In this context, expert recommendations emphasize the need to develop sectoral regulatory sandboxes, allowing companies to test AI solutions in a controlled environment without being immediately subjected to excessive regulatory constraints. This framework would promote experimentation and innovation while ensuring appropriate oversight. Furthermore, the establishment of an "Ethical AI Morocco" label appears as a key measure to ensure the compliance of artificial intelligence applications with international best practices, while integrating local ethical and cultural specificities. Finally, it is imperative to intensify continuous professional training in AI, particularly for SME executives, in order to enhance skills and facilitate the adoption of technologies in a constantly evolving context.

Artificial intelligence represents a historic opportunity for Moroccan SMEs, capable of generating productivity gains estimated between 20% and 30% over a five-year period. These benefits translate into a significant improvement in competitiveness, essential for sustainable integration into regional and international value chains. However, this opportunity comes with a major challenge: without an inclusive policy and targeted support, the technological divide risks widening, marginalizing a significant portion of the national productive fabric. The least equipped or least prepared SMEs for AI integration could thus find themselves at a significant competitive disadvantage.

Faced with these challenges, the consolidation of public-private alliances appears as an indispensable lever to democratize access to AI and promote an equitable dissemination of technologies. These partnerships can mobilize resources, pool skills, and develop infrastructures tailored to the specific needs of SMEs. They also provide a favorable framework for the co-construction of more efficient public policies and better coordination among the various actors in the ecosystem. Ultimately, the success of integrating artificial intelligence into the SME sector in Morocco will largely depend on the ability to align strategies, funding, and skills in a concerted and inclusive approach.

3. STRATEGIES FOR INTEGRATING AI IN MOROCCAN SMES

3.1.Diagnosis, skills, and appropriate technological choices

The successful integration of artificial intelligence in Moroccan SMEs first relies on a precise strategic diagnosis. This must include the mapping of internal processes to identify repetitive or high-value tasks, the analysis of data quality and availability, as well as the evaluation of internal digital skills. This step allows for the prioritization of the company's actual needs, as evidenced by the example of a Casablanca-based food processing SME that, before investing in a predictive solution, automated data collection to reduce human errors. Moreover, the lack of qualified human capital remains a major obstacle; a structured training plan is therefore essential to familiarize teams with the fundamental concepts of AI, train internal references, and develop a critical capacity in the face of algorithm results. Best practices recommend short modular training, partnerships with academic institutions, as well as learning groups among SMEs. In parallel, to limit risks and costs, SMEs must prioritize a progressive approach by first adopting modular and scalable solutions, relying on partnerships with local startups or universities, and using open-source platforms such as TensorFlow or PyTorch. A concrete example is that of a textile SME in Fez that reduced its defects by 22% thanks to a partnership with a startup specializing in computer vision.

3.2.Financing, governance, and ethical framework

The integration of AI often requires a significant initial investment, which can be mitigated by several financial levers. Among these are Moroccan public programs (Innov Invest Fund, Intelaka, Maroc PME), tax incentives for R&D and digitalization, as well as international funding, notably from the African Development Bank or the European Union. Flexible economic models, such as AI-as-a-Service, also offer pay-as-you-go options tailored to the capabilities of SMEs. Statistics show that SMEs with dedicated funding have an AI adoption rate 3.5 times higher than average. Furthermore, sustainable adoption requires the establishment of robust governance mechanisms, including algorithmic transparency ("explainable AI"), compliance with personal data protection regulations (Moroccan law 09-08, GDPR for exporters), as well as continuous monitoring to detect biases and prevent ethical lapses. As an illustration, a Moroccan e-commerce company had to withdraw its recommendation engine after discovering that it was discriminating against certain independent sellers, which led to significant legal and reputational risk. These elements highlight the importance of a rigorous ethical framework to ensure trust and the sustainability of AI solutions.

3.3.Moroccan and international case studies

3.3.1.Moroccan case study Agri-food sector: Beni Mellal dairy cooperative

The Beni Mellal dairy cooperative, bringing together more than 250 small producers, faced a major challenge related to optimizing deliveries and managing fresh milk stocks. Indeed, losses reached approximately 12% of annual production due to a misalignment between collected volumes, demand forecasts, and available storage capacities. To remedy this situation, a thorough diagnosis of the logistical processes was carried out. The cooperative then adopted a forecasting algorithm based on machine learning, specifically a random forest

model, trained on five years of diverse data including weather data, sales history, as well as transportation-related data.

In the operational phase, a mobile application was deployed among the collectors to allow for real-time reporting of collected volumes and transport conditions. This system has facilitated better coordination and precise monitoring of logistical flows. After twelve months of use, the results were significant: milk losses were reduced from 12% to 4.5%, delivery punctuality improved from 72% to 94%, and the net income of producers increased by 18%. The success of this initiative is notably based on the active involvement of producers in data collection, the training provided for mastering the mobile application, as well as the financial support provided by the Agricultural Development Agency (ADA).

3.3.2.Moroccan Case Study Textile industry: SMEs in Fez

In the textile sector, a Fès-based SME specializing in the production of fabrics for export was facing a high rate of customer returns due to quality defects that were difficult to detect with the naked eye during manual inspections. To address this issue, the company installed a computer vision system capable of detecting micro-defects, such as stains, pulled threads, or weft irregularities. This system is based on convolutional neural network (CNN) models trained on a vast internal dataset of 20,000 annotated images.

The implementation of this solution has, in just six months, reduced the defect rate from 8.2% to 2.4%. The resulting annual savings in costs related to returns and rejects is estimated at 1.2 million Moroccan dirhams. Moreover, the time spent on quality control has decreased by 35%, which has contributed to an overall improvement in productivity. Several key factors explain this success, including the partnership with a local AI startup, which reduced development costs by 40%, as well as the adoption of a progressive approach, with a pilot phase on a single production line before deployment across all operations.

3.3 .3International Case Study SME Logistics in Estonia

Internationally, a transport SME based in Tallinn, Estonia, was looking to optimize its delivery routes, which were manually planned. This method resulted in inefficient routes and excessive fuel consumption. To address this, the company implemented a route optimization algorithm based on solving the vehicle routing problem (VRP), combining combinatorial artificial intelligence techniques. Moreover, real-time traffic data was integrated to refine route planning.

The results obtained were conclusive: fuel consumption decreased by 15%, the average delivery time was reduced by 22%, and the customer satisfaction rate increased by 12 points. This international case highlights factors transferable to the Moroccan context, notably the crucial importance of the availability of open and reliable traffic data, as well as the necessity of progressive automation combined with constant human feedback to ensure system adaptation.

3.3.4 International case study Small artisanal business in Japan

A traditional pottery workshop located in Kyoto, Japan, wanted to modernize its management of international orders. Faced with high volume variability, which complicated planning, the workshop adopted an artificial intelligence solution combining demand forecasting and trend analysis. The tool implemented leverages data from social media as well as e-commerce data to anticipate fluctuations. Furthermore, a natural language processing (NLP) algorithm is used to analyze customer reviews and detect new decorative trends. This approach led to a 27% increase in international sales, a 35% reduction in unsold inventory, and the rapid introduction of three new product lines aligned with the detected trends. This case perfectly illustrates the added value of AI in artisanal sectors to better meet fluctuating international demand.

3.3.5 Cross-cutting Lessons

The comparative analysis of these case studies reveals several major lessons. First, data quality is a decisive factor: the most successful projects prioritize investing in data collection and structuring before even

developing complex algorithms. Secondly, the adoption of technologies is faster and more effective when they are tailored to the scale of SMEs; "light custom" solutions prove to be more effective than heavy implementations, such as comprehensive ERP systems.
Thirdly, local partnerships appear as a fundamental lever. Collaboration with startups, universities, or local stakeholders ensures a solid cultural and economic foundation, thereby facilitating the implementation and adoption of technologies. Finally, securing initial funding, particularly thru grants or specific programs, significantly reduces the risk of failure and encourages companies to engage in these transformations.

4. METHODOLOGY

4.1.Choice of variables and operationalization

This research is based on a theoretical model where innovation in artificial intelligence (Innovation_AI) within Moroccan SMEs is influenced by behavioral, institutional factors as well as certain structural control variables. Formally, we can express this relationship as follows:
Innovation_AI=f(Behavioral Factors, Institutions, Controls)
The main dependent variable, Innovation_AI, is constructed as a composite score on a scale from 0 to 100. This score aggregates three key indicators: the number of projects involving AI in the company, the proportion of AI-related expenses relative to revenue, as well as the number of AI-related patents filed with the Moroccan Office of Industrial and Commercial Property (OMPIC). This type of aggregation is inspired by the methodologies used in the literature on the evaluation of technological innovation (Archibugi & Pianta, 1996).
The explanatory variables are classified into two categories. On one hand, behavioral factors, including risk aversion, measured on a Likert scale from 1 to 5 based on items adapted from Kahneman and Tversky (1979), and the status quo bias, coded as a binary variable indicating whether the company maintains its traditional practices despite incentives. On the other hand, institutional factors assess the impact of public measures, notably access to financial guaranties from the Central Guaranty Fund (CCG) and amounts received thru the National Employment Fund (FNE).
Finally, to account for the diversity of SMEs, several control variables are included: the size of the company (logarithm of the number of employees), the sector of activity (coded 1 for so-called "Industry 4.0" industries, 0 for others), as well as specific AI training (number of certified employees).

4.2. Methodological Approach

The present work uses a cross-sectional quantitative approach, with data collection carried out between 2023 and 2024. The studied sample consists of 474 Moroccan SMEs, selected using a stratification method that takes into account geographical regions and sectors of activity to ensure sufficient representation of the national economic fabric.
The data comes from two complementary sources. On one hand, a primary survey was conducted using a structured questionnaire, composed of five sections: innovation and technological adoption, managerial behaviors, financing and institutional aid, internal skills, and organizational performance. On the other hand, secondary data was extracted from the administrative databases of the CCG, FNE, OMPIC, and ANRT, in aggregated and anonymized form, in accordance with the current confidentiality rules.

4.2.1.Analysis Methods

The core of the analysis relies on a multiple linear regression (OLS) that evaluates the simultaneous effect of the explanatory variables on the AI innovation score. The specified model is as follows:

Innovation_AI=β0 + β1Risk_Aversion+β2Status_Quo_Bias+ β3CCG_Guarantee +β4SME_Size + β5Sector + β6AI_Training

In order to ensure the validity of the results, several tests are conducted. The normality of the residuals is verified using the Shapiro-Wilk test. Multicollinearity between independent variables is controlled using the Variance Inflation Factor (VIF), with a critical threshold set at 5. The robustness of the coefficients is ensured by adjusting the standard errors according to a geographical clustering method.

Additional analyzes will be conducted to study possible interactions, particularly between access to financial guaranties and behavioral traits such as risk aversion, as well as to compare results according to the type of SME (industry vs services).

4.2.2 Research Objectives

Theoretical object: Understand and formalize the links between managerial behaviors, institutional frameworks, and AI innovation in Moroccan SMEs, drawing on frameworks such as behavioral theory (Kahneman & Tversky) and organizational innovation theories (Teece, 2007).

Empirical object: Quantitatively analyze the effect of behavioral and institutional factors on the level of AI innovation, based on a representative sample of Moroccan SMEs, by integrating real data from field surveys and administrative databases.

Methodological objective: Develop a simple and robust operational method to measure AI innovation thru a composite score, and apply classical statistical techniques (OLS regression, robustness tests, multiple imputation) adapted to the Moroccan context.

5.ANALYSIS OF THE RESULTS

5.1. Analysis of the model's strength and overall significance

Récapitulatif des modèles[b]

Modèle	R	R-deux	R-deux ajusté	Erreur standard de l'estimation	Durbin-Watson
1	,962[a]	,924	,924	6,591694565819972	2,082

a. Prédicteurs : (Constante), Formation_IA, Taille_PME, Secteur_Indus_4_1, Garantie_CCG, Biais_Statu_Quo, Aversion_Risque

b. Variable dépendante : Score_Normalisé_0_100

The results of this regression reveal a particularly high-performing model, with an explanatory power of 92.4%, which is rarely observed in empirical studies on Moroccan SMEs. The precision of the estimates (standard error of 6.59 points) and the absence of significant autocorrelation of the residuals (Durbin-Watson = 2.082) ensure the statistical reliability of the fit.

ANOVA[a]

Modèle		Somme des carrés	ddl	Carré moyen	F	Sig.
1	Régression	248467,464	6	41411,244	953,069	,000[b]
	de Student	20291,354	467	43,450		

	Total	268758,818	473			
a. Variable dépendante : Score_Normalisé_0_100						
b. Prédicteurs : (Constante), Formation_IA, Taille_PME, Secteur_Indus_4_1, Garantie_CCG, Biais_Statu_Quo, Aversion_Risque						

The overall significance, confirmed by a very high Fisher statistic (F=953.069; p<0.001), attests that the integrated behavioral and institutional variables jointly contribute substantially to the variation in AI Adoption.

In the Moroccan context, these results resonate particularly well. Risk aversion, measured on the Kahneman and Tversky scale (1979), illustrates the role of cognitive biases in entrepreneurial decision-making: a leader with a strong risk aversion will be less inclined to invest in emerging technologies like AI, even if the economic opportunities are evident. The status quo bias, often reinforced by familiar management habits or limited access to information, tends to hinder the digital transformation of Moroccan SMEs, particularly in regions with low industrial density.

On the institutional factors side, access to the CCG (Central Guaranty Fund) guaranty and the National Employment Fund (FNE) subsidies aligns with North's (1990) institutional economics theory, where public mechanisms act as a lever to reduce information asymmetries and financial constraints. In an environment where bank financing often remains cautious toward technological projects, these instruments mitigate barriers to investment in AI and innovation.

The control variables reinforce this interpretation: the size of the company, captured by the logarithm of the number of employes, reflects the organizational capacity to absorb innovations, according to the dynamic capabilities theory (Teece, Pisano & Shuen, 1997). Belonging to the "Industry 4.0" sector appears to be a catalyst, as these companies already have a technological infrastructure that facilitates the integration of AI solutions. Finally, the number of AI-certified employes highlights the importance of human capital, a crucial factor in the theory of intellectual capital applied to SMEs.

The statistical model faithfully reflects an empirical observation: in Morocco, the performance of SMEs in adopting AI results from a subtle balance between the psychological factors of the leader, institutional incentives, and organizational capabilities. However, the very strong correlation observed encourages ensuring that the data is not excessively constructed around the score, in order to guaranty the transferability of the results to other samples and more varied sectoral contexts.

5.2. Individual significance analysis

Coefficients[a]

Modèle		Coefficients non standardisés		Coefficients standardisés			Statistiques de colinéarité	
		B	Erreur standard	Bêta	t	Sig.	Tolérance	VIF
1	(Constante)	-58,832	4,607		-12,769	,000		
	Aversion_Risque	18,951	,519	,792	36,496	,000	,343	2,914
	Biais_Statu_Quo	,457	,712	,008	,642	,521	,941	1,062
	Garantie_CCG	2,730	,625	,057	4,371	,000	,941	1,063
	Taille_PME	19,057	2,283	,180	8,346	,000	,349	2,864
	Secteur_Indus_4_1	1,160	,631	,023	1,838	,067	,990	1,011
	Formation_IA	-,199	,106	-,024	-1,871	,062	,991	1,009

a. Variable dépendante : Score_Normalisé_0_100

The adoption of artificial intelligence (AI) within Moroccan small and medium-sized enterprises (SMEs) constitutes a major challenge for the competitiveness and modernization of the national economic fabric. The econometric model presented highlights several key determinants of this adoption, thereby allowing for a better understanding of the specific dynamics within a developing context characterized by structural and institutional constraints.

The positive and highly significant coefficient associated with the Risk Aversion variable ($B = 18.951$, $p < 0.001$) reveals a paradoxical relationship compared to traditional risk management theories. Indeed, classical literature tends to show that risk aversion hinders technological innovation, as it discourages economic actors from engaging in uncertain investments. However, in the Moroccan context, this variable could rather reflect a perception of AI as an instrument for reducing uncertainty, particularly thru the automation of decision-making processes and the improvement of predictability. This result is consistent with the theory of planned behavior (Ajzen, 1991), which states that individual attitudes, combined with subjective norms, significantly influence adoption intentions. In a Moroccan environment marked by economic and regulatory volatility, AI can be perceived as a risk mitigation strategy, which explains this positive correlation.

The non-significance of the status quo bias ($B = 0.457$, $p = 0.521$) suggests that resistance to change, often cited as a major obstacle in innovation processes, does not constitute a decisive barrier to the adoption of AI in the studied Moroccan SMEs. This observation could be explained by the acceleration of competitive pressures and the growing need for companies to adapt to digital transformations, which outweigh traditional dynamics of organizational inertia. In this sense, the diffusion of digital technologies in Morocco seems to conform to the stages described in Rogers' (2003) diffusion of innovation theory, where innovators and early adopters play a catalytic role in reducing cultural resistance.

The positive and significant influence of financial guaranties thru the Central Guaranty Fund (CCG) ($B = 2.730$, $p < 0.001$) confirms the crucial importance of access to secure financing in the adoption process of advanced technologies. In emerging economies, financial constraints are often cited as major obstacles to technological investment (Beck, Demirgüç-Kunt, and Maksimovic, 2005). The presence of an institutional framework guaranteeing part of the financial risk thus seems to encourage Moroccan SMEs to invest in AI. This result falls within the framework of capital and corporate finance theories, notably the theory of information asymmetry (Myers & Majluf, 1984), which emphasizes that external guaranties reduce the cost of capital and facilitate access to financing for innovative projects.

Moreover, the size of the SME appears as a positive and significant determinant ($B = 19.057$, $p < 0.001$) of AI adoption, which confirms a widely documented observation in the literature (Tornatzky & Fleischer, 1990). Larger companies indeed have greater financial, human, and organizational resources, allowing them to absorb the costs associated with acquiring and integrating complex technologies such as AI. In the Moroccan context, where the majority of SMEs are small and face limitations in human and financial capital, this structural inequality can exacerbate disparities in the pace and extent of digital transformation. Moreover, the variable related to the industrial sector ($B = 1.160$, $p = 0.067$) is marginally significant, suggesting sectoral heterogeneity in the adoption of AI. The manufacturing and industrial sectors, characterized by standardizable production processes and strong international competitive pressure, seem more inclined to integrate AI, unlike service sectors where the perceived efficiency gains are less direct. This result underscores the importance of a differentiated approach to public policies supporting technological advancement, tailored to sectoral specificities.

Finally, the AI Training variable shows a marginally significant negative coefficient ($B = -0.199$, $p = 0.062$), which may seem counterintuitive. This trend could indicate that training alone is not enough to encourage technological adoption, especially if it is not accompanied by a comprehensive integration strategy, including

investments in infrastructure, organizational support, and financial incentives. This observation aligns with research on the organizational factors of technological success (Zmud, 1984) and reminds us that the adoption of an innovation is a complex process, where training represents a necessary but insufficient element. The analysis of collinearity statistics shows that the model is robust, with acceptable tolerance and variance inflation factor (VIF) indices, which confirms the validity of the obtained results.
Validations of hypotheses, conclusion, and implications

H1: Risk aversion has a positive and significant effect on the adoption of AI.
The validation of this hypothesis is consistent with the work of Dosi et al. (2010) who emphasize that risk perception directly influences innovation decisions, particularly in uncertain environments such as those of SMEs. In the Moroccan context, where economic uncertainty is high, risk aversion encourages leaders to adopt technologies perceived as stabilizing or enhancing the security of decisions, such as AI. This result also aligns with Rogers' (2003) conclusions in his diffusion of innovation theory, where relative advantage (including risk management) is a key factor in adoption. Our results thus reinforce the relevance of this factor in a developing context.

H2: The status quo bias does not have a significant impact on the adoption of AI.
This observation aligns with the analyzes of Samuelson and Zeckhauser (1988) which show that the status quo bias can be circumvented when external pressures (competitiveness, market) become too strong. In our case, the strong collinearity with risk aversion suggests that the latter captures the essential part of the psychological effect related to change. This corroborates the findings of Ben Letaifa (2015), who observes that, in SMEs in emerging contexts, the barriers related to organizational inertia are sometimes less decisive than the perceptions of risks associated with adoption.

H3: The guaranty offered by the CCG has a positive influence on the adoption of AI.
Financial guaranties are a classic lever recognized in economic literature to facilitate access to financing and reduce perceived risks associated with innovation (Hall, 2002). Our observation is in line with studies on public policies supporting innovation in Morocco (El Amrani et al., 2019), which highlight the role of guaranty mechanisms as catalysts for the adoption of digital technologies. This result underscores the importance of institutional mechanisms to remove financial barriers specific to Moroccan SMEs.

H4: The size of the SME is positively correlated with the adoption of AI.
This relationship is widely confirmed in the literature, notably by Cohen and Levinthal (1990) who explain that larger companies have superior organizational and financial capacities, thus facilitating the integration of complex innovations. Specific studies on Moroccan SMEs (Bensaid, 2021) also show that size is a determining factor for the adoption of ICT and AI, thru access to qualified human resources and dedicated budgets. This result thus validates a robust trend, both theoretical and empirical.

H5: AI training has a positive but moderate impact on AI adoption.
The negative and near-significant coefficient raises questions about the effectiveness of current training programs, which contrasts with the classical recommendations from technological skills models (Bresnahan and Trajtenberg, 1995). Some recent studies on developing countries (Khumalo & Mthiyane, 2022) indicate that training must be contextualized and operational to generate a real impact. Our results suggest that AI training in Moroccan SMEs might be too theoretical or insufficiently adapted to real needs, which limits its immediate positive effect. A more targeted training, combined with practical support, thus seems necessary to maximize its influence.

The results obtained thru this econometric model confirm that the adoption of artificial intelligence in Moroccan SMEs is influenced by a multidimensional set of factors, combining individual variables (risk aversion), organizational variables (size, sector), financial variables (CCG guarantee), and contextual

variables (training). These conclusions call for a holistic approach in the design of public policies and business strategies aimed at promoting digital transformation. In particular, institutional support thru guaranty mechanisms and the development of innovation ecosystems tailored to Moroccan specificities appear essential. Furthermore, the integration of training programs within a broader framework of technical and financial support is recommended to maximize the impact of investments in human capital.

5.3. Recommended integration steps (roadmap)

The integration of artificial intelligence (AI) in Moroccan SMEs must be part of a structured and progressive approach, going beyond mere technological transfer to encompass a profound organizational transformation. The first phase, focused on preparation, involves a comprehensive internal diagnosis, raising awareness among leaders and teams, as well as a rigorous audit of available data to precisely identify needs and opportunities. Next comes the experimentation phase, where targeted pilot projects, generally of short duration (less than six months), allow for the evaluation of actual costs and benefits, while adjusting methods based on the results obtained. The third deployment phase focuses on the gradual integration of validated AI solutions, supported by continuous employe training and the establishment of key performance indicators (KPIs) such as the correct prediction rate or cost savings, ensuring rigorous monitoring of impacts. Finally, the optimization phase aims to continuously improve the models, extend the use of AI to other business processes, while ensuring constant technological and regulatory monitoring to anticipate industry developments. This roadmap is based on lessons learned from international experiences, notably in Singapore, Estonia, or Israel, where the successful integration of AI results from a national strategy combining adapted infrastructures, ambitious training programs, relevant tax incentives, and agile regulation. For Morocco, adopting such a holistic approach is essential in order to maximize the economic impact of AI, while reducing the digital divide and ensuring effective inclusion of SMEs in the digital transformation.

Phase 1: Preparation o Comprehensive internal diagnosis o Awareness of leaders and teams
Audit of available data

Phase 2: Experimentation o Targeted pilot projects (duration < 6 months) o Cost/benefit evaluation o Adjustment of methods

Phase 3: Deployment o Gradual integration of validated AI solutions o Continuous training Implementation of AI KPIs (e.g., correct prediction rate, savings achieved)

Phase 4: Optimization o Continuous improvement of models

The integration of AI in Moroccan SMEs cannot be a simple technological transfer: it requires a profound organizational adaptation, skill enhancement, and structured financial support. International experiences (Singapore, Estonia, Israel) show that a national strategy combining infrastructure, training, tax incentives, and agile regulation is essential to maximize the economic impact of AI and reduce the digital divide.

Overall, the majority of the validated hypotheses are based on solid theoretical foundations and are corroborated by international and Moroccan empirical literature. The observed gap in training highlights a specific challenge in the Moroccan context, prompting a rethinking of skills development strategies to accelerate the effective adoption of AI in SMEs.

Thus, this study contributes to enriching the literature on technological innovation in emerging countries by offering a fine and contextualized empirical analysis, useful for both researchers and Moroccan practitioners and decision-makers.

6.GENERAL CONCLUSION

This study offers an in-depth analysis of the challenges related to the adoption of artificial intelligence by Moroccan SMEs, revealing both promising opportunities and complex challenges. Our results highlight the need for a multidimensional approach to understand and facilitate this technological transition in an emerging economic context.

The research confirms the relevance of traditional conceptual frameworks of innovation, while highlighting the need to adapt them to the specific context of Moroccan SMEs. The Schumpeterian theory of creative destruction and the Resource-Based View approach remain valid, but they must integrate behavioral and institutional variables to fully explain the dynamics of technological adoption. Our study notably demonstrates how risk aversion can paradoxically become a catalyst for AI adoption when it is associated with appropriate support mechanisms.

The empirical results suggest several priority areas for intervention by policymakers and economic actors:

Firstly, the development of hybrid financial instruments appears as a sine qua non condition to overcome investment barriers. Data shows that SMEs benefiting from public guaranties have an adoption rate 3.5 times higher than average, highlighting the effectiveness of these mechanisms.

Secondly, human resource training must be rethought to focus on directly applicable operational skills. Our analyzes reveal that traditional theoretical training has a limited impact without continuous practical support.

To accelerate the digital transformation of Moroccan SMEs, we propose a roadmap articulated around four pillars:

The strengthening of regional innovation ecosystems, with a particular focus on the development of sectoral clusters and the creation of bridges between universities and businesses.

The establishment of suitable regulatory frameworks, including regulatory sandboxes and certification labels to guide SMEs in their adoption of AI.

The development of frugal technological solutions, specially designed for the specific constraints of Moroccan SMEs.

The establishment of integrated support programs, combining financial assistance, practical training, and technical assistance.

This research opens several avenues for further work. A more in-depth investigation of differentiated sectoral dynamics could refine our recommendations. Similarly, a longitudinal analysis would allow for a better understanding of the evolution over time of technological adoption processes. Finally, an international comparison with other emerging economies could reveal best practices that are transferable to the Moroccan context.

In conclusion, this study emphasizes that the successful adoption of AI in Moroccan SMEs does not solely depend on technological factors, but on a subtle balance between organizational innovations, behavioral adaptations, and institutional reforms. The realization of the full potential of AI will require enhanced collaboration between the public and private sectors, as well as a tailored approach that takes into account the diversity of the Moroccan entrepreneurial landscape.

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