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Introduction

The global wine industry represents a fascinating paradox: it is an economic sector deeply rooted in millennia of tradition, artisanal craftsmanship, and a profound connection to terroir, yet it operates within a modern, dynamic, and hyper-competitive global marketplace (Anderson & Pinilla, 2022). This industry operates on a vast global scale, with a market value of approximately $340 billion (Anderson & Pinilla, 2022). For many traditional wine-producing nations, it constitutes a cornerstone of the rural economy and export revenues, while in key growth markets, it fuels dynamic retail, hospitality, and digital commerce sectors. Thus, beyond being a cultural ambassador, the industry also functions as a significant economic engine and a barometer of changing consumer lifestyles. A key contemporary trend is the marked shift towards premiumization and a growing appreciation for sustainability and authenticity, which is reshaping market dynamics (Bruwer et al., 2021). Concurrently, the industry is undergoing a profound digital transformation, leveraging technologies from precision agriculture to blockchain to enhance traceability, efficiency, and consumer engagement (Klerkx et al., 2019). However, this enduring industry faces a confluence of unprecedented challenges that threaten its traditional models and long-term viability. Climate change poses an existential threat to established viticultural maps, with rising temperatures and extreme weather events jeopardizing grape yields and profiles in iconic regions (Jones et al., 2005). Simultaneously, the industry grapples with shifting consumer demographics—most notably the rise of Millennial and Generation Z consumers who prioritize experiences, authenticity, digital engagement, and ethical production over inherited brand loyalty (Bruwer et al., 2021). Furthermore, global supply chains have become increasingly complex and vulnerable, while competitive pressure intensifies not only from traditional rivals but also from new beverage categories. These multifaceted challenges demand a strategic response that honors the industry's' heritage while boldly embracing transformation.

Amidst these pressures, a profound opportunity emerges: the strategic application of innovation as the central driver for sustainable development, market growth, and competitive resilience. The trajectory of the wine industry's future is increasingly being charted not in the cellar alone, but in the vineyard through precision agriculture, in the packaging through eco-design, in the supply chain through blockchain, and most visibly, in the marketplace through digital and experiential marketing (Klerkx et al., 2019). Innovation, therefore, is no longer a peripheral activity for leading firms but a core strategic imperative. It is the critical mechanism through which the industry can reconcile its cherished traditions with the demands of the 21st century, ensuring environmental stewardship, economic prosperity, and social relevance. In this doctoral study, it is postulated that unpacking the multifaceted nature and impacts of innovation across the wine value chain, particularly where it intersects with critical growth markets, constitutes a core requirement for delineating sustainable development trajectories in the global wine sector.

The importance of innovation manifests across three critical, interconnected domains that form the pillars of this research. First, innovation is paramount for environmental sustainability and eco-efficiency. The wine industry, as an agricultural and manufacturing sector, has a significant environmental footprint involving water use, chemical inputs, energy consumption, and packaging waste (Christ & Burritt, 2013). Technological and process innovations, often encapsulated in concepts like Agriculture 4.0, offer pathways to a "win-win" scenario where ecological performance and economic efficiency are enhanced simultaneously (Muscio et al., 2017). A case in point is that the deployment of precision viticulture tools, such as IoT-based monitoring sensors, aerial drones, and data-driven analytical frameworks, facilitates the operationalization of Cleaner Production (CP) initiatives. These allow for the precise application of water and fertilizers, reducing runoff and pollution while optimizing resource use and crop quality (Stasi et al., 2016). This digital transformation for eco-innovation represents a proactive shift from reactive End-of-Pipe (EoP) solutions, fundamentally aligning operational excellence with environmental responsibility and

responding to both regulatory pressures and a growing consumer demand for sustainably produced wines (Schäufele & Hamm, 2017).

Second, innovation is crucial in sales and marketing channel strategy, especially when navigating culturally and technologically distinct foreign markets. The linear, relationship-driven channel model dominant in Old World regions (relying on Ho.Re.Ca. [Hotels, Restaurants, Cafés] and specialized retail) clashes with the integrated, platform-centric digital ecosystems of markets like China (Zhang & Benyoucef, 2016). Here, consumer journeys for discovery, evaluation, purchase, and post-purchase sharing are seamlessly woven into social commerce digital platforms like Douyin (TikTok) and Xiaohongshu (Little Red Book) (Asia Beverage Media Group, 2021). For international wine enterprises, market success does not depend on the superficial localization of existing marketing collateral, but rather on a more profound process of digital acculturation—that is, the strategic embedding into these distinctive digital ecosystems. This requires innovating in content format (e.g., live-streaming, short-form video), partnership models (e.g., Key Opinion Leader collaborations), and commerce integration (e.g., in-app mini-programs). Innovation in channel strategy is thus a non-negotiable prerequisite for visibility, brand building, and ultimately, market share in the world's most dynamic consumer markets.

Third, and integrally linked to channel strategy, innovation is vital for product differentiation and demand creation in new markets, where traditional terroir narratives may not resonate fully. Food innovation is crucial for food companies in order to produce healthier, safer, and more convenient foods. However, there is a segment of consumers reluctant to accept new foods. This attitude is even more important when those novelties are developed in products such as wine that have habitually relied on heritage and traditional production as their main competitive advantage (Rabadán, 2021). Wine is a complex product, and, for this reason, consumer wine preferences are influenced by a wide range of factors from the emotional and social to intrinsic quality factors (Lockshin & Corsi 2012; Bernabéu et al., 2013; Niimi et al., 2019; Rabadán, 2021). The importance attributed to each quality factor, from origin to wine barrel aging,

depends on consumer involvement with the product (Lockshin et al., 2006; Rabadán, 2021), but also on individual attitudes that appear as a result of social background (Nguyen et al., 2019). Hence, aligning innovation initiatives with local consumer values (a practice herein referred to as innovation alignment) functions as a crucial driver for activating demand and achieving a sustainable premium market stance.

Despite the acknowledged centrality of innovation, significant and multifaceted gaps persist at the nexus of theory and practice, which this collection of papers seeks to address. The literature on innovation in the wine industry, while rich, often remains siloed (Rabadán, 2021) and exhibits several specific limitations that hinder a holistic understanding.

From a technology-driven and supply-side perspective, a critical gap exists in understanding the role of digital transformation as a strategic enabler of eco-innovation in traditional industries like viticulture. While research on Industry 4.0 and environmental innovation is growing, most studies are confined to manufacturing or high-tech contexts, failing to capture the unique dynamics of agriculture and its fragmented, biology-dependent supply chains (Klerkx et al., 2019). Furthermore, Agriculture 4.0 has often been treated merely as a technological extension of Industry 4.0, rather than as a distinct transformation pathway. More importantly, prior works frequently emphasize technological or environmental outcomes in isolation, overlooking how digital transformation can underpin strategic differentiation and competitiveness (Ponte et al., 2023). This leaves a gap in empirical evidence on whether and how digital adoption (e.g., Agriculture 4.0) fosters proactive eco-innovation (Cleaner Production) and supports a “win-win” sustainable differentiation strategy in premium markets.

From a consumer behavior and demand-side perspective, research on innovation adoption in key growth markets like China suffers from its own set of theoretical and empirical shortcomings. First, as Rabadán (2021) stated: within wine attributes, wine makers should pay special attention to the type of wine, the wine barrel aging, and the brand image as these are the key attributes considered by this consumer segment in the

purchasing process. Wine makers should also consider that consumer segments eager to try innovative wines exist; however, not all of them are open to the same kinds of innovations, and wines including specific innovations intended for specific consumers segments would need to be developed (Rabadán, 2021). Second, the psychological mechanisms through which innovations influence behavior remain underspecified. While frameworks like the Theory of Planned Behavior (TPB) are applicable, the specific role of Perceived Value as a central mediating mechanism translating innovation attributes into purchase intention has been largely overlooked in wine innovation literature. Third, existing studies rarely account for the contingent nature of innovation adoption in a nuanced way. Although demographic moderators are theoretically justified (e.g., through Diffusion of Innovation theory's adopter categories), they are seldom empirically tested in integrated models that account for both psychological and sociological factors, leading to over-reliance on conventional segmentation wisdom.

A further, overarching gap exists in the integrated analysis that directly contrasts the innovation capabilities and strategies of incumbent producers (the supply-side) with the specific innovation demands and channel behaviors of consumers in key growth markets (the demand-side). Few studies offer a triangulated, data-driven assessment of how the internal trajectories and constraints of traditional wine firms align—or, more often, misalign—with the external realities of digitally advanced, consumer-driven markets. This fragmented understanding leads to a key theoretical and practical shortcoming: an inability to systematically diagnose the precise points of strategic misalignment in market entry strategies. Recent knowledge suggests that innovations considered too radical could face rejection even among more pro-innovation consumers. In this regard, specific studies about consumers' acceptance of nontechnological innovations, including marketing and organizational innovations, should be developed (Rabadán, 2021).

To systematically address these interconnected gaps, this dissertation is structured around three sequential research questions. First, from the supply-side perspective, how

does the adoption of digital technologies (Agriculture 4.0) influence the environmental innovation strategies of incumbent wine producers, and does it enable a 'win-win' outcome that enhances both eco-innovation and competitive market positioning? Second, shifting to the demand-side, how do different dimensions of wine innovation (technological, process, packaging, conceptual) shape consumer purchase intentions in a key growth market, through what psychological mechanism does this influence occur, and how do consumer demographics moderate these relationships? Finally, integrating both perspectives, what specific strategic misalignments exist between the innovation capabilities of traditional producers and the expectations of the new market, what factors perpetuate this disconnect, and what integrated strategic framework can bridge it to enable successful market entry? This progression from internal capabilities to external demand, and ultimately to strategic synthesis, forms the core investigative arc of the research.

Accordingly, the research design adopts a tripartite structure, comprising three sequential articles that are cognizant of their interdependence. This framework facilitates a systematic exploration of the interconnected gaps and core questions. Each article is designed to tackle a specific facet of the overarching research problem, collectively forming a comprehensive investigative arc from internal capabilities to external demand and, finally, to strategic synthesis.

Paper 1, "Digital Transformation for Eco-Innovation: Evidence from Agriculture 4.0 Adoption in Wine Firms", directly addresses the first research question concerning the supply-side. It investigates how digital technology adoption influences environmental strategy and competitive positioning (Muscio et al., 2017; Stasi et al., 2016). By analysing survey data from 387 Italian wine firms, this paper provides empirical evidence on the firm-level determinants and outcomes of technological innovation. Its findings confirm that adopting Agriculture 4.0 technologies is a significant driver for proactive Cleaner Production strategies, moving beyond reactive End-of-Pipe solutions, and is positively associated with competitive upgrading into premium markets (Ponte et al., 2023). However, it also uncovers systemic barriers—high costs, knowledge gaps,

and insular collaborative networks—that limit the full potential of this digital-eco-innovation nexus, thereby addressing a critical gap in literature focused on traditional industries (Klerkx et al., 2019).

Paper 2, "How Does Innovation Shape Wine Demand in China?" shifts focus to answer the second research question on the demand-side. It develops and tests a multidimensional innovation framework to overcome the limitation of treating innovation as a monolithic construct (Dewan et al., 2025; Yuan et al., 2025). Utilizing a survey of 2,016 Chinese consumers, the paper elucidates how distinct innovation dimensions (Technological, Process, Packaging, and Conceptual) differentially influence Purchase and Recommendation Intention. Crucially, it identifies Perceived Value as the central psychological mechanism mediating this relationship—a link previously underexplored in wine literature. Furthermore, it empirically validates the moderating role of demographics, revealing that older and female consumers are key receptive segments, thus providing nuanced insights beyond conventional market wisdom and directly responding to calls for more contingent models of innovation adoption.

Paper 3, "Navigating New Terroirs: An Integrated Analysis of Italian Wine Firms' Channel Strategies, Innovation Trajectories, and Market Entry Potential in China", performs the crucial integrative work to answer the third, synthetic research question. It directly juxtaposes the supply-side data from Paper 1 with the demand-side insights from Paper 2, a triangulation method rarely employed in prior studies. This comparative analysis empirically diagnoses the specific strategic misalignments: a clash between linear, offline channel models and China's integrated digital ecosystems (Zhang & Benyoucef, 2016), and a divergence between product-centric R&D and value-driven consumer preferences (Peng & Huang, 2025). To explain the persistence of this disconnect, Paper 3 delves deeper, using Structural Equation Modeling on the Italian firm data to reveal that internal organizational inertia—driven by perceived barriers and deep embeddedness in local networks—statistically predicts resistance to change. Finally, synthesizing these cross-perspective findings, the paper constructs an original

integrated strategic framework. It posits that bridging the identified gap and achieving successful market entry, as implied in the dissertation's title focusing on market outcomes, necessitates a dual transformation: Digital Acculturation for channel integration and Innovation Alignment for product-value resonance.

Collectively, this three-paper structure meticulously traces the pathway from Digital Transformation (Paper 1), through its interplay with multi-faceted Innovation on consumer perception (Paper 2), to the resultant strategic imperatives for achieving positive Market Outcomes (Paper 3). This journey provides a holistic, evidence-based understanding of innovation's role. It demonstrates that for the wine industry to achieve sustainable development—encompassing environmental integrity, economic resilience, and social relevance—innovation must be understood not as a series of discrete projects but as a strategic capability. This capability must be consciously developed within firms, carefully aligned with the value systems of target consumers, and deftly deployed through the digital architectures that define modern commerce. This doctoral research contributes both to academic theory, by bridging siloed literature streams and offering new integrated frameworks, and to industry practice, by providing actionable insights for firms, consortia, and policymakers navigating the complex but essential journey towards a sustainable and innovative future for wine.

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Chapter 1 Digital Transformation for Eco-Innovation: Evidence from Agriculture 4.0 Adoption in Wine Firms

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Abstract

Firms face a fundamental strategic dilemma: how to align digital transformation with environmental sustainability while maintaining competitive advantage. Drawing on the eco-innovation and green business strategy literature, this paper investigates how Agriculture 4.0 technologies act as enablers of sustainability strategies. Using original survey data from 387 Italian wine firms, we examine the relationship between digital adoption, eco-innovation, and competitive positioning within premium segments, reflecting a "win–win" sustainable differentiation strategy. We operationalize eco-innovation through Cleaner Production (proactive) and End-of-Pipe (reactive) strategies. Results show that Agriculture 4.0 adoption is strongly associated with Cleaner Production with precision agriculture, weather monitoring, and management software emerge as the most effective digital tools to foster eco-innovation, while blockchain and big data remain limited due to capability gaps. Importantly, digital adopters are more likely to compete in premium and ultra-premium market segments, suggesting that digital transformation enables sustainable differentiation strategies.

Keywords: Agriculture 4.0, eco-innovation, digital transformation, environmental sustainability, cleaner production, wine industry

1 Introduction

A central theme in sustainability research concerns how firms can simultaneously achieve environmental improvements and competitive advantage. This "win–win" paradigm has been widely debated in the eco-innovation and business strategy literature (Porter & van der Linde, 1995; Ambec & Lanoie, 2008; Boakye et al., 2020; Passaro et al., 2023). Yet, the role of digital transformation as a strategic enabler of eco-innovation remains underexplored, particularly in traditional industries. While environmental regulations and market pressures demand substantial investments in cleaner technologies and processes, firms fear that these investments may compromise their competitive position through increased costs and reduced operational flexibility (Blasi et al., 2025; De Haas et al., 2025).

Recent studies highlight that digital technologies can improve efficiency and enable environmental upgrading, contributing to the so-called *twin transition* (digital + green) (Montresor & Vezzani, 2023; Neligan et al., 2023). Industry 4.0 and Agriculture 4.0 are closely interconnected through their shared foundation in advanced digital technologies (Klerkx et al., 2019). Industry 4.0 introduced the concept of smart, interconnected systems in manufacturing, which has directly influenced the evolution of Agriculture 4.0. In agriculture, these technologies enable precision farming, automated machinery, and real-time data analytics, promising to lead to increased efficiency, sustainability, and productivity (Kazancoglu et al., 2024). Essentially, Agriculture 4.0 aims to transform traditional farming into a data-driven, technology-enhanced practice (Liu et al., 2020). However, empirical evidence on whether this promise holds true in practice remains limited, particularly for traditional industries that face structural constraints in adopting new technologies.

In fact, while a growing body of research has explored the intersection of Industry 4.0 and environmental innovation (e.g., Ghobakhloo, 2020; Montresor & Vezzani, 2023; Neligan et al., 2023), most of these studies are confined to manufacturing or high-tech contexts and fail to capture the specific dynamics of agriculture. Agriculture 4.0 has

often been treated as a technological extension of Industry 4.0, rather than as a distinct transformation shaped by biological processes, climatic uncertainty, and fragmented supply chains (Klerkx et al., 2019; Rose et al., 2021). Consequently, the literature provides only partial insights into how digitalization can foster eco-innovation in resource-dependent, low-margin sectors such as agriculture and viticulture (Boakye et al., 2020; De Haas et al., 2025). Moreover, prior works on eco-innovation largely emphasize technological or environmental outcomes in isolation, overlooking how digital transformation can underpin strategic differentiation and competitiveness (Ponte et al., 2023).

This study addresses this gap by examining how Agriculture 4.0 adoption affects eco-innovation in the wine industry. As a sector rooted in tradition but under pressure from climate change, regulatory tightening, and consumer demand for sustainable products (Santini et al., 2013; Schäufele & Hamm, 2017), wine firms illustrate the challenge of balancing competitiveness and environmental sustainability. Their reliance on quality and reputation makes them an ideal setting to examine sustainable differentiation strategies.

Using original survey data from 387 Italian wine firms, we perform a multi-layered empirical analysis to examine the relationship between Agriculture 4.0 adoption and eco-innovation outcomes. Our approach integrates different levels of analysis to capture both breadth and depth: First, we analyze a composite eco-innovation index reflecting the firm's overall capacity to develop and implement green technologies. This index combines process innovations aimed at improving environmental performance, including both Cleaner Production (CP) and End-of-Pipe (EoP) solutions. Second, we conduct a technology-specific heterogeneity analysis, disaggregating Agriculture 4.0 into its component technologies (e.g., precision agriculture, IoT sensors, weather monitoring, blockchain, and specialized software). This allows us to identify which technologies are the primary drivers of eco-innovation. Finally, we explore the relationship between Agriculture 4.0 adoption and firms' market positioning, testing whether digitalization supports strategic differentiation into premium and ultra-

premium product segments. This adds a competitive dimension to the sustainability analysis.

This study makes several important contributions to the literature on environmental strategies, industrial policy, innovation, and eco-innovation. First, it provides empirical evidence that technological upgrading can resolve rather than exacerbate the tension between environmental and competitive objectives, demonstrating that Agriculture 4.0 technologies enable proactive eco-innovation while supporting competitive upgrading toward premium market segments. Second, it shows that different digital technologies have heterogeneous impacts on eco-innovation, offering actionable guidance for firms and policymakers on where to focus technological investments to achieve the "twin transition". Third, it fills a critical gap by extending the eco-innovation and Industry 4.0 debates to the agricultural domain, focusing on the wine industry as a paradigmatic case of a traditional sector undergoing digital transformation.

The paper is structured as follows. Section 2 sets the theoretical background by reviewing the literature on the sustainability-competitiveness tension, Agriculture 4.0, and eco-innovation. Section 3 presents the research framework, data collection process, and variable measurement strategy. Section 4 reports the econometric results, including the core models, technology-specific heterogeneity analysis, and the relationship between Agriculture 4.0 adoption and market positioning. Section 5 discusses findings and proposes the implications for theory, policy, and management. Section 6 concludes by highlighting the study's contributions, limitations, and avenues for future research.

2 Theoretical Framework

2.1 The Sustainability-Competitiveness Tension

Porter & Van der Linde (1995) provide the theoretical foundation for understanding the relationship between environmental themes and firm competitiveness, proposing that environmental regulations can trigger innovation that compensates for compliance

costs. Ambec & Lanoie (2008) found through a systematic review that green innovation can offset the burden of environmental regulations by reducing costs and enhancing market competitiveness. De Haas et al. (2025) further validated this viewpoint and found that digital technology enables businesses to obtain market premiums through innovation while meeting strict environmental regulations. While some studies support this "win-win" perspective, others find evidence of trade-offs, particularly in the short term and for firms with limited resources (Palmer et al., 1995; Ambec & Lanoie, 2008).

In the eco-innovation literature, CP innovations are typically associated with proactive, cost-saving, and strategic sustainability strategies, while EoP innovations are often reactive compliance measures (Frondel et al., 2007; Horbach et al., 2012). This distinction aligns closely with a branch of business strategies with a focus on green strategies as either proactive or reactive responses to environmental pressures. Environmental upgrades may require substantial changes to production processes, potentially disrupting established routines and requiring new capabilities or resources that firms may lack (Teece et al., 1997; Neligan et al., 2023).

In recent years, many studies have noticed the tension and operational difficulties that may arise from corporate green innovation transformation. For example, Boakye et al. (2020) pointed out through data analysis of multinational corporations that environmental compliance costs pose significant resource constraints for small and medium-sized enterprises, especially in low-profit industries such as agriculture. This means that there are significant industry heterogeneities in the compensation effect of environmental innovation. This makes specific industry research on wine valuable (Sun et al., 2020). On the one hand, the EU regulatory environment is tightening, and agriculture is considering stricter control over pesticides, land use, and water resources. Traditional agricultural and wine regions are also facing sustainable risks in terms of production capacity and cultivation due to climate vulnerability in forests[1]. On the other hand, sustainable agricultural products and particularly wine, as a high-premium

1 https://eos.org/articles/climate-change-threatens-70-of-winemaking-regions

product, has greater room for industrial innovation and can avoid negative technological crowding-out effects[2].

Industry and Agriculture 4.0 technologies offer a potential pathway out of this dilemma by enabling firms to achieve environmental improvements through enhanced efficiency. Digital technologies can optimize resource utilization, reduce waste, and enable real-time monitoring and control of environmental parameters. Unlike traditional "end-of-pipe" environmental solutions that add costs without improving productivity, Industry 4.0 technologies can deliver environmental benefits as a byproduct of improved operational efficiency (Ghobakhloo, 2020).

2.2 Agriculture 4.0 and Environmental Dimensions

The adoption of Industry 4.0 technologies in traditional industries can be approached through the Technology-Organization-Environment (TOE) framework, which posits that technology adoption results from the interaction between technological characteristics, organizational capabilities, and environmental pressures (Tornatzky et al., 1990; Nguyen et al., 2022). This theoretical lens proves particularly valuable for analyzing how agricultural producers evaluate and implement digital solutions for eco-innovation and environmental sustainability.

Within the agricultural context, the technological dimension encompasses the functional capabilities of Agriculture 4.0 systems, including resource optimization through precision agriculture and real-time monitoring via IoT sensors. In the case of viticulture, this also involves the integration of wine cultivation technologies, blockchain-based traceability systems, and data-driven decision-making tools, which

2https://www.bain.com/about/media-center/press-releases/20252/fine-wine-market-and-restaurants-hit-58-billion-in-2024--reinforcing-their-role-as-a-pillar-of-global-luxury/

jointly support sustainable production practices and transparent supply chains (Adamashvili et al., 2024; Mulligan et al., 2024).

The organizational dimension comprises enterprise characteristics such as firm size, human capital development, and winemakers' technical expertise and innovation orientation. Employee training, the professional knowledge of winemakers, and their scientific and innovation-driven mindset play a critical role in determining the extent to which Agriculture 4.0 solutions can be effectively adopted and scaled. Moreover, the internal organizational design, including digital readiness and managerial structure, may be associated with the firm's ability to integrate new technologies into existing production processes (Dayıoğlu & Turker; 2021).

The environmental dimension encompasses external drivers including consumer sustainability preferences, competitive pressures, and regulatory compliance requirements (Adamashvili et al., 2024). Particularly in the wine industry, the growing demand for certified sustainable products, the density of industry competitors, and environmental regulations specific to viticulture and agrifood supply chains intensify the need for firms to adopt innovative solutions that ensure both compliance and market competitiveness (Giacomarra et al., 2016).

By expanding the TOE framework to the Agriculture 4.0 context, this study conceptualizes digital adoption as the result of multi-level interactions among technological potential, organizational capabilities, and environmental demands. This perspective allows for a more nuanced understanding of why some firms are able to transform digital investment into eco-innovation outcomes while others lag behind. For instance, while precision agriculture may demonstrate technical feasibility, its deployment depends critically on organizational readiness (financial resources, technical competencies) and environmental context (regulatory mandates, market incentives).

Agriculture 4.0 technologies facilitate eco-innovation through multiple pathways that enhance both environmental performance and operational efficiency (Dayıoğlu & Turker, 2024). First, these mechanisms include precision agriculture technologies

which enable optimal application of inputs such as water, fertilizers, and pesticides, reducing both environmental impact and input costs. GPS-guided tractors, variable-rate application systems, and soil sensors allow farmers to apply inputs only where and when needed, minimizing waste and environmental damage (Zhang et al., 2002; Getahun et al., 2024). Second, IoT sensors and monitoring systems provide real-time data on environmental conditions, enabling rapid responses to environmental problems and preventive measures to avoid resource waste (Madakam et al., 2015; Pandey et al., 2025). In viticulture, sensors can monitor soil moisture, weather conditions, and plant health, enabling precise irrigation and pest management decisions. Third, data analytics and artificial intelligence can optimize complex production decisions that balance multiple objectives, including environmental and economic goals (Zamani et al, 2023). For example, machine learning algorithms can identify patterns in historical data that reveal opportunities for simultaneous improvements in environmental and economic performance. Fourth, blockchain and traceability systems can support environmental certification and sustainable supply chain management, enabling firms to capture price premiums for sustainable products while improving environmental monitoring and control (Mulligan et al., 2024).

2.3 Agriculture 4.0 and Eco-Innovation

Following Rennings' (2000) "double externality" problem, eco-innovation requires strong drivers - regulation, market demand, or internal strategic orientation. Agriculture 4.0 provides firms with tools to overcome such barriers by integrating efficiency gains with sustainability, offering a strategic pathway to align competitiveness and environmental responsibility. The Digital Transformation-Environmental Performance (DTEP) model emphasizes the role of data-driven technology in improving corporate environmental performance (Song et al., 2024). This model demonstrates that digital transformation enhances environmental performance through "green technology upgrading", "increasing external attention", and "enhancing internal management control". The framework incorporates measurement factors such as employee training

and inter-company cooperation, providing a comprehensive understanding of how digital technologies can stimulate eco-innovation. Integrating the DTEP model into the TOE framework enables a comprehensive view of how digital tools facilitate eco-innovation through both technological and organizational pathways.

Eco-innovation encompasses the development and implementation of new or significantly improved products, processes, marketing methods, or organizational structures that reduce environmental impact relative to relevant alternatives (Kafetzopoulos et al., 2024). The motivation for enterprises to engage in eco-innovation emerges from multiple dimensions including regulatory pressures, environmental management systems, market turbulence, and research and development activities, ultimately affecting both corporate reputation and financial performance (Shao et al., 2020). Research demonstrates that eco-innovation is driven not only by internal capabilities and external regulations but also significantly enhances corporate reputation and performance, though its effects vary depending on cultural context, economic background, and innovation type (Ayoub & Lhuillery, 2024; Kafetzopoulos et al., 2024).

In this context, Agriculture 4.0 acts as a bridge between digital transformation and sustainability transitions. Precision agriculture, IoT sensors, and big data analytics collectively enable firms to implement proactive environmental strategies. This integration allows for a clearer articulation of the conceptual boundaries between the three perspectives. The Porter & van der Linde's (1995) framework defines the underlying strategic tension between environmental and competitive objectives. The TOE framework explains how firms' technological capabilities, organizational readiness, and environmental pressures jointly shape digital adoption decisions. The eco-innovation literature contributes the distinction between proactive (CP) and reactive (EoP) strategies, linking strategic intent and innovation type. Together, these frameworks provide complementary explanations of how digital transformation acts as a mechanism that converts environmental constraints into sources of competitive advantage.

In the wine industry, specifically, Muscio et al. (2017) demonstrate that while the importance of eco-innovation has risen exponentially, several factors concur to firms' performance in eco-innovation. Their results confirm the importance of firms' openness in the innovation process, highlighting the role of internal and external knowledge sourcing. Moreover, the authors find new evidence in support of the positive impact of voluntary certifications (e.g., the ISO 14000) on eco-innovation.

Digital technologies can enhance eco-innovation through several pathways. The data generated by digital systems can reveal previously unknown opportunities for environmental improvement, sparking innovation activities. For example, real-time monitoring of resource flows and environmental parameters can identify inefficiencies and waste streams that were previously invisible. Moreover, digital technologies can reduce the costs and risks of environmental experimentation by enabling virtual testing and simulation. Firms can evaluate eco-innovations using digital twins and modelling systems before committing to full-scale implementation. Finally, digital platforms can facilitate collaboration and knowledge sharing with external partners, including universities, research institutions, and other firms. This enhanced connectivity can accelerate the development and diffusion of environmental eco-innovations (Diaz-Garcia et al., 2015).

In addition, the integration of advanced analytics and artificial intelligence into environmental management processes allows companies to implement proactive strategies. Predictive maintenance and forecasting models, for instance, can anticipate potential failures or resource inefficiencies, enabling interventions before environmental damage occurs. Blockchain technology can also contribute by increasing the transparency and traceability of supply chains, ensuring that sustainability criteria are respected at every production stage. Furthermore, digitalization can support the development of new business models based on circular economy principles, such as product-service systems or collaborative consumption platforms, which inherently reduce environmental impacts. By leveraging these technological advances, firms not

only improve their environmental footprint but also gain strategic advantages in increasingly sustainability-conscious markets (Bigliardi et al., 2022).

2.4 Cleaner Production and End of Pipe technologies

In the context of process innovation, the literature identifies two main types of eco-innovation (Frondel et al., 2007; Rennings et al., 2006): CP and EoP technologies. CP focuses on reducing resource use and pollution at the source by adopting more sustainable production methods or using greener inputs. In contrast, EoP technologies aim to reduce emissions by adding control measures after the production process. While both approaches target reductions in CO_2 and other emissions or waste, CP involves modifying the production process itself, whereas EoP addresses the environmental impacts of production through mitigation and monitoring (Hammar & Löfgren, 2010). According to Frondel et al. (2007), the two differ significantly in terms of adoption drivers: EoP adoption is more influenced by environmental regulations and policy stringency, whereas CP is often motivated by cost savings, broader management strategies, and specific environmental management tools.

CP eco-innovation indicators include:

- Improved energy efficiency
- Reduction or reuse of waste
- Reduction in water consumption
- Reduction or optimization in the use of chemical products
- Innovations in packaging
- Enhanced efficiency in transportation and logistics
- Acquisition of environmental certifications or adherence to sustainability standards

EoP indicators include:

- Improved waste management systems
- Reduction of gas emissions through the use of anti-pollution technologies
- Noise reduction measures
- Enhanced cleaning and washing systems

From a strategic perspective, CP and EoP technologies can be interpreted as expressions of proactive and reactive eco-innovation, respectively (Horbach et al., 2012; Dangelico et al., 2017). Proactive strategies are characterized by a long-term orientation, continuous organizational learning, and cross-functional coordination that embed sustainability into the firm's innovation processes. They often rely on internal R&D, employee training, and collaboration with research or technology partners to develop sustainability-oriented dynamic capabilities (Bossle et al., 2016; Dangelico et al., 2017). Reactive strategies, by contrast, tend to emerge as short-term responses to regulatory pressures, emphasizing compliance and risk mitigation rather than capability development. While both approaches contribute to environmental performance, proactive strategies are more closely associated with innovation-based competitiveness and long-term adaptability, whereas reactive strategies reflect efficiency-oriented adaptation to external constraints.

2.5 Research Framework

We integrate three complementary theoretical perspectives: 1) Porter's hypothesis on innovation offsets; 2) the Technology–Organization–Environment (TOE) framework; and 3) the eco-innovation strategy literature distinguishing proactive and reactive approaches (Passaro et al., 2023). This integration helps in framing Agriculture 4.0 adoption as a strategic choice shaped by technological capabilities, organizational conditions, and environmental pressures. This integration responds to the complexity of eco-innovation in traditional industries such as wine production, where firms must simultaneously address competitiveness, digital transformation, and rising sustainability expectations.

The first perspective, the sustainability–competitiveness tension (Porter & van der Linde, 1995; Ambec & Lanoie, 2008), emphasizes that environmental improvements can generate "win–win" outcomes through cost savings, productivity gains, and enhanced market differentiation. However, the realization of these benefits depends on firms' ability to innovate and reconfigure their production systems (De Haas et al., 2025; Boakye et al., 2020). Agriculture 4.0 technologies provide such opportunities by enabling resource efficiency, precision management, and quality improvements that can reinforce competitive advantage, particularly in premium agricultural sectors.

Second, the TOE framework (Tornatzky et al., 1990) explains how the adoption of Agriculture 4.0 technologies is shaped by technological readiness, organizational capabilities, and external environmental conditions. In the wine industry, this includes the availability and maturity of precision viticulture tools, the firm's human and technical expertise, and the regulatory and market pressures promoting sustainable production (Adamashvili et al., 2024; Mulligan et al., 2024). Agriculture 4.0 adoption thus depends on firms' ability to integrate new technologies into existing routines, align them with organizational structures, and respond to external incentives such as sustainability certifications and evolving consumer preferences.

Third, the data-driven technology–environment–performance (DTEP) model (Song et al., 2024) provides a process-oriented perspective on how digital technologies enhance environmental outcomes by improving monitoring, enabling predictive analytics, and facilitating cross-boundary collaboration. This perspective aligns with recent eco-innovation literature that distinguishes proactive from reactive strategies. Agriculture 4.0 technologies, particularly those enabling real-time monitoring and data-driven decision-making, are well positioned to support proactive, preventive environmental strategies.

Bringing these perspectives together, we propose that Agriculture 4.0 technologies promote eco-innovation through three interrelated pathways: 1) Technological upgrading and resource optimization, where precision and automation reduce inputs, waste, and environmental impacts while improving efficiency, thereby supporting the

"win–win" logic; 2) Technology adoption shaped by technological, organizational, and environmental conditions, consistent with the TOE framework; successful adoption requires organizational readiness, human capital, and responsiveness to regulatory and market pressures; 3) Data-driven environmental innovation processes, consistent with the DTEP model; digital technologies enable firms to evolve from compliance-oriented environmental management to proactive eco-innovation, including circular practices, predictive environmental control, and the development of certified sustainable products.

The wine industry represents an ideal empirical setting for examining these mechanisms. It is a traditional sector rooted in historical production methods but increasingly exposed to regulatory pressures and consumer demand for sustainable products (Vrontis et al., 2016; Ponte et al., 2023). Wine production generates significant environmental impacts, from pesticide and fertilizer use to water consumption, energy-intensive processing, and organic waste generation (Christ & Burritt, 2013), and faces growing regulatory scrutiny, particularly in the European Union (Corsinovi & Gaeta, 2019). At the same time, demand for sustainable wine continues to rise (Schäufele & Hamm, 2017), encouraging firms to invest in environmental improvements.

Meanwhile, intense global competition requires producers to maintain high product quality and cost efficiency, creating a classic sustainability–competitiveness tension (Anderson & Pinilla, 2022). Agriculture 4.0 technologies have become increasingly relevant in this context: precision viticulture tools support site-specific management; IoT sensors enable real-time tracking of environmental conditions; and data analytics assist in optimizing irrigation, harvest timing, and pest management. These innovations provide a unique opportunity to align sustainability with quality and competitiveness.

Finally, Italy, one of the world's largest wine producers, offers a diverse context with both large industrial producers and small family-owned firms. This variation in size, capabilities, and resource endowments allows us to investigate how different types of firms adopt Agriculture 4.0 technologies and translate them into eco-innovation outcomes.

3 Empirical analysis

3.1 Data Collection

The empirical analysis draws on primary data collected through a structured questionnaire survey administered to Italian wineries. The sampling frame was constructed by integrating two complementary databases: the membership list of the Associazione Italiana Sommelier (AIS), which included 2,353 companies in 2024, and the Beverfood company database, which listed 1,020 wineries and wine-related businesses operating in the Italian market. AIS is one of the most prominent Italian associations in the wine and beverage sector, with a membership base primarily composed of wineries engaged in sommelier-related activities and wine promotion. Beverfood, by contrast, is a specialized publisher and data provider that offers comprehensive coverage of firms in the food and beverage industry. Together, these two sources provide a broad and up-to-date representation of the Italian wine industry, encompassing both technologically advanced and more traditional firms, and thus constitute an appropriate sampling frame for studying Agriculture 4.0 adoption and eco-innovation.

From the integrated database, wineries were randomly selected and invited to participate in the survey, which targeted company managers as key informants. Data collection combined a web-based survey with face-to-face interviews. The online questionnaire, administered via the SurveyMonkey platform, was distributed by email and required an average of 21 minutes to complete; this mode yielded 313 completed questionnaires, corresponding to an online response rate of 9.28% relative to the invitations sent. To increase coverage and reduce non-response, an additional 74 interviews were conducted in person at the Vinitaly international trade fair in Verona in 2023, resulting in a final sample of 387 wineries.

As in many firm-level surveys, the response rate is moderate, raising the possibility of non-response bias. We address this concern in several ways. First, the sampling frame integrates two extensive sectoral databases that jointly cover a broad spectrum of Italian

wineries, from small traditional producers to technologically advanced firms, reducing the risk that entire categories of firms were systematically excluded. Second, where observable characteristics are available (e.g., geographic area, company size categories, and presence in AIS vs. Beverfood), respondents do not differ significantly from the underlying population, suggesting that non-response is unlikely to be strongly selective. Third, combining online data collection with face-to-face interviews at a major trade fair helped reach firms less likely to respond to web-based questionnaires alone. Nonetheless, non-response bias cannot be entirely ruled out, and results should be interpreted with this limitation in mind. To mitigate potential biases, the econometric models include controls for the data-collection mode (online survey vs. trade-fair interviews), geographical location, interviewer and company size.

3.2 Variable Measurement

The empirical analysis is based on a set of econometric models aimed at investigating the relationship between Agriculture 4.0 adoption and eco-innovation in the wine industry. The primary dependent variable is eco-innovation. To capture a broad eco-innovation capability, we construct a composite eco-innovation index. This index combines measures of environmental innovation adoption with the firm's capacity to develop and implement green technologies. Specifically, the index accounts for both process innovations CP and EoP solutions, as well as other types of related innovations.

The core econometric model is specified as follows:

$$Y_i = \beta_0 + \beta_1 (\text{Agriculture 4.0})_i + \beta_2 (\text{Controls})_i + \varepsilon_i$$

Where Y_i is the variable representing the underlying eco-innovation capacity.

Dependent variables. We use the following innovation indicators across the models:

- CP innovations: number of CP innovations introduced by the company (maximum = 8).
- EoP innovations: number of EoP innovations introduced by the company (maximum = 4).
- Other innovations: number of other types of innovations introduced by the company (maximum = 8).
- Any innovation: a cumulative variable indicating whether the firm has introduced at least one innovation across any of the above categories (maximum = 20).

These indicators are treated as count variables. Due to the overdispersion present in the data (variance exceeding the mean), we estimate negative binomial regression models[3]. In addition to models based on aggregated innovation measures, we also estimate models for each specific eco-innovation indicator to assess domain-specific effects. Scale items were adapted from previous studies on eco-innovation (Muscio et al., 2017), and pre-tested with company managers and academic experts. Scale reliability and factor structure met conventional thresholds, indicating acceptable internal consistency.

Independent Variables. The key independent variable is the firm's adoption of Agriculture 4.0 (A4.0) technologies. We consider two main measures:

- A binary variable indicating whether the firm has adopted at least one Agriculture 4.0 technology (yes/no).

3 We also tested the models running ordered logit regressions, that are appropriate when the dependent variable represents ordered categories that reflect increasing (or decreasing) levels of the phenomenon of interest. The results fully support the estimations obtained with negative binomial models and are available upon request.

- A count variable ranging from 0 to 10, reflecting the number of different A4.0 technologies adopted.

The 10 Agriculture 4.0 technologies considered in this study are listed below. They are also described in detail in Table 1 (See Table 1, at the end of this chapter.):

1. Precision farming;
2. Internet of Things (IoT);
3. Big Data & Analytics;
4. Robotics and automation;
5. Remote monitoring;
6. Blockchain;
7. Environmental sensors;
8. Weather monitoring systems;
9. Software management tools;
10. Augmented/Virtual Reality (AR/VR).

Finally, our models include several firm-level control variables. Table 1 summarizes the description of all variables adopted in the regression models. Table 2 presents the descriptive statistics.

Table 1 Variables description

[Table 1 around here]

Table 2 Descriptive statistics

[Table 2 around here]

As shown in Table 2, while on average 42% of wine companies have invested in some areas of Agriculture 4.0, in general, they hardly invest in more than one type of technology (1.20 average). The greatest area of investment in Agriculture 4.0 technologies is weather monitoring followed by precision farming and by software management.

4 Results

4.1 Agriculture 4.0 and Eco-Innovation

Results confirm that Agriculture 4.0 adoption is strongly associated with CP strategies, while links with EoP solutions are weaker. This indicates that digital adoption fosters proactive sustainability strategies rather than reactive compliance. As summarized in Table 2, the most frequent eco-innovations concern energy efficiency improvements and the reduction or optimization of chemical inputs. Approximately 36% of firms report having introduced innovations aimed at improving energy efficiency, while 30% have focused on reducing or optimizing chemical usage. Waste reduction and water conservation practices are less frequent, with 20% and 18% of firms reporting initiatives in these areas, respectively. The data also reveal that eco-innovation efforts are often incremental and focused on specific production phases, rather than on comprehensive environmental strategies. This pattern is consistent with prior studies on small and medium-sized enterprises in traditional sectors, where eco-innovation tends to follow a problem-solving logic rather than a systemic transformation approach (Passaro et al., 2023).

Table 3 Areas of companies' innovation

[Table 3 around here]

Figure 1 illustrates the main obstacles to innovation reported by wine firms. On a likert scale ranging from 0=*lowest* to 5=*highest*, the most common barriers include the lack of financial resources, uncertainty about returns on investment, and limited technical knowledge. These constraints suggest that the adoption of Agriculture 4.0 technologies could help overcome some of the typical limitations faced by SMEs by offering solutions that simultaneously improve efficiency and environmental performance.

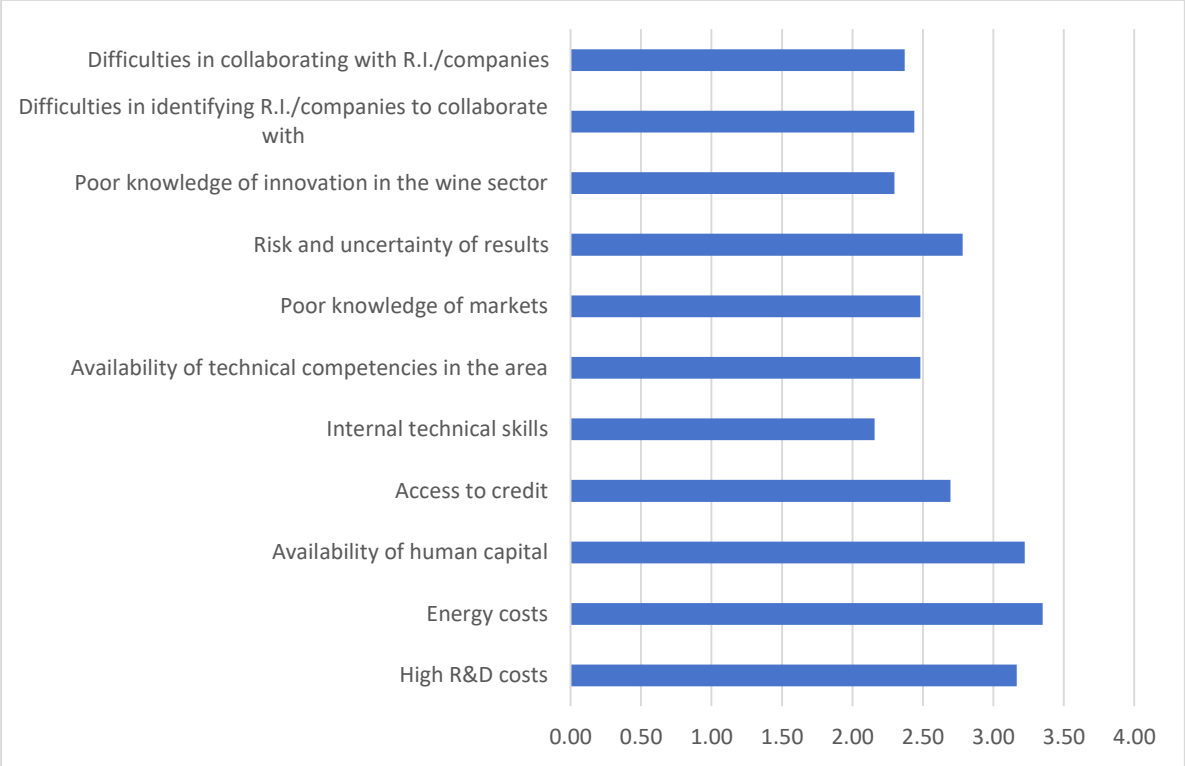

Figure 1 Problems in Innovation (0~5)

4.2 The Relationship between Agriculture 4.0, Environmental Performance and Eco-Innovation

The results presented in Table 3 indicate a strong and positive association between the adoption of Agriculture 4.0 technologies and eco-innovation outcomes. Firms that adopt at least one Agriculture 4.0 technology, such as sensors, drones, automated monitoring systems, or data-driven decision tools are more likely to introduce CP innovations, EoP solutions, and other types of innovation compared to non-adopters.

These technologies appear to make it easier for firms to monitor inputs, reduce waste, optimize vineyard operations, and detect inefficiencies, which in turn facilitates the development of CP practices and other types of eco-innovation.

The extent of Agriculture 4.0 adoption also matters. Firms that implement a broader set of digital tools exhibit higher levels of eco-innovation. This suggests that cumulative adoption creates synergies: for example, combining precision viticulture tools with digital monitoring can improve water control, reduce chemical inputs, and enable more efficient use of labour and machinery. In practice, this means that wineries that progressively digitalize multiple steps in the production chain gain increasing opportunities to reduce environmental impacts.

The results are consistent with existing evidence (e.g., Hammar & Löfgren 2010) showing that absorptive capacity, especially when expressed in terms of R&D units and staff training (Muscio, 2007), supports eco-innovation. Practically, this means that wineries that invest in technical staff, internal knowledge development, and continuous training are better positioned to transform digital information into concrete process improvements. However, the findings also show that Agriculture 4.0 adoption contributes to eco-innovation even in firms without formal R&D units, highlighting that digital tools can partially substitute for internal research capabilities by providing ready-to-use data and operational support.

The effects, however, are not uniform. The strongest impacts are observed for CP innovations. This is intuitive: digital technologies are particularly useful for optimising vineyard and cellar processes, for example by adjusting irrigation, managing fertilizer use, monitoring energy consumption, or improving fermentation control. These are areas where data-driven insights can quickly translate into more efficient and environmentally friendly practices. In contrast, their association with EoP innovations is weaker. This is expected because EoP solutions, such as filtration equipment or wastewater treatment, often depend more on specialized machinery and regulatory compliance than on digitalization.

Overall, these results imply that Agriculture 4.0 technologies can help wineries lower the practical and organizational barriers that typically prevent them from adopting eco-innovations. By making production conditions more transparent and measurable, digital tools simplify environmental management decisions and help firms detect where improvements are possible. However, since adoption rates remain low, many wineries may still face obstacles such as limited digital skills, high investment costs, or inadequate connectivity in rural areas. This indicates that targeted policies, such as subsidies for digital equipment, training programmes for vineyard managers, or investments in broadband infrastructure, could significantly enhance the sector's capacity to engage in sustainable innovation.

Table 4 A4.0 and eco-innovation

[Table 4 around here]

4.2.1 Control Variables and Firm Characteristics

Based on the results presented in Table 3, several firm-level characteristics emerge as important determinants of eco-innovation capacity in the wine industry, complementing the core relationship with Agriculture 4.0 adoption. The presence of internal R&D units shows a robust and consistent positive association with all forms of eco-innovation. In practical terms, wineries with dedicated R&D or technical offices are better equipped to identify environmental problems, test alternative production practices, and integrate new technologies into vineyard and cellar operations. Such structures provide firms with the in-house expertise needed to turn environmental objectives into concrete innovations, for example, by redesigning fermentation processes, experimenting with lower-impact treatments, or developing new resource-efficient workflows.

Recent employee training also emerges as a significant predictor of eco-innovation performance. This highlights the complementary role of human capital development in sustainability transitions. In practice, training programs expose winemakers and

technical staff to updated agronomic practices, digital tools, and environmental management techniques, enabling them to more effectively use new technologies and to recognize opportunities for reducing inputs or emissions. The consistency of this effect across different innovation types suggests that skilled and continuously updated personnel are essential for converting technological opportunities into environmental improvements.

Collaboration with other companies shows particularly strong and consistent positive effects across all model specifications. This finding underscores the importance of inter-organizational knowledge flows for environmental innovation. For many wineries, especially SMEs, eco-innovation involves challenges that exceed their internal capabilities. Partnerships with peer firms allow them to share experiences about sustainable viticulture, jointly test technological solutions, or learn from early adopters. Such collaborations can facilitate access to tacit knowledge, help spread best practices, and reduce the risks and costs associated with environmental innovation. The significance of collaborative activities also extends, though more variably, to relationships with technical service providers, indicating that different external partners may contribute complementary forms of expertise, for example, precision agriculture consultants offering digital know-how, while peer wineries provide operational insights.

Notably, traditional firm characteristics such as size and local industry concentration exhibit limited explanatory power. This suggests that eco-innovation capacity in the wine sector depends less on structural attributes and more on strategic choices concerning knowledge development, staff capability, and participation in collaborative networks. In practical terms, even small wineries, often assumed to face structural disadvantages, can achieve strong environmental performance when they invest in training, build partnerships, and selectively adopt new technologies.

4.3 Technology-Specific Heterogeneity Analysis

Table 4 presents the heterogeneity analysis examining how specific Agriculture 4.0 technologies relate to different types of eco-innovation, revealing distinct patterns between CP and EoP solutions. For CP innovations, several Agriculture 4.0 technologies show strong and consistent positive associations. Precision farming emerges as a particularly robust driver, reflecting its direct contribution to resource optimization and process efficiency. Its ability to support variable-rate applications, targeted treatments, and real-time vineyard monitoring aligns closely with CP principles of waste prevention and environmentally efficient production. Software management tools display similarly strong effects, suggesting that digital platforms enabling data-driven decision-making and process optimization help wineries identify inefficiencies and implement preventive environmental measures. The significance of software solutions highlights the importance of digital infrastructure in supporting systematic approaches to CP. Weather monitoring systems also exhibit positive associations with CP innovations: access to real-time meteorological data allows firms to adjust operations proactively, optimizing timing and resource use while preventing environmental problems before they occur. Remote sensing technologies show positive effects as well, indicating that vineyard-level monitoring can support resource-efficient practices. By contrast, IoT applications display only marginal significance, suggesting that sensor networks may enhance CP only when effectively integrated into broader digital management systems.

The pattern for EoP innovations reveals a markedly different technological landscape. Precision farming maintains a positive association with EoP solutions, though the relationship is less consistent across specifications, indicating that precision technologies, while mainly preventive, may still contribute to remedial environmental measures in certain contexts. Notably, big data analytics shows a negative association with EoP innovations, in contrast to its neutral role in CP. This counterintuitive result may reflect the standardized, equipment-intensive nature of EoP solutions, which generally require less complex data analysis. It may also signal a strategic trade-off:

firms investing heavily in analytics may prioritize preventive, process-oriented CP strategies over end-of-pipe measures. Other technologies, including IoT, automation, and software management, show positive but non-significant effects on EoP adoption, suggesting that EoP solutions depend less on advanced digital technologies and more on dedicated pollution-control equipment.

Across both innovation types, the control variables reinforce the patterns observed in the aggregate analysis. Collaboration with other companies remains a strong and consistent predictor of eco-innovation, underscoring the importance of inter-firm knowledge exchange for both preventive and remedial environmental solutions. R&D capabilities and employee training continue to display positive associations - particularly for CP innovations - highlighting the importance of internal knowledge development for identifying and implementing preventive environmental measures. Their weaker role in EoP solutions likely reflects the different technical and organizational requirements of pollution-control technologies compared with cleaner production approaches.

Table 5 A4.0 technologies and eco-innovation

[Table 5 around here]

4.4 Agriculture 4.0 and market positioning

Finally, we tested the correlation between companies' investments in Agriculture 4.0 and their market positioning. For this purpose, we developed indicators summarizing companies' presence in specific market segments, as presented in Table 6 and described in Table 1. Findings show that premium and super-premium products dominate: most firms produce higher-end wines - premium (70%) and super-premium (54.7%) - suggesting the sample may skew toward higher-quality producers. On the contrary, lower-end wine is rare: only a small fraction makes super-economy (2.4%) wines. This could indicate that this is a niche or declining market. It must be noted that the survey

responses are based on dummy variables not summing to 1, which means that companies may produce wines across multiple price tiers. For instance, a firm could produce both economic and ultra-premium wines.

We measured companies' market positioning with two indicators: *market_score* measures the cumulative market positioning across wine tiers. It adds up all tiers the firm is involved in, weighted by their rank (1–6). Therefore, while a firm that makes all types of wine would get the highest score (*market_score* = 1 + 2 + 3 + 4 + 5 + 6 = 21), a firm producing cheap and luxury wine would get a higher total score than one producing only cheap wine (1 + 6 > 1). This indicates how broad and upscale a firm's wine production is, but it assumes producing in multiple tiers is cumulatively valuable.

The second indicator, *market_tier*, is ordered and measures the highest tier the firm produces, ignoring how many other tiers the firm covers and capturing the top end of the firm's portfolio. Therefore, if a firm makes only cheap wine, *market_tier* = 1, and if it produces luxury wine *market_tier* = 6. If it makes all types of wine, then *market_tier* = 6. This indicator takes into account the maximum market segment a firm reaches. While it is easier to interpret, it loses nuance about breadth. The two indicators show two different aspects: the first one highlights the diversity production across market segments. The second highlights firms' capability to reach premium markets, regardless of what else they produce.

Agriculture 4.0 adoption seems to be mainly linked to participation in premium and ultra-premium wine markets, suggesting that digital eco-innovation supports competitive upgrading and sustainable differentiation strategies (Walsh & Doods, 2017).

Table 6 Market segments

[Table 6 around here]

Table 6 reports the regression results examining the association between Agriculture 4.0 adoption and market positioning. The findings suggest a positive relationship between the adoption of Agriculture 4.0 and firms' market orientation toward premium and ultra-premium segments. Firms adopting at least one Agriculture 4.0 technology tend to have higher market tier scores, indicating a stronger presence in top-end market segments. This result is consistent with the idea that digital and precision agriculture technologies support quality enhancement, traceability, and process control - key features valued in premium wine production.

However, the relationship between Agriculture 4.0 and the market score (i.e., the breadth of market participation) is less robust. The estimates suggest that while technology-adopting firms may produce in multiple price tiers, the primary association is with reaching higher-end segments, not necessarily with diversification across all market levels. This indicates that Agriculture 4.0 adoption is more closely linked to quality positioning than to broad market coverage.

These results align with prior research on innovation-driven differentiation in agri-food industries (e.g., Matese & Di Gennaro, 2015). Digital technologies such as precision viticulture, environmental monitoring, and blockchain for traceability can contribute to improved product quality, reduced defects, and enhanced sustainability credentials - characteristics that are increasingly demanded in premium and luxury wine markets.

Moreover, the positive association between Agriculture 4.0 and market positioning may reflect not only production-side advantages but also marketing and reputational benefits. Technology adoption can serve as a signal of innovation and sustainability commitment, both of which are important drivers of competitive advantage in higher-end wine segments.

Table 7 A4.0 and market positioning

[Table 7 around here]

5 Discussion

Our findings provide compelling evidence that Agriculture 4.0 technologies can simultaneously enhance environmental and innovation performance in traditional industries, challenging the conventional view that firms must trade off economic and environmental objectives. While previous studies have argued that digital tools may support environmental improvements (e.g., Boakye et al., 2020; Mulligan et al., 2024), they have rarely examined whether these technologies shift firms toward more proactive eco-innovation strategies. We extend this literature by demonstrating that Agriculture 4.0 functions not merely as a technological upgrade but as a capability-building platform that supports preventive, CP innovations. This represents a departure from earlier work emphasizing compliance-driven, EoP solutions in agriculture-based industries. The positive association between Agriculture 4.0 adoption and premium market positioning further illustrates how digital transformation enables firms to pursue sustainability and competitive differentiation jointly, reinforcing the "win–win" perspective (Ambec & Lanoie, 2008).

Firms adopting digital technologies are not simply optimizing existing practices; they are building dynamic capabilities for future eco-innovation. This advances the dynamic capabilities framework (Teece, 2007) by showing that capability development in traditional sectors can be digitally mediated, whereas prior research often emphasizes slow, path-dependent learning processes. Agriculture 4.0 provides a concrete mechanism through which firms sense environmental opportunities, seize digital solutions, and reconfigure routines to support sustainability-oriented competitiveness. By linking these digitally enabled processes primarily to CP - rather than EoP - innovations, our study enriches eco-innovation strategy research and clarifies how digital transformation connects dynamic capability development with environmental strategy. The technology-specific results support this interpretation: precision farming, environmental monitoring systems, and data management tools act as capability-building infrastructures rather than isolated technological add-ons, aligning with and

extending recent work suggesting that digital technologies enhance environmental monitoring and coordination (Song et al., 2024).

Our findings also offer empirical support for Porter and van der Linde's (1995) hypothesis that environmental improvements can result from innovation rather than compliance costs. However, we go beyond previous studies by providing evidence that Agriculture 4.0 allows firms to improve operational efficiency, environmental performance, and competitive positioning simultaneously, an outcome often assumed but seldom empirically verified in traditional industries. The positive relationship between digital adoption and premium market placement suggests that digital transformation creates new, sustainability-aligned competitive pathways. Precision viticulture, environmental monitoring technologies, and blockchain-supported traceability appear especially relevant for enhancing product quality, reducing defects, and strengthening sustainability credentials, dimensions increasingly valued in premium market segments.

The heterogeneity analysis deepens this contribution by showing that Agriculture 4.0 technologies do not uniformly support eco-innovation. Instead, their effects differ systematically between preventive and remedial environmental strategies. Resource-optimization tools (precision farming), real-time monitoring systems (weather and environmental sensors), and data-driven management platforms are particularly effective for CP innovations, while their influence on EoP solutions is weaker or inconsistent. Notably, big data analytics exhibits a negative association with EoP innovations. While initially counterintuitive, several interpretations are possible. Firms investing heavily in analytics may prioritize preventive, CP-oriented strategies over remedial measures, reflecting a strategic choice toward risk minimization and efficiency. Alternatively, the organizational effort required to implement advanced analytics may temporarily divert resources from EoP adoption. From a broader digitalization perspective, this pattern aligns with recent debates suggesting that digital tools are more effective in proactive, process-oriented contexts than in compliance-

focused interventions (Bai et al., 2021; Song et al., 2024). Thus, the negative association may reflect strategic prioritization rather than technological inadequacy.

Across all models, the results show that digital technologies alone are insufficient to generate substantial environmental transformation. Organizational capabilities remain essential. Internal R&D structures, employee training, and inter-firm collaboration consistently deepen the relationship between digital adoption and eco-innovation, echoing but also extending prior findings on the role of absorptive capacity in sustainability-oriented innovation. Collaboration, in particular, provides access to external expertise, complementary resources, and specialized knowledge needed to address the complex and interdisciplinary nature of environmental challenges. These findings reinforce the view that Agriculture 4.0 adoption should be understood as part of a broader organizational change process, requiring investment in human capital, ongoing learning, and a culture that supports experimentation and cross-functional integration, rather than a purely technological intervention.

6 Conclusions

This paper contributes to the business strategy and sustainability literature by showing that digital transformation - specifically through Agriculture 4.0 - enables proactive eco-innovation strategies in traditional industries. Using original data from 387 Italian wine firms, the study provides robust evidence that Agriculture 4.0 technologies are not merely tools for productivity enhancement but powerful drivers of eco-innovation and competitive differentiation. The findings demonstrate that adopting digital technologies improves environmental performance while supporting strategic positioning in premium market segments, particularly in sectors like viticulture where balancing tradition and innovation remains a critical challenge. Moreover, this study demonstrates that the relationship between digital transformation and environmental sustainability is not predetermined but depends on the specific technologies adopted, and the related organizational capabilities developed, and the strategic approaches pursued.

The study combines three major frameworks - Porter's innovation-offset hypothesis, the OE framework, and the DTEP model - to explain how Agriculture 4.0 technologies act as strategic enablers of sustainability-oriented competitiveness. This conceptual integration has not been previously applied to the agricultural domain. By distinguishing between proactive (CP) and reactive (EoP) innovations, the study reveals that digital transformation primarily drives preventive, efficiency-based sustainability strategies. Moreover, the evidence that Agriculture 4.0 adoption correlates with firms' presence in premium and ultra-premium markets demonstrates that environmental and competitive advantages can be achieved simultaneously - a result that challenges the traditional trade-off paradigm.

Our findings make several important theoretical contributions. First, this study contributes to the broader innovation literature by extending research on Industry 4.0 and digital transformation, demonstrating that Agriculture 4.0 serves as a capability-building platform for broader innovation capabilities. The positive relationship between the number of Agriculture 4.0 technologies adopted and eco-innovation outcomes suggests that complementarities among technologies are as important as their individual effects, highlighting the systemic nature of digital innovation. Second, we extend eco-innovation strategy research by distinguishing how digital technologies reinforce proactive versus reactive approaches (Frondel et al., 2007; Horbach et al., 2012). This distinction is theoretically relevant as it clarifies the preventive versus remedial logic of different environmental strategies and shows that digital transformation is particularly suited to proactive environmental management. Moreover, we show that investments in Agriculture 4.0 - when combined with R&D, employee training, and collaboration - enable firms to pursue sustainable differentiation strategies, linking eco-innovation directly with competitiveness. Third, our findings provide compelling empirical evidence for the innovation offset hypothesis (Porter & van der Linde, 1995) in the context of digital transformation. Contrary to traditional views that regard environmental improvements as costly constraints on performance, we demonstrate that Agriculture 4.0 technologies enhance eco-innovation and sustainability-oriented

competitiveness, supporting the "win–win" perspective (Ambec & Lanoie, 2008). Fourth, we advance the theory of dynamic capabilities (Teece, 2007; Dangelico et al., 2017) by conceptualizing Agriculture 4.0 as a digitally mediated mechanism through which firms sense environmental opportunities, seize digital innovations, and reconfigure resources to align competitiveness with sustainability goals. In this view, digital transformation embeds environmental objectives within strategic decision-making and innovation routines, thereby extending the scope of dynamic capabilities toward sustainability-oriented competitiveness. Fifth, we provide empirical support for the role of absorptive capacity (Cohen & Levinthal, 1990) in environmental innovation. The consistent positive effects of R&D capabilities, employee training, and collaborative partnerships across all model specifications confirm that firms must possess the organizational capabilities to recognize, assimilate, and apply digital technologies effectively to achieve environmental benefits. These findings position absorptive capacity as a critical microfoundation linking digital transformation, learning, and eco-innovation. Finally, our technology-specific analysis contributes to the emerging literature on the heterogeneous effects of Industry 4.0 technologies. We demonstrate that precision agriculture, environmental monitoring systems, and data management tools are particularly effective drivers of CP innovations, while showing differential or weaker effects on EoP solutions. This granular understanding of technology–environment interactions provides important insights into the mechanisms through which digitalization influences environmental and innovation outcomes.

The implications extend beyond individual firms to encompass broader questions about industrial policy, regional development, and the role of technology in addressing global environmental challenges. As the world grapples with climate change, biodiversity loss, and resource depletion, understanding how digital transformation can enable sustainable industrial development becomes increasingly crucial. Our findings suggest a fundamental reorientation of environmental and innovation policy frameworks. Rather than treating environmental objectives as separate from competitiveness concerns, policies should recognize and exploit the synergies between digital

transformation and sustainability. Supporting the adoption of digital technologies can generate dual dividends, fostering both competitiveness and environmental improvement in traditional sectors. This suggests moving beyond narrow environmental subsidies toward broader digital transformation incentives that make sustainability a co-benefit of technological upgrading. Such an approach could be more politically feasible and economically efficient than traditional environmental policies, as it aligns with firms' competitiveness objectives while achieving environmental goals. The technology-specific effects we identify offer practical guidance for targeted policy interventions. Given the heterogeneity of effects across technologies, regulatory frameworks and grant programs should prioritize precision agriculture, environmental monitoring systems, and data management tools, as these demonstrate the highest environmental returns. Policymakers should also be cautious about providing universal support for all Agriculture 4.0 technologies, as not all generate comparable eco-innovation outcomes. In fact, we identify which digital technologies - such as precision farming, environmental monitoring systems, and management software - deliver the strongest environmental returns, thus offering clear priorities for public support and investment. Furthermore, the differential effects on CP versus EoP innovations suggest that policies should explicitly favor preventive environmental technologies over remedial ones. This could be achieved through regulatory frameworks that reward pollution prevention over pollution control, or through innovation incentives that prioritize upstream environmental solutions. Supporting preventive eco-innovation may provide greater long-term benefits both environmentally and economically. Targeted financial instruments - such as low-interest innovation loans, fiscal incentives, and digital transition funds - can reduce barriers to adoption, particularly for small and medium-sized wineries. These interventions would strengthen the absorptive and adaptive capacities necessary for leveraging Agriculture 4.0 as a driver of eco-innovation and sustainable competitiveness.

Our findings also highlight the critical importance of collaborative innovation ecosystems. The positive effects of inter-firm collaboration and knowledge networks

suggest that regional innovation policies should foster platforms for knowledge sharing between firms, research institutions, and technology providers. Examples include innovation clusters, digital consortia, and technology transfer programs, which could amplify the benefits of Agriculture 4.0 adoption. Building such ecosystems may accelerate technology adoption and environmental innovation while reducing the individual costs and risks faced by participating firms.

For managers, the results indicate that Agriculture 4.0 adoption is not only a productivity strategy but also an environmental one. Firms in traditional industries can leverage digital technologies to improve sustainability without sacrificing competitiveness. In fact, our results suggest that environmental improvements may enhance, rather than undermine, competitive positioning. The positive association between Agriculture 4.0 adoption and premium market presence suggests that digital transformation can create new pathways to differentiation and value creation. This is particularly relevant for traditional sectors facing commoditization pressures, as digitalization enables upmarket positioning while simultaneously improving environmental performance. However, successful green digital transformation requires a systemic approach that integrates technological investments with complementary organizational capabilities. Firms cannot simply purchase technologies and expect automatic environmental improvements. They must also invest in workforce development, R&D capabilities, and inter-organizational collaboration. Our findings confirm that absorptive capacity - through employee training, internal R&D, and collaborative partnerships - is a key enabler of digital and environmental innovation. For example, wineries should invest in employee training and digital literacy programs to overcome skills shortages, while establishing partnerships with technology providers and research centers to accelerate capability development. Agriculture 4.0 adoption should therefore be viewed as an organizational transformation process, not merely a technological upgrade. Firms that recognize the complementary nature of technological and human capital investments and develop integrated strategies will be best positioned to capture both competitive and environmental advantages.

Nevertheless, this study has certain limitations that also open promising avenues for future research. Given the cross-sectional nature of the data, causal interpretations should be treated with caution. While the results are theoretically consistent and statistically robust, future studies could employ longitudinal designs or exploit natural experiments to better identify the causal mechanisms linking digital adoption, eco-innovation, and competitive performance. In addition, our measures rely on firm-reported data - standard in management research - but future analyses could complement these findings with objective indicators of environmental performance, such as emissions, water use, or energy efficiency. Furthermore, the focus on the Italian wine sector limits generalizability, although the results are likely relevant to other traditional industries undergoing digitalization. Building on this foundation, future research should conduct comparative analyses across agri-food sectors to examine whether similar mechanisms operate beyond viticulture and explore the interaction between Agriculture 4.0, circular economy models, and social sustainability dimensions. Such studies would provide a more comprehensive understanding of the green digital transition as a multidimensional process that integrates technological, environmental, and social transformations.

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Tables

[TABLE 1]

Variable	
CP innovations	Number of CP innovations introduced by the company (0-8).
EoP innovations	Number of EoP innovations introduced by the company (0-4).
Other innovations	Number of other types of innovations introduced by the company (0-8) in any of the following categories: New grape varieties; Innovative winemaking techniques; Advancements in wine aging and maturation, including the use of specialized barrels; Design and architectural innovations in wineries and wine farms; Innovations in marketing and packaging, enhancing brand identity and sustainability; Commercial innovations, such as the use of online sales channels and digital platforms; Tourism-related innovations.
Any innovations	Number of innovations introduced by the company in the categories indicated above (0-20).

A4.0: n. technology types	Number of different types of A4.0 technologies adopted by the company.
A4.0: any tech adoption	Adoption of any type of A4.0 technologies (y/n).
4.0: Precision farming	GPS-guided equipment and variable-rate application systems.
A4.0: IoT	Sensors for real-time monitoring of environmental and production conditions.
A4.0: Big Data and analytics	Advanced data analysis for process optimization.
A4.0: Robotics and automation	Automated systems for vineyard and cellar operations.
A4.0: Remote monitoring	Remote sensing and telemetry systems.
A4.0: Blockchain	Digital traceability and certification solutions.
A4.0: Environmental sensors	Sensors and smart actuators for monitoring of environmental parameters (e.g., soil, air, water).
A4.0: Weather monitoring systems	Weather forecasting and real-time meteorological data.
A4.0: Software management tools	Vineyard and production management software.
A4.0: AR & VR	AR and VR technologies for training and process visualization.

R&D unit	Presence of an R&D unit in the company (y/n).
Winemakers	Number of winemakers involved in the production process.
Recent employee training	Recent employee participation in training programs (y/n).
Coll. with res. centres	Company engagement in collaboration agreements with scientific institutions in the last 3 years (e.g. universities) (y/n).
Coll. with tech providers	Company engagement in collaboration agreements with technical service providers in the last 3 years (y/n).
Coll. with other firms	Company engagement in collaboration agreements with other wineries, suppliers and clients in the last 3 years (y/n).
Firm size	Firm size measured in terms of the number of FTE employees.
Wine firms in the area	Number of wine firms in the province (NUTS3 level) where the main premises of the company are located.
Market score	Cumulative company market positioning across wine tiers, from 1="super value" to 6="ultra-premium & luxury" (1-21).
Max market tier	Top market tier in which the company operates (1-6), from 1="super-value" products to 6="ultra-premium & luxury".

[TABLE 2]

Variable	Obs	Mean	Std. Dev.	Min	Max
CP innovations	387	1,690	2,004	0	8
EoP innovations	387	0,310	0,721	0	4
Other innovations	387	2,049	2,019	0	8
Any innovations	387	4,049	4,085	0	17
A4.0: n. technology types	387	1,204	1,721	0	7
A4.0: any tech adoption	387	0,429	0,496	0	1
A4.0: Precision farming	387	0,233	0,423	0	1
A4.0: IoT	387	0,041	0,199	0	1

A4.0: Big Data and analytics	387	0,103	0,305	0	1
A4.0: Robotics and automation	387	0,098	0,298	0	1
A4.0: Remote monitoring	387	0,127	0,333	0	1
A4.0: Blockchain	387	0,057	0,232	0	1
A4.0: Environmental sensors	387	0,085	0,280	0	1
A4.0: Weather monitoring systems	387	0,253	0,435	0	1
A4.0: Software management tools	387	0,194	0,396	0	1
A4.0: AR & VR	387	0,013	0,113	0	1
R&D unit	387	0,158	0,365	0	1
Winemakers	366	1,424	0,681	0	3
Recent employee training	387	0,646	0,479	0	1
Coll. with res. centres	387	0,214	0,411	0	1

Coll. with tech providers	387	0,295	0,456	0	1
Coll. with other firms	387	0,395	0,490	0	1
Firm size	337	6,077	7,265	0	66
Wine firms in the area	350	6,371	6,661	0	33
Market score	287	9,798	5,192	2	21
Max market tier	287	5,003	1,066	2	6

[TABLE 3]

CP innovations	
Improved energy efficiency	36,18%
Reduction or reuse of waste	20,16%
Reduction in water consumption	18,35%

Reduction or optimization in the use of chemical products	30,49%
Innovations in packaging	27,65%
Enhanced efficiency in transportation and logistics	9,30%
Acquisition of environmental certifications or adherence to sustainability standards	13,18%
EOP innovations	
Improved waste management systems	7,24%
Reduction of gas emissions through the use of anti-pollution technologies	10,08%
Noise reduction measures	8,79%
Enhanced cleaning and washing systems	4,91%
Other innovations	
Introduction of new grape varieties	17,05%
Innovative winemaking techniques (e.g., microvinification)	26,36%
Advancements in wine aging and maturation (e.g., use of specialized barrels)	35,66%

Design and architectural innovations in wineries and wine farms	18,86%
Innovations in marketing and packaging, enhancing brand identity and sustainability	37,98%
Commercial innovations (e.g. use of online sales channels and digital platforms)	21,71%
Tourism-related innovations (e.g. wine tasting, vineyard tours, on-site accommodations)	20,41%

[TABLE 4]

	1	2	3	4	5	6	7	8
VARIABLES	Other	CP	EoP	Other	CP	EoP	Any	Any
A4.0: any tech adoption	0.578**	0.667**	0.868**				0.681**	
	[0.103]	[0.134]	[0.320]				[0.110]	
A4.0: n. technology types				0.125**	0.172**	0.095		0.172**
				[0.029]	[0.039]	[0.089]		[0.035]

R&D unit	0.322**	0.474**	0.164	0.331**	0.472**	0.132	0.442**	0.437**
	[0.112]	[0.157]	[0.338]	[0.117]	[0.159]	[0.345]	[0.138]	[0.142]
Recent employee training	0.216+	0.377*	0.565	0.215+	0.369*	0.582	0.322*	0.320*
	[0.115]	[0.154]	[0.383]	[0.118]	[0.154]	[0.385]	[0.126]	[0.128]
Winemakers	0.128+	-0.012	0.076	0.124+	-0.021	0.085	0.051	0.047
	[0.072]	[0.093]	[0.228]	[0.074]	[0.093]	[0.229]	[0.078]	[0.080]
Coll. with res. centres	0.154	0.227	-0.062	0.190+	0.269+	-0.041	0.205	0.249+
	[0.106]	[0.145]	[0.339]	[0.110]	[0.146]	[0.351]	[0.125]	[0.128]
Coll. with tech providers	0.222+	-0.088	0.118	0.250*	-0.016	0.160	0.128	0.183
	[0.121]	[0.170]	[0.367]	[0.126]	[0.172]	[0.379]	[0.141]	[0.144]
Coll. with other firms	0.389**	0.496**	0.691+	0.404**	0.450**	0.829*	0.485**	0.450**
	[0.122]	[0.164]	[0.367]	[0.129]	[0.170]	[0.397]	[0.134]	[0.141]
Firm size	-0.001	0.010	0.032	-0.003	0.005	0.037	0.005	0.002

	[0.006]	[0.009]	[0.021]	[0.007]	[0.009]	[0.023]	[0.008]	[0.009]
Wine firms in the area	0.005	-0.006	0.023	0.003	-0.006	0.022	0.005	0.004
	[0.007]	[0.010]	[0.023]	[0.007]	[0.010]	[0.023]	[0.008]	[0.008]
Constant	-0.285+	-0.415+	-3.221**	-0.146	-0.273	-2.983**	0.268	0.411*
	[0.168]	[0.213]	[0.562]	[0.167]	[0.210]	[0.551]	[0.179]	[0.181]
Observations	296	296	296	296	296	296	296	296

Standard errors in brackets

** p<0.01, * p<0.05, + p<0.1

[TABLE 5]

	1	2	3	4	5	6	7	8	9	10
VARIABLES	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP

A4.0: Precision farming	0.563**				
	[0.143]				
A4.0: IoT		0.502+			
		[0.302]			
A4.0: Big Data and analytics			0.097		
			[0.260]		
A4.0: Robotics and automation				-0.179	
				[0.231]	
A4.0: Remote monitoring					0.543**
					[0.177]
A4.0: Blockchain					

A4.0: Environmental sensors							0.265			
							[0.225]			
A4.0: Weather monitoring systems								0.529**		
								[0.137]		
A4.0: Software management tools									0.613**	
									[0.140]	
A4.0: AR & VR										-0.073
										[0.479]
R&D unit	0.357*	0.427**	0.406*	0.385*	0.469**	0.408*	0.424**	0.378*	0.443**	0.399*
	[0.158]	[0.160]	[0.163]	[0.161]	[0.162]	[0.160]	[0.162]	[0.158]	[0.155]	[0.161]
Recent employee training	0.362*	0.430**	0.400*	0.403*	0.377*	0.403*	0.375*	0.404**	0.328*	0.395*
	[0.155]	[0.158]	[0.158]	[0.157]	[0.156]	[0.157]	[0.158]	[0.156]	[0.153]	[0.157]
Winemakers	0.023	-0.027	-0.006	-0.001	0.002	-0.018	-0.007	-0.020	-0.026	-0.007

	[0.094]	[0.095]	[0.095]	[0.095]	[0.094]	[0.095]	[0.095]	[0.094]	[0.092]	[0.095]
Coll. with res. centres	0.307*	0.334*	0.319*	0.317*	0.339*	0.321*	0.332*	0.180	0.269+	0.322*
	[0.147]	[0.148]	[0.150]	[0.149]	[0.148]	[0.149]	[0.149]	[0.151]	[0.144]	[0.149]
Coll. with tech providers	-0.045	-0.075	-0.089	-0.092	-0.002	-0.090	-0.061	-0.061	-0.082	-0.087
	[0.172]	[0.175]	[0.176]	[0.175]	[0.177]	[0.175]	[0.177]	[0.172]	[0.169]	[0.175]
Coll. with other firms	0.554**	0.668**	0.724**	0.756**	0.591**	0.718**	0.668**	0.619**	0.561**	0.729**
	[0.165]	[0.165]	[0.163]	[0.166]	[0.167]	[0.162]	[0.169]	[0.162]	[0.161]	[0.163]
Firm size	0.012	0.015+	0.014	0.017+	0.010	0.015+	0.014	0.012	0.010	0.015+
	[0.009]	[0.009]	[0.009]	[0.010]	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]
Wine firms in the area	-0.012	-0.004	-0.003	-0.002	-0.004	-0.002	-0.003	-0.005	0.001	-0.003
	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]
Constant	-0.283	-0.237	-0.238	-0.259	-0.273	-0.235	-0.217	-0.327	-0.254	-0.234
	[0.211]	[0.212]	[0.213]	[0.215]	[0.212]	[0.212]	[0.213]	[0.213]	[0.206]	[0.213]

Observations	296	296	296	296	296	296	296	296	296	296
	1	2	3	4	5	6	7	8	9	10
VARIABLES	EoP	EoP	EoP	EoP	EoP	EoP	EoP	EoP	EoP	EoP
A4.0: Precision farming	0.676*									
	[0.305]									
A4.0: IoT		0.720								
		[0.620]								
A4.0: Big Data and analytics			-2.043*							
			[0.908]							
A4.0: Robotics and automation				0.127						

	[0.452]				
A4.0: Remote monitoring	-0.206				
	[0.433]				
A4.0: Blockchain	-21.758				
	[40,984.663]				
A4.0: Environmental sensors	-0.062				
	[0.490]				
A4.0: Weather monitoring systems	0.360				
	[0.313]				
A4.0: Software management tools	0.450				
	[0.328]				
A4.0: AR & VR	0.555				
	[0.853]				

R&D unit	0.032	0.153	-0.012	0.125	0.093	0.093	0.107	0.076	0.128	0.097
	[0.338]	[0.343]	[0.328]	[0.348]	[0.348]	[0.342]	[0.348]	[0.345]	[0.346]	[0.345]
Recent employee training	0.495	0.701+	0.529	0.591	0.593	0.583	0.597	0.584	0.537	0.634
	[0.381]	[0.402]	[0.373]	[0.386]	[0.386]	[0.386]	[0.387]	[0.385]	[0.388]	[0.392]
Winemakers	0.108	0.059	0.062	0.090	0.084	0.121	0.093	0.067	0.074	0.109
	[0.224]	[0.230]	[0.219]	[0.229]	[0.229]	[0.227]	[0.228]	[0.229]	[0.228]	[0.229]
Coll. with res. centres	-0.057	0.024	0.157	0.010	0.010	0.003	0.004	-0.072	-0.047	-0.009
	[0.343]	[0.345]	[0.327]	[0.348]	[0.348]	[0.348]	[0.348]	[0.353]	[0.351]	[0.347]
Coll. with tech providers	0.119	0.156	0.174	0.115	0.077	0.107	0.100	0.146	0.147	0.102
	[0.369]	[0.377]	[0.358]	[0.377]	[0.380]	[0.374]	[0.377]	[0.374]	[0.378]	[0.374]
Coll. with other firms	0.830*	0.897*	1.031**	0.985**	1.076**	1.033**	1.028**	0.901*	0.848*	0.989**
	[0.363]	[0.372]	[0.341]	[0.373]	[0.383]	[0.357]	[0.377]	[0.369]	[0.378]	[0.360]
Firm size	0.034	0.040+	0.053**	0.041+	0.045*	0.041+	0.043+	0.041+	0.042+	0.040+

	[0.021]	[0.021]	[0.019]	[0.023]	[0.023]	[0.022]	[0.023]	[0.022]	[0.023]	[0.022]
Wine firms in the area	0.016	0.023	0.025	0.023	0.024	0.023	0.024	0.023	0.027	0.024
	[0.023]	[0.023]	[0.022]	[0.023]	[0.023]	[0.022]	[0.023]	[0.023]	[0.023]	[0.023]
Constant	-2.946**	-3.024**	-2.983**	-2.980**	-2.992**	-2.994**	-3.006**	-3.010**	-2.984**	-3.028**
	[0.539]	[0.555]	[0.535]	[0.555]	[0.552]	[0.551]	[0.555]	[0.551]	[0.550]	[0.555]
Observations	296	296	296	296	296	296	296	296	296	296

Standard errors in brackets

** p<0.01, * p<0.05, + p<0.1

[TABLE 6]

Segment	Share companies
Super Value (<€1.99)	2,44%

Value (€2-€5.99)	21,25%
Economy (€6-€8.99)	47,39%
Pop. Premium & Premium (€9-€14.99)	70,04%
Super Premium (€15-€24.99)	54,70%
Ultra Premium & Luxury (>€25)	37,28%

[TABLE 7]

	1	2	3	4
VARIABLES	market score	market score	market tier	market tier
A4.0: any tech adoption	1.000		0.269+	
	[0.670]		[0.159]	
A4.0: n. technology types		0.145		0.074

		[0.201]		[0.049]
R&D unit	2.015*	1.975*	0.214	0.218
	[0.789]	[0.793]	[0.189]	[0.190]
Recent employee training	0.352	0.353	0.157	0.154
	[0.743]	[0.746]	[0.175]	[0.175]
Winemakers	0.256	0.244	-0.155	-0.159
	[0.473]	[0.475]	[0.113]	[0.113]
Coll. with res. centres	-1.265+	-1.169	-0.199	-0.186
	[0.732]	[0.733]	[0.173]	[0.172]
Coll. with tech providers	0.383	0.414	0.049	0.067
	[0.822]	[0.826]	[0.194]	[0.194]
Coll. with other firms	0.074	0.161	-0.059	-0.081
	[0.802]	[0.828]	[0.190]	[0.196]

Firm size	0.124*	0.126*	0.014	0.012
	[0.049]	[0.051]	[0.012]	[0.012]
Wine firms in the area	-0.013	-0.015	0.003	0.002
	[0.047]	[0.047]	[0.011]	[0.011]
Constant	7.404**	7.704**		
	[1.081]	[1.062]		
Observations	240	240	240	240
R-squared	0.179	0.173		

Standard errors in brackets

** p<0.01, * p<0.05, + p<0.1

Chapter 2 How Does Innovation Shape Wine Demand in China?

[Under review in: Journal of Business Research]

Abstract

This study examines the impact of multidimensional innovation on wine demand within the Chinese market. Integrating the Theory of Planned Behavior and the Diffusion of Innovations theory, this research analyzes how four distinct innovation dimensions – Technological, Process, Packaging, Conceptual – influence purchase and recommendation intentions. Using survey data from 2,016 Chinese consumers, it analyzes the effects of technological, process, packaging, and conceptual innovations on purchase and recommendation intentions. The results show a clear hierarchy of impact, with packaging innovation emerging as the strongest driver, followed by conceptual, technological, and process. Perceived value plays a central mediating role, explaining how innovation attributes translate into consumer intentions. In addition, demographic factors significantly shape innovation responses, with female and older consumers showing higher adoption propensities. The findings highlight China as a distinct, digitally driven and consumer-led innovation environment, offering insights into how firms can prioritize and tailor innovation strategies in emerging markets.

Keywords: Wine Innovation, Chinese Consumer Behavior, Perceived Value, Theory of Planned Behavior, Diffusion of Innovations

1 Introduction

The Chinese wine market has undergone a significant transformation, evolving from a landscape dominated by status-driven gifting towards a more mature, diversified, and consumer-centric environment (CADA, 2024). This evolution has been characterized by increasingly sophisticated consumer preferences emphasizing quality, authenticity, health consciousness, and experiential value (Somogyi et al., 2011). In this dynamic context, innovation has emerged as a critical strategic lever for capturing consumer attention and stimulating demand.

To comprehensively understand how innovation influences consumer behavior in this complex market, this study integrates two complementary theoretical frameworks: the Theory of Planned Behavior (TPB) and the Diffusion of Innovations (DOI) theory. The TPB (Ajzen, 1991) provides a robust psychological framework for understanding how attitudes, subjective norms, and perceived behavioral control shape behavioral intentions. Meanwhile, DOI theory (Rogers, 2003) offers a sociological perspective on how innovation attributes (relative advantage, compatibility, complexity, trialability, and observability) influence adoption rates across different consumer segments.

The integration of these theories is particularly powerful for this research context. TPB helps explain the cognitive mechanisms through which consumers evaluate innovations, while DOI provides the framework for understanding how different innovation types diffuse through the Chinese wine market's distinct social system. This theoretical synergy allows for a more holistic investigation of innovation adoption that accounts for both individual psychological processes and broader social diffusion patterns.

Despite the recognized importance of innovation, significant theoretical and empirical gaps persist in the literature. Existing studies often treat innovation monolithically or focus on single dimensions, lacking a comprehensive framework that captures its multifaceted nature. In the wine market context, specifically, while general trends and consumer segmentation studies exist (e.g., Mackenzie et al., 2025; Peng & Huang,

2025), empirical research dissecting how specific innovation dimensions influence Chinese consumers' decision-making processes remains limited.

This study makes several distinct theoretical and empirical contributions. First, it develops and validates a multidimensional framework of innovation encompassing four distinct dimensions: Technological, Process, Packaging, and Conceptual innovation. Second, it introduces and tests the mediating role of Perceived Value (PV), theorizing it as the central psychological mechanism through which innovations influence consumer intentions. Third, it examines the moderating effects of key demographic variables, acknowledging that innovation adoption varies systematically across consumer segments. This study focuses on the Italian wine manufacturing industry and its market entry capabilities in China, a highly dynamic and fast-growing market for wine companies worldwide. By combining TPB and DOI theories and deconstructing innovation into specific dimensions, this research provides a more comprehensive understanding and moves beyond generic assertions to offer actionable insights.

The article is organized as follows. Section 2 sets the theoretical background by reviewing the literature on innovation adoption, TPB and diffusion theory. Section 3 presents the research methodology. Section 4 reports the results of our quantitative exercise, while Section 5 discusses findings and proposes the implications for theory, policy, and management. Section 6 concludes by highlighting the study's contributions, limitations, and avenues for future research.

2 Theoretical Framework, and Conceptual Model

2.1 Innovation adoption intentions in the Wine Industry

Innovation adoption intention refers to an individual's likelihood of accepting and using a new technology or idea. This intention is shaped by key perceived attributes of the innovation, including its relative advantage (benefits), compatibility with existing values and practices, complexity (ease of use), trialability (testability), and

observability (visibility). Established theoretical models, such as Rogers' DOI Theory, explain the adoption process through a sequence of stages—from awareness to decision—and by categorizing adopters into groups like innovators and early adopters. Marketing strategies frequently leverage this framework by targeting specific adopter categories and emphasizing the innovation's positive attributes to facilitate the transition from intention to actual behavior (Rogers, 2003).

In the wine industry, the adoption of innovation is accelerating in response to pressures such as climate change, sustainability imperatives, and evolving consumer demands (Muscio et al., 2025). Wineries are increasingly integrating technologies like AI for vineyard management, drones for monitoring, digital sales platforms, and robotics (Adamashvili et al., 2024; Izquierdo-Bueno et al., 2024). However, the rate of adoption varies, as producers balance tradition with the perceived benefits of new tools—such as gains in efficiency (relative advantage), ease of implementation (complexity), and alignment with environmental or quality values (compatibility) (Rogers, 2003; Stasi et al., 2016). Key innovative areas include precision viticulture, sustainable winemaking practices, enhanced consumer experiences via AR/VR, and data-driven decision-making (Muscio et al., 2025). This broad scope underscores that relevant innovation extends beyond mere technology to include novel processes and strategic concepts, reflecting a comprehensive view of organizational innovation (Damanpour & Aravind, 2012). Consequently, this study examines four dimensions that capture both technological and non-technological facets of wine innovation. Ultimately, the adoption of these innovations is influenced by the core factors outlined in Rogers' theory: perceived advantage, compatibility, complexity, trialability, and observability.

A critical prerequisite for innovations to gain successful market acceptance lies in their ability to create and deliver unique value for consumers (Holbrook, 1999). Holbrook’s (1999) classic framework conceptualizes consumer value as a multidimensional, relativistic, and experience-dependent construct, which provides a fundamental theoretical lens for understanding how innovations shape consumers’ behavioral intentions by influencing their perceived value. Accordingly, this study positions

perceived value at the core of its theoretical model, framing it as a pivotal bridge linking external innovation attributes and internal behavioral intentions.

2.2 The Theory of Planned Behavior and the Wine Industry

The Theory of Planned Behavior (TPB) (Ajzen, 1991) provides the psychological foundation for understanding how innovation adoption intentions are formed. In this framework (**错误!未找到引用源。**), behavioral intention—the immediate precursor to actual behavior—is determined by three core factors: attitude (positive or negative evaluation of adopting innovative wines), subjective norms (perceived social pressure), and perceived behavioral control (confidence in one's ability to adopt the innovation). The TPB has been successfully applied to predict intentions in various consumer contexts, including ethically-minded purchasing decisions, where perceived value related to sustainability significantly shapes behavioral antecedents (Paul et al., 2016). While TPB offers a robust framework for understanding adoption decisions, its application to experiential products like wine requires critical consideration. The standard TPB constructs, being primarily cognitive, may not fully capture the affective, sensory, and hedonic dimensions central to wine consumption (Quintal et al., 2015). Wine choices are often influenced by emotional responses (Niimi et al., 2019; Rahmani et al., 2024), ambiance, and social context—factors not directly accounted for in the original TPB framework. To capture these affective and experiential dimensions, this study incorporates Perceived Value as a complementary construct within the extended TPB framework.

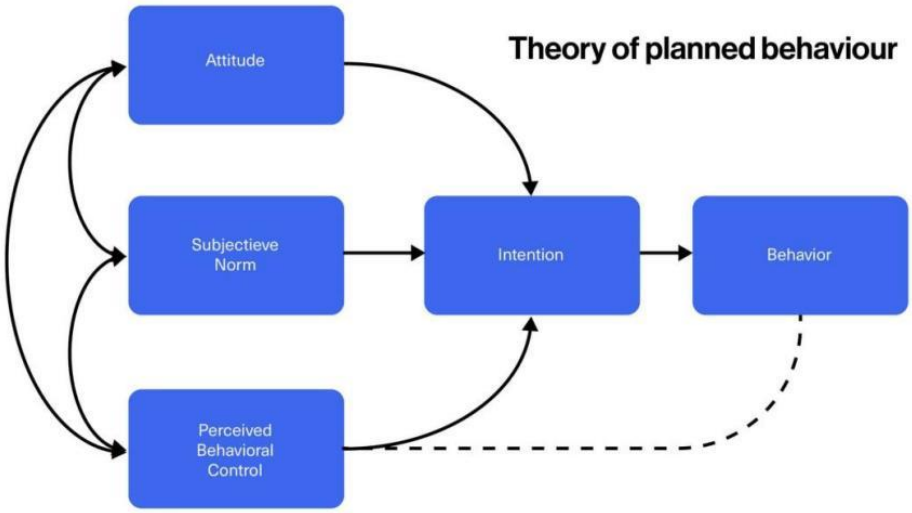

Figure 2 Theory of Planned Behaviour

Source: authors' elaboration.

The TPB provides a mechanism to explain how exposure to different types of wine innovations shapes consumers' cognitive and affective evaluations (attitudes), perceptions of social trends (subjective norms), and confidence in their ability to purchase and use the product (PBC), which collectively forge their purchase intentions (Barber et al., 2012). While the TPB is highly applicable, its application to experiential products like wine warrants a critical discussion. The TPB is primarily a cognitive model, and its constructs (attitude, subjective norm, PBC) may not fully capture the affective, sensory, and hedonic dimensions of wine consumption (Quintalet al., 2015). The experience of drinking wine is often emotional and subjective, influenced by ambiance, companionship, and mood (Niimi et al., 2019; Rahmani et al., 2024) — factors not directly accounted for in the standard TPB framework.

While the Theory of Planned Behavior provides a robust framework for explaining behavioral intentions, prior research has repeatedly noted its limitations in capturing the holistic evaluation processes underlying consumption decisions, particularly for experiential and symbolic products such as wine. In this context, Perceived Value offers

a more comprehensive explanatory mechanism, as it reflects consumers' overall assessment of the benefits derived from a product relative to the costs incurred (Zeithaml, 1988). Rather than representing a simple attitudinal judgment, perceived value is widely conceptualized as a multidimensional construct encompassing functional, social, emotional, and epistemic dimensions (Holbrook, 1999; Sweeney & Soutar, 2001).

Recent research in business and marketing increasingly positions perceived value as a key mediator between innovation-related stimuli and consumer behavioral outcomes, particularly in digitally mediated markets (Hollebeek et al., 2022). Innovations do not influence purchase intentions directly through their technical attributes alone; instead, consumers interpret these attributes through value-based evaluations that integrate utilitarian benefits, symbolic meaning, and experiential enhancement. This perspective is especially relevant in emerging markets such as China, where digital platforms play a critical role in shaping information access, trust, and value co-creation between firms and consumers (Vargo & Lusch, 2008). Consequently, positioning perceived value as the central psychological mechanism allows for a more nuanced understanding of how different innovation dimensions translate into purchase and recommendation intentions.

Future research could integrate affective components to provide a more holistic understanding of the drivers behind wine purchase intention.

2.3 The Diffusion of Innovation Theory and the Wine Industry

Rogers' (2003) DOI theory complements TPB by furnishing a sociological lens to unpack how innovations permeate social systems. Two DOI constructs are particularly germane to the present inquiry: adopter categories, which enable the segmentation of consumers along the continuum of innovativeness, and perceived innovation attributes, which account for the heterogeneous diffusion rates of different innovations across target populations.

Building on this theoretical framework, the four dimensions of wine innovation examined in this study can be individually conceptualized through their distinct configurations of perceived attributes. These attributes, in turn, exert a systematic and differential influence on the core antecedents of TPB. For instance, Packaging Innovation (PKI)—marked by its high observability and compatibility (e.g., its utility as a gift item)—primarily reinforces subjective norms; by contrast, Process Innovation (PI) may constrain perceived behavioral control owing to its inherent technical complexity. This mapping mechanism, which explicitly links DOI-derived innovation attributes to TPB's core constructs, constitutes the theoretical underpinning of Hypothesis H1 (see Figure 3 for a schematic illustration).

Furthermore, the adopter categories delineated in DOI theory—stratified by demographic and psychographic traits—provide an explicit sociological rationale for this study's investigation of demographic variables (e.g., age, income level, and wine consumption frequency) as moderators in Hypothesis H3. Specifically, innovations with superior relative advantage and strong compatibility tend to cultivate favorable attitudes among potential adopters, whereas those characterized by high complexity may diminish individuals' perceived behavioral control. Concurrently, innovations with high observability strengthen subjective norms by amplifying social visibility. This theoretical integration facilitates a more nuanced elucidation of how idiosyncratic innovation characteristics shape the psychological mechanisms underlying consumer adoption behavior. Notably, this attribute-construct linkage is not merely correlational: an innovation's relative advantage and compatibility directly shape attitudinal orientations, its complexity exerts a constraining effect on perceived behavioral control, and its observability acts as a salient trigger for subjective norm activation.

Crucially, the drivers and mechanisms underpinning innovation adoption are not universal; instead, they are profoundly contingent on the technological, organizational, and environmental contexts in which firms operate (Tornatzky et al., 1990; Nguyen et al., 2022; Muscio et al., 2025). Empirical research on mature European wine markets—most notably Italy—highlights the predominance of a producer-driven innovation

paradigm, distinguished by firm-specific capabilities and vertical supply chain collaboration (Stasi et al., 2016; Muscio et al., 2017). By contrast, the rise of New World wine regions (e.g., Chile and Argentina) has been catalyzed by exogenous knowledge spillovers and robust institutional support structures (Farinelli, 2013; Kunc & Tiffin, 2008). Against this contextual backdrop, this study posits that the Chinese wine market embodies a distinct innovation trajectory— a proposition that constitutes a key original contribution of the present research. This expectation aligns with the broader perspective that emerging markets like China necessitate a rethinking of established marketing and innovation paradigms developed in Western contexts (Sheth, 2011).

2.4 Theoretical Limitations in Existing Literature

This paper uniquely examines and provides empirical evidence for a third, distinct model in China: a digitally-enabled, demand-pull model where innovation effectiveness is primarily determined by its ability to generate perceived value for specific, segmented consumers, rather than by producer scale or traditional institutional linkages.

Current research on wine innovation exhibits several key theoretical gaps. First, innovation is often conceptualized as a monolithic construct, failing to account for its multidimensional nature. Studies typically examine single innovation types (e.g., technological or sustainable) without considering how different innovation dimensions interact and influence consumer decisions differently (Dewan et al., 2025; Yuan et al., 2025).

Another important limitation in the existing literature concerns the tendency to conceptualize innovation as a monolithic construct. Innovation research increasingly recognizes that firms deploy multiple, qualitatively distinct types of innovation that differ in visibility, complexity, and consumer relevance (Garcia & Calantone, 2002; Damanpour & Aravind, 2012). Institutional frameworks such as the OECD Oslo Manual explicitly distinguish between technological, process, and marketing-related

innovations, underscoring the need for multidimensional operationalizations of innovation outcomes (OECD, 2018).

From a consumer perspective, different innovation types are likely to activate distinct value perceptions and behavioral responses. Highly visible innovations—such as packaging and concept innovations—tend to generate immediate symbolic and experiential value, while less observable process innovations may primarily appeal to knowledgeable or highly involved consumers. Xie et al. (2014), increasingly, emphasize that innovation effectiveness depends not only on novelty but also on how innovations are translated into consumer-perceived value through communication, design, and digital interfaces. Accordingly, adopting a multidimensional view of innovation is essential to capture the heterogeneous pathways through which innovation shapes consumer demand.

Furthermore, the psychological mechanisms through which innovations influence behavior remain underspecified. While TPB provides a general framework, it lacks specificity regarding how different innovation types trigger distinct cognitive and affective responses. The role of value perception as a central mediating mechanism has been largely overlooked in wine innovation literature.

Finally, existing studies rarely account for the contingent nature of innovation adoption. Demographic and behavioral moderators—though theoretically justified through DOI's adopter categories—are rarely subjected to empirical testing within integrated analytical frameworks that account for both psychological and sociological factors.

This research addresses these gaps through three key theoretical advancements:

- Developing a Multidimensional Innovation Framework: Moving beyond monolithic treatments by conceptualizing and measuring four distinct innovation dimensions (Technological, Process, Packaging, Conceptual)
- Proposing an Integrated Mediation Mechanism: Introducing Perceived Value as a central mediating construct that captures the holistic assessment of innovation benefits

- Constructing a Comprehensive Moderating Framework: Systematically testing how demographic factors moderate innovation adoption pathways

These contributions provide a more nuanced theoretical understanding of innovation adoption that accounts for both the multifaceted nature of innovation and the complex psychological processes underlying adoption decisions.

The relevance of a value-based, multidimensional innovation framework is further amplified in the context of emerging markets. Scholars have emphasized that consumer behavior in emerging economies often deviates from patterns observed in mature Western markets, due to differences in institutional development, digital infrastructure, and socio-cultural dynamics (Sheth, 2011). In China, digital platforms such as social commerce and mobile applications play a pivotal role in mediating consumer perceptions of product quality, authenticity, and innovation, thereby shaping perceived value and adoption decisions (Huang & Benyoucef, 2017).

Prior research suggests that in such environments, innovation outcomes are increasingly filtered through digitally enabled experiences rather than evaluated solely on intrinsic product attributes (Zhang et al., 2018). This implies that the effectiveness of innovation depends on how well different innovation dimensions are aligned with platform-mediated value creation processes. By integrating innovation typologies with perceived value and digital consumption dynamics, this study responds to recent calls in Journal of Business Research for more context-sensitive models that explain how innovation translates into consumer behavior in emerging, digitally advanced markets.

2.5 Theoretical，Conceptual Framework and Hypothesis Development

This study establishes its overarching theoretical framework by synthesizing the TPB (Ajzen, 1991) and the DOI theory (Rogers, 2003). This integrated framework, visually represented in Figure 2, outlines the proposed psychological and sociological pathways through which different types of wine innovation influence consumer behavioral intentions. The framework posits a sequential and moderated process:

Innovation Stimuli (input factors): The process is triggered by consumer exposure to one or more of the four distinct dimensions of wine innovation—Technological, Process, Packaging, and Conceptual. According to DOI theory, each dimension possesses a unique profile of perceived attributes (e.g., relative advantage, compatibility, complexity, trialability, observability) that serve as the initial external stimuli.

Cognitive-Affective Appraisal (Mediation & TPB Antecedents): Consumers evaluate these innovation attributes through a cognitive-affective appraisal. This appraisal primarily shapes two core constructs from the TPB: Attitude toward purchasing the innovative wine (a positive or negative evaluation) and Perceived Behavioral Control regarding the purchase (confidence in one's ability to acquire and use it). Additionally, Subjective Norm—the perceived social pressure—is influenced, particularly by innovations that are highly observable (e.g., distinctive packaging) or carry strong social meaning (e.g., sustainability concepts).

Behavioral Intention (result): The combined effect of these three TPB antecedents—Attitude, Subjective Norm, and Perceived Behavioral Control—determines the Behavioral Intention (BI). In this model, BI is defined as the intention to both purchase and recommend the innovative wine.

Moderating Factors: The strength of the relationships described above is not uniform across all consumers. This integrated framework proposes that these pathways are influenced, or moderated, by individual characteristics. These moderators, such as demographics (gender, age, income) and wine-related experience, correspond to the adopter category typology in Rogers' DOI theory, explaining why different consumer segments may respond differently to the same innovation.

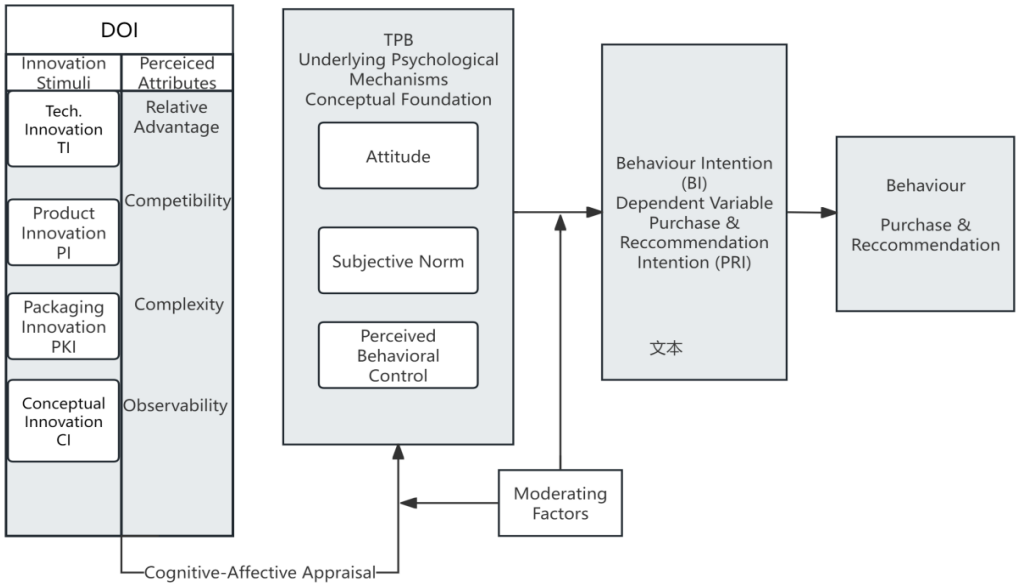

Figure 3 Theoretical Framework

Source: authors' elaboration.

Guided by a synthesized theoretical framework that anchors the TPB as the core psychological mechanism and DOI as the external stimulus source, this study proposes its original conceptual model (see Figure 3)—a model whose novelty lies in specifying four distinct, measurable dimensions of wine innovation (Technological, Process, Packaging, Conceptual), thus moving beyond the generic treatment of innovation in extant literature. This multidimensional conceptualization is aligned with established frameworks for analyzing innovation, such as the taxonomy presented in the Oslo Manual (OECD, 2018), which distinguishes between product, process, marketing, and organizational innovations. Specifically, the four innovation types are hypothesized to shape consumers' potential attitudes, subjective norms, and perceived behavioral control—the core TPB constructs denoted by boxes in the figure, which form the theoretical foundation of this research; these potential evaluation mechanisms, in conjunction with the direct cognitive impacts of innovation, are integrated into and reflected in "perceived value" (PV), the study's measurable core mediating variable; then, PV influences directly the Purchase and Recommendation Intention (PRI), while

solid arrows in the model represent the hypothesized paths H1, H2, and H3. All these relationships are moderated by demographic factors.

This study positions Perceived Value (PV) as a distinct construct that extends beyond the traditional attitude concept in TPB. While attitude represents a general evaluation, PV encompasses a comprehensive assessment of the net benefits (Zeithaml, 1988) derived from innovation across multiple dimensions—functional, social, emotional, and epistemic (Sweeney & Soutar, 2001). This distinction is theoretically significant because:

- Broader Scope: PV captures not just affective evaluation (like attitude) but also cognitive calculations of benefits versus costs.
- Multidimensional Nature: It accounts for diverse value types that different innovation dimensions may activate.
- Contextual Relevance: In experience products like wine, value perceptions often drive decisions more strongly than simple attitudes.

4. By positioning PV as a central mediator, this research enriches the TPB framework to better capture the complex evaluation processes involved in wine innovation adoption. This integrated model allows for a granular investigation of the direct, indirect (mediated), and contingent (moderated) effects of innovation, addressing the identified research gap.

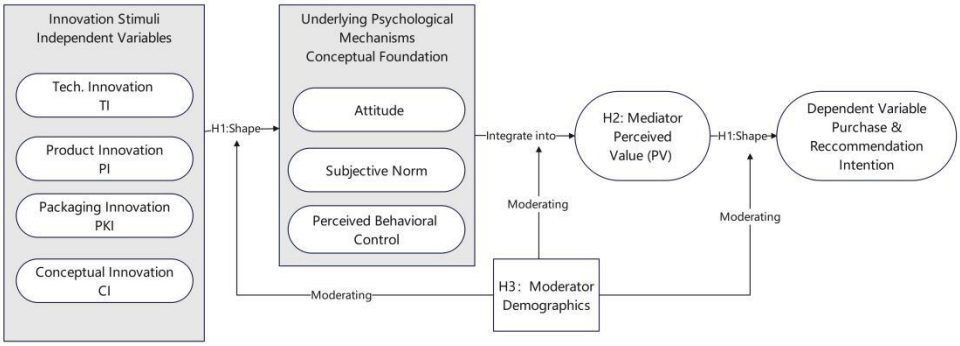

Figure 4 Conceptual Research Model

Source: authors' elaboration.

The Conceptual Research Model (Figure 4) operationalizes the integrated TPB-DOI framework by specifying the key constructs and their hypothesized relationships. The model proposes that four distinct dimensions of wine innovation influence consumers' Perceived Value (PV), with this relationship moderated by demographic factors; then, PV influences directly the Purchase and Recommendation Intention (PRI). The core constructs are defined and operationalized as follows:

Technological Innovation (TI) refers to the application of digital technologies within the wine product or its associated services. This construct captures innovations such as QR codes for traceability, augmented reality (AR) labels, and blockchain platforms that enhance product information access, authenticity verification, and interactive consumer experiences. These innovations range in their degree of technological novelty, a critical factor influencing adoption as discussed in innovation typology literature (Garcia & Calantone, 2002). In the context of this study, TI encompasses elements that enhance the digital interface between the product and the consumer, creating functional and epistemic value. Technological innovation creates functional value by enhancing

transparency and reducing perceived risks. For instance, blockchain-based traceability systems and AR tags provide product information that was previously difficult to access, mitigating information asymmetry. This value creation mechanism is closely tied to trust-building in the digital environment. Wang and Herrando (2019) demonstrated that in social commerce contexts, explicit privacy safeguards can effectively strengthen millennial users' trust, which in turn influences their engagement and perceived value. By the same token, if technological innovations in the wine sector can deliver digital experiences while properly addressing consumers' concerns regarding data privacy and product authenticity—i.e., by providing digital trust—they will be able to boost consumers' perceived value more effectively.

Process Innovation (PI) encompasses novel techniques employed in the viticulture and winemaking stages to improve quality, efficiency, or sustainability. This includes advancements like precision fermentation, sustainable water management, or new filtration technologies that may not be directly visible in the final product but signal production excellence.

Packaging Innovation (PKI) involves innovations in the materials, design, form, and functionality of a wine's primary and secondary packaging. Examples include lightweight glass bottles, alternative packaging formats (e.g., bag-in-box, cans), and smart labels. PKI is often highly observable and carries significant symbolic value.

Conceptual Innovation (CI) represents an innovation in the core product philosophy or positioning, aligning with broader consumer values related to health, well-being, and the environment. This dimension includes concepts such as organic/natural wine production, low-alcohol wine, and wines with specific health-functional claims. The proposition that such value-based innovations influence purchase intentions is supported by research applying the TPB to green consumption, which finds that environmental attitudes and concerns are significant predictors of green purchase intention (Yadav & Pathak, 2017). Therefore, we hypothesize that CI enhances compatibility with consumers' lifestyles and values, thereby positively influencing PRI (H1d).

Perceived value (PV) is defined as a multidimensional construct that reflects consumers' overall assessment of the net benefits derived from innovative wine products. This definition draws on classic consumer value theories (Holbrook, 1999) and specifically references the multi-item scale developed by Sweeney and Soutar (2001), encompassing multiple dimensions including functional value (e.g., quality and cost-performance ratio), social value (e.g., identity recognition and social approval), and emotional value (e.g., sense of pleasure and aesthetic enjoyment). For wine—a typical experiential product—these dimensions collectively constitute the core psychological mechanism underlying consumers' evaluation of innovations. In this study, PV is operationalized as the measure of consumers' importance scores for wine information acquisition channels, along with their willingness levels toward choosing particular offline venues or online platforms to purchase wine, as these channels and platforms are central to value creation and access in the contemporary Chinese market.

This model allows for a granular test of how each specific innovation dimension contributes indirectly through the central mechanism of PV to shape behavioral intentions.

2.5.1. Effects of Innovation Dimensions (H1)

Following these arguments, and building on the conceptual research model, we hypothesize that:

H1: The perception of wine innovation has a significant positive influence on Purchase and Recommendation Intention (PRI).

H1a: Technological Innovation (TI) increases PBC and reduces complexity by enhancing traceability and information access, thereby positively influencing PRI.

HA2: Process Innovation (PI) enhances the relative advantage of the product by signaling quality improvements and production excellence, thereby positively influencing PRI.

H1c: Packaging Innovation (PKI) strengthens subjective norms and social approval through its high observability and symbolic value, thereby positively influencing PRI.

H1d: Conceptual Innovation (CI) enhances compatibility with consumers' lifestyles by aligning with health and environmental values, thereby positively influencing PRI.

2.5.2. Mediating Role of Perceived Value (H2)

Based on the synthesized theoretical framework and conceptual research model, this study positions PV as the central psychological mechanism that explains how and why different innovation dimensions ultimately influence consumers' PRI. The hypothesis for its mediating role (H2) is developed through the following integrated reasoning.

The direct paths proposed in H1 are grounded in the premise that innovation attributes directly influence TPB's antecedents. However, consistent with TPB and consumer value theory, we argue that this influence is channeled through an internal cognitive appraisal where innovations are evaluated for their net benefits. PV embodies this critical appraisal process, defined as the consumer's overall assessment of the net benefits (Zeithaml, 1988) derived from an innovative wine, encompassing functional (e.g., quality, convenience), social (e.g., status, belonging), emotional (e.g., enjoyment, trust), and epistemic (e.g., novelty, knowledge) dimensions (Sweeney & Soutar, 2001).

Therefore, we propose that the influence of each innovation dimension on behavioral intention is not merely direct but is fundamentally channeled through the construct of PV. This mediating role serves as the crucial link that translates the objective or perceived attributes of an innovation (from DOI theory) into a personal motivational state (leading to intention in TPB). For example:

- TI enhances PV by reducing perceived risk and increasing transparency (functional value) and by offering an engaging, novel experience (epistemic value).
- PI builds PV primarily by signaling superior and consistent quality (functional value), which is a core driver in wine appreciation.

- PKI contributes to PV by enhancing aesthetic appeal and gift suitability (emotional & social value) and by communicating modernity or environmental ethos (social value).
- CI boosts PV by aligning with the consumer's personal identities and ethical principles (social and emotional value).

In the context of China's digital-first, experience-driven market, where consumers heavily rely on online platforms for information and purchases, the mediation pathway via PV is particularly salient. The value of an innovation is often co-created and realized through these digital interfaces, a process facilitated by mobile technology that engages consumers in interactive experiences (Zhang et al., 2018). Consequently, the path from innovation exposure to intention is theorized to be significantly indirect, operating through the enhancement of overall perceived value.

Thus, building on the cognitive mediation pathway inherent in TPB and the value-creation perspective, we formalize the following hypothesis:

H2: PV mediates the relationships between TI, PI, PKI, CI and PRI.

This hypothesis posits that the significant positive influences hypothesized in H1a-d will be, at least partially, explained by the positive impact these innovations exert on PV, which in turn strengthens the intention to purchase and recommend.

2.5.3. Moderating Role of Demographic Factors (H3)

Building upon the integrated TPB-DOI framework, this study further posits that the core relationships within the model—between innovation dimensions, PV, and PRI—are not universal but are conditioned by individual consumer characteristics. This proposition is firmly grounded in both constituent theories. The Theory of Planned Behavior (Ajzen, 1991) explicitly acknowledges that background factors, including demographics, can moderate the strength of the relationships between its core constructs (attitude, SN, PBC) and behavioral intention. More directly, the Diffusion of Innovations (DOI) theory (Rogers, 2003) provides a robust sociological foundation by

categorizing consumers into distinct adopter segments (e.g., innovators, early adopters, early majority) based largely on demographic and psychographic variables, asserting that the rate and nature of innovation adoption vary systematically across these groups.

Therefore, we hypothesize that demographic factors act as moderators, altering the strength or even the direction of the paths in our conceptual model. Specifically, we focus on five key demographic variables theorized to be particularly relevant in the context of the Chinese wine market:

- Gender is expected to moderate the relationships, particularly those involving PKI and CI. Given evolving social roles, women in China are often key household decision-makers and may place greater emphasis on aesthetics, health, and social meaning, making them more responsive to innovations that enhance these values.
- Age may challenge conventional assumptions. While younger consumers are often stereotyped as early adopters, older Chinese consumers may have higher disposable income, more wine experience, and greater confidence in evaluating novel offerings, potentially strengthening the impact of TI and PI on their value perception and intentions.
- Income is hypothesized to be a critical moderator, especially for CI and TI, which may associated with premium pricing. Higher income provides the financial capacity to act on positive perceptions and purchase innovative, often higher-value, wine products.
- Education likely influences the cognitive appraisal process. Higher education may enhance a consumer's ability to process complex information about innovations (e.g., technical details of Process Innovation or sustainability claims of Conceptual Innovation), thereby strengthening the path from innovation perception to PV and subsequently to intention.
- Wine Drinking Frequency (as a proxy for product involvement and expertise) is theorized to be a crucial moderator for PI. The benefits of PI (e.g., novel fermentation techniques) are often intangible and require a baseline level of

knowledge to appreciate. Frequent drinkers, with their greater expertise, are expected to exhibit a stronger link between PI and PV/PRI compared to novice drinkers.

In essence, these demographic factors serve as the empirical operationalization of DOI's adopter categories within our integrated psychological model. They specify for whom different innovation pathways exert the strongest effects. This approach aligns with foundational market segmentation theory, which seeks to identify subgroups of consumers who respond differently to marketing stimuli, thereby enabling targeted strategy development (Wedel & Kamakura, 2012). Consequently, we formalize the following overarching hypothesis:

H3: The relationships in the model—specifically, the paths from innovation dimensions to PV and from PV to PRI — are moderated by demographics: (a) Gender, (b) Age, (c) Income, (d) Education, and (e) Wine Drinking Frequency.

This hypothesis posits that the effectiveness of wine innovation in driving PV and PRI is contingent upon the consumer's demographic profile, advocating for a segmented, rather than a one-size-fits-all, approach to innovation strategy in the Chinese market.

3 Research Methodology

3.1 Data Collection and Sample Description

This study utilized a cross-sectional online survey to collect data from Chinese wine consumers. The final dataset comprises 2,016 valid responses collected through a professional online survey platform (Wenjuanxing). The sample was drawn from major urban centers across China, with quotas established to reflect key demographic proportions based on industry market reports of wine consumers.

The sample characteristics (Table 8) indicate a diverse representation of Chinese wine consumers, with a focus on economically active segments (ages 26-45: 65.27%). The sample is predominantly male (55.95%), reflecting current market consumption

patterns, and highly educated (74.8% with college education or higher). Income distribution shows concentration in middle-income brackets (RMB 3,000-9,999: 62.9%), consistent with the target market for premium wine products.

While the online methodology facilitated efficient data collection from geographically dispersed urban consumers, several limitations should be acknowledged: The sample may underrepresent older consumer demographics (56+ comprising only 4.37%) and consumers from lower-tier cities with limited access to digital channels; the cross-sectional design establishes correlations but not causality; self-reported behavioural intentions may diverge from actual purchasing behaviour; the online format may attract more tech-savvy consumers, potentially inflating scores on innovation perception constructs. These limitations are considered in the interpretation of findings and suggest caution in generalizing to the entire Chinese wine-consuming population.

Table 8 Demographic Profile of Respondents (N=2016)

Variable	Category	Frequency	Percentage
Gender	Male	1128	55.952%
	Female	700	34.722%
	Prefer not to say	188	9.325%
Age	18-25	456	22.619%
	26-35	672	33.333%
	36-45	644	31.944%
	46-55	156	7.738%
	56 and over	88	4.365%
Education	Middle school and below	108	5.357%
	High school/vocational school	248	12.302%
	Junior college	684	33.929%

	Undergraduate course	824	40.873%
	Master's degree or above	152	7.54%
Occupation	Corporate staff	848	42.063%
	Student	400	19.841%
	Individuals/ freelancers	392	19.444%
	Civil service/public institutions	276	13.69%
	other	80	3.968%
	retire	20	0.992%
Monthly disposable income (RMB)	＜3000	148	7.341%
	3000-5999	596	29.563%
	6000-9999	672	33.333%
	10000-14999	324	16.071%
	15,000 and above	276	13.69%
Frequency of wine consumption	never	312	15.476%
	Occasionally (less than 1 time/month)	492	24.405%
	Sometimes (1-3 times/month)	432	21.429%
	Frequently (≥1 time per week)	396	19.643%
	Every Day	384	19.048%

Before detailing the measurement of each variable, it is necessary to clarify the measurement conceptualization of the core independent variables, the four innovation dimensions (TI, PI, PKI, CI). This study measures consumers' perceptions and evaluations of specific innovation attributes, rather than their own stable innovation propensity. This distinction is crucial to ensuring the validity of the research conclusions: it avoids the tautological logical logical pitfall that "individuals with a high

innovation propensity may give higher ratings to all innovations," thus allowing us to more purely examine the differentiated effects of different types of innovation as external stimuli.

To clarify potential concerns about tautology—that is, an individual's intrinsic innovative tendency might generalize to the evaluation of all innovations—this study clearly distinguishes between "perceived innovative attributes" and "individual innovative tendency" both conceptually and operationally. According to Rogers' (2003) diffusion theory, the former refers to consumers' cognitive assessment of the relative advantages and compatibility of specific innovations (such as the four types of wine innovations in this study), representing a contextualized response to external stimuli; the latter is a stable personal trait, reflecting their general tendency as adopters. This study's measurement aims to capture the former: we specifically assess the concrete benefits of each innovation through targeted scales (e.g., "environmentally friendly production processes can reduce carbon emissions, energy consumption, and pollution," "oak chips/oak strips replace traditional oak barrels, reducing costs and being environmentally friendly"), rather than broadly measuring whether respondents "like new things." This design allows this study to test the core hypothesis of "how different types of innovation shape consumer intentions through different pathways," rather than simply confirming that "people who are willing to innovate are more likely to buy innovative products." Therefore, our model focuses on the mechanism by which innovation acts as a stimulus to market segments, effectively avoiding the methodological pitfall of conflating innovation attributes with individual traits.

Based on the above conceptual definition, the survey was designed to operationalize all constructs in the conceptual model in accordance with established psychometric measurement principles:

- Independent Variables: TI, PI, PKI, CI

Each construct was measured using multi-item 5-point Likert scales, with items assessing respondents' perceived influence of and agreement with the core attributes of each innovation dimension.

- Mediating Variable: PV

This construct was operationalized to reflect the perceived utility derived from traditional events and advertisements, new media channels, online social platforms, offline purchasing locations, and online e-commerce platforms—all of which facilitate innovation adoption—capturing consumers' cognitive assessments of value across functional, social, emotional, and epistemic dimensions (Sweeney & Soutar, 2001). It was measured using multi-item 5-point Likert scales, with items assessing respondents' perceived value after accounting for all benefits and costs derived from each innovation dimension. This construct incorporates but is not confined to attitudinal orientations, also encompassing cognitive and behavioral components.

- Dependent Variable: PRI

This variable was directly measured using dedicated willingness scales assessing consumers' behavioral intentions toward innovative wine products.

- Moderating Variables:

These were captured through standard demographic questions pertaining to gender, age, education level, household income, and wine drinking frequency.

The survey instrument demonstrated excellent reliability (Cronbach's α=0.959) and construct validity (KMO=0.964), confirming its suitability for the purposes of this study.

Multiple regression analysis was employed to test the direct effects of four innovation dimensions on behavioral intentions, corresponding to Hypothesis 1 (H1). To address potential multicollinearity concerns while preserving theoretical clarity, we conducted separate regression analyses for each innovation dimension, with demographic factors included as control variables. We then utilized bootstrapping procedures to test the

indirect effects of innovation dimensions on intentions through PV, generating robust estimates of the hypothesized mediation effects (Hypothesis 2, H2). Additionally, multi-group structural equation modeling and moderated regression analysis were employed to examine how demographic factors moderate the relationships posited in the conceptual model, thereby testing the moderating effects proposed in Hypothesis 3 (H3). This comprehensive analytical strategy ensures rigorous testing of all theoretical propositions while upholding methodological transparency. The research design directly operationalizes the integrated TPB-DOI framework, as evidenced by the following correspondences:

- The four innovation dimensions correspond to the distinct perceived innovation attributes articulated in DOI theory;
- The measurement of PV captures the cognitive appraisal mechanisms central to the TPB framework;
- The demographic moderators reflect the classic adopter categories derived from DOI theory;
- The analytical sequence mirrors the theoretical causal ordering, progressing from innovation exposure to cognitive appraisal and ultimately to behavioral intention.

This alignment ensures that empirical testing directly addresses the theoretical propositions developed in Section 2.

3.2 Methodological Justification and Analytical Rationale

Our comprehensive strategy, which integrates multiple regression, structural equation modeling (SEM), and moderation analyses, was deliberately designed for robustness, clarity, and complementary insights, rather than representing a fragmented approach.

While a full SEM could simultaneously test all paths, we elected to conduct separate regression analyses for each innovation dimension (H1a-d) primarily to mitigate severe multicollinearity concerns and to achieve superior interpretational clarity. Preliminary

correlation analyses (Appendix C) indicated very high inter-correlations among the four innovation dimensions (ranging from .710 to .779). Including them all in a single model would have inflated standard errors and made it difficult to isolate the unique contribution of each dimension—a key objective of H1. By modeling each dimension separately with demographic controls, we ensured that the reported coefficients (Table 9) reflect the distinct, unique effect of each innovation type on behavioral intention, free from the confounding influence of the others. The low Variance Inflation Factor (VIF < 1.2) in each model confirms that multicollinearity was successfully managed through this approach.

The exclusion of respondents (n=188) who selected "prefer not to say" for gender in specific analyses (i.e., moderation tests involving gender) was a necessary methodological decision to maintain analytical precision and theoretical validity. The core moderating hypothesis (H3a) explicitly aims to compare differences between male and female consumer segments. Including a third, undefined category would have muddied this comparison, making the dummy variable coding (0=Male, 1=Female) logically incoherent and the group comparison in multi-group SEM (MGA) uninterpretable. This exclusion was applied only to analyses requiring a clear gender binary (moderation and MGA). Crucially, these respondents were fully retained in all other analyses (descriptive statistics, correlations, main regressions, and mediation), ensuring their data contributed to the overall picture while allowing for clean tests of gender-specific hypotheses.

The combined use of regression, SEM-based mediation, and multi-group/moderation techniques is a strength, not a contradiction, providing a holistic and robust examination of our complex conceptual model. Regression (for H1) provided the most straightforward and statistically robust test of the unique effects of each highly correlated independent variable. SEM/Mediation Analysis (for H2) was the optimal and established method for testing the indirect pathways through the mediator PV, using bootstrapping to generate accurate confidence intervals for the mediation effects. Multi-Group SEM & Moderated Regression (for H3) offered flexible and powerful tools to

test how demographic factors alter the strength of key relationships (moderation), with MGA being particularly suited for categorical moderators like gender and education groups.

In summary, these analytical decisions were driven by the specific characteristics of our data (high multicollinearity) and the distinct requirements of each hypothesis. They constitute a coherent, complementary suite of tests that collectively provide a more nuanced and defensible empirical validation of our theoretical model than any single method alone could offer.

4 Results

This section presents the empirical findings testing the conceptual model developed in section 2. The analysis proceeds through three main stages: establishing measurement quality, testing direct effects of innovation dimensions on behavioral intentions (H1), and examining the mediating role of Perceived Value (H2) and moderating effects of demographics (H3). To enhance readability, detailed descriptive statistics and comprehensive ANOVA results are presented in the appendices, while the main text focuses on hypothesis testing with clear interpretive commentary for each key finding.

The final dataset comprised 2,016 valid responses from Chinese wine consumers. Detailed demographic characteristics are provided in Appendix 1A.

Key constructs showed moderately positive mean scores (3.01-3.09 on 5-point scales), indicating generally favorable perceptions of wine innovations among respondents. Technological Innovation received the highest average rating (M=3.09), while all constructs demonstrated sufficient variance for statistical analysis. Complete descriptive statistics are available in Appendix Table 1B.

Correlation analysis revealed strong positive relationships between all innovation dimensions and Purchase & Recommendation Intention ($r=0.710$-0.745, $p<0.01$), providing preliminary support for H1. Packaging Innovation showed the strongest

correlation with behavioral intentions (r=0.745), suggesting its particular importance in the Chinese context.

Perceived Value demonstrated strong correlations with all innovation dimensions (r=0.773-0.789) and with behavioral intentions (r=0.743), supporting its potential mediating role (H2). The complete correlation matrix is presented in Appendix Table 1C.

These correlation patterns indicate that different innovation types are perceived as related yet distinct concepts, and that value perception is closely linked to both innovation exposure and behavioral outcomes.

ANOVA results revealed significant demographic differences across all constructs ($p<0.001$), providing preliminary evidence for H3. The most notable patterns include:

- Gender Effects: Female respondents reported consistently higher scores across all innovation dimensions and behavioral intentions, with the largest differences observed for Technological Innovation and Perceived Value
- Age Patterns: Contrary to conventional expectations, older consumers (56+) showed the most positive perceptions, while the youngest group (18-25) was least positive
- Socioeconomic Gradients: Clear positive relationships emerged between education/income levels and innovation acceptance
- Experience Matters: Frequent wine drinkers demonstrated significantly higher innovation appreciation than occasional or non-drinkers

Complete ANOVA results with detailed mean comparisons are provided in Appendix Table 1D.

These demographic variations underscore the need for segmented marketing approaches and suggest that innovation adoption follows complex patterns beyond simple age-based stereotypes.

4.1 Testing Direct Effects: Innovation Dimensions on Behavioral Intentions (H1)

To test H1 while addressing multicollinearity concerns, we conducted separate regression analyses for each innovation dimension while controlling for demographic factors. This approach allows clear interpretation of each innovation type's unique contribution to behavioral intentions. Each regression model was specified as follows, where innovation accounts for TI, PI, PKI and CI.

$$PRI = \beta_0 + \beta_1(Innovation) + \beta_2(Gender) + \beta_3(Age) + \beta_4(Education) + \beta_5(Income) + \beta_6(Drinking\ Frequency) + \varepsilon$$

Where the control variables were operationalized as: Gender (dummy: 1=Female, 0=Male), Age (continuous), Education (ordinal: 1=Middle school to 5=Master's+), Income (ordinal: 1=<3000 to 5=≥15000), Drinking Frequency (ordinal: 1=Never to 5=Daily). The results of the four regression analyses are presented in Table 9.

Table 9 Regression Analysis of Innovation Dimensions on Behavioral Intentions

Variable	Model 1: TI	Model 2: PI	Model 3: PKI	Model 4: CI
Innovation Dimension				
Technological Innovation (TI)	0.682*** (0.019)	-	-	-
Process Innovation (PI)	-	0.654*** (0.020)	-	-
Packaging Innovation (PKI)	-	-	0.695*** (0.019)	-
Conceptual Innovation (CI)	-	-	-	0.683*** (0.019)
Control Variables				

Variable	Model 1: TI	Model 2: PI	Model 3: PKI	Model 4: CI
Gender (Female=1)	0.184***	0.192***	0.178***	0.186***
	(0.032)	(0.033)	(0.032)	(0.032)
Age	0.045**	0.048**	0.042*	0.046**
	(0.017)	(0.017)	(0.017)	(0.017)
Education	0.038*	0.041*	0.036*	0.039*
	(0.018)	(0.018)	(0.018)	(0.018)
Income	0.052**	0.049*	0.054**	0.051**
	(0.019)	(0.019)	(0.019)	(0.019)
Drinking Frequency	0.067***	0.064***	0.069***	0.066***
	(0.016)	(0.016)	(0.016)	(0.016)
Model Statistics				
R^2	0.598	0.586	0.612	0.601
Adjusted R^2	0.596	0.584	0.610	0.599
F-value	298.45***	283.92***	317.68***	302.17***
VIF (Innovation var.)	1.12	1.15	1.09	1.11

*Note: Unstandardized coefficients reported with standard errors in parentheses. *p<.05, **p<.01, ***p<.001*

The regression results provide strong support for H1, with all four innovation dimensions demonstrating significant positive effects on Purchase & Recommendation Intention ($p<0.001$). The regression coefficients reveal a clear hierarchy of influence among innovation types: Packaging Innovation ($\beta=0.695$) emerges as the strongest predictor, highlighting the visual and symbolic importance of wine presentation in China's market. Conceptual and Technological Innovations show very similar strong effects ($\beta=0.683$ and 0.682), indicating that both value-based positioning and digital features significantly drive adoption. Process Innovation, while still highly significant ($\beta=0.654$), has a relatively smaller impact, suggesting that production methods are less immediately visible or compelling to consumers.

The control variables reveal important contextual patterns: female consumers and frequent drinkers show stronger behavioral intentions, while socioeconomic factors (income, education) demonstrate consistent but modest effects.

The Variance Inflation Factor (VIF) for each innovation dimension in its respective model is well below 2, confirming that multicollinearity is not an issue in this separate modeling approach. All models show strong explanatory power, with R^2 values ranging from 58.6% to 61.2%.

Therefore, H1 is fully supported through this more robust analytical approach. Each dimension of innovation significantly positively influences purchase and recommendation intention, with Packaging Innovation having the strongest unique effect when considered in isolation with demographic controls.

4.2 Testing for Mediation and Moderation (H2 & H3)

Mediation analysis using bootstrapping procedures tested whether Perceived Value explains how innovations influence behavioral intentions. The results (Table 10) provide consistent support for H2 across all innovation dimensions. The mediation results reveal that Perceived Value acts as a complementary partial mediator for all innovation types. This means that innovations influence purchase intentions both directly and indirectly through enhanced value perception. The significant indirect effects (all $p<0.001$) confirm that consumers evaluate innovations based on the net value they provide. Technological and Conceptual Innovations show the strongest mediation effects, suggesting they are particularly dependent on value perception.

The persistent direct effects indicate that innovations also create immediate appeal beyond calculated value assessments.

This pattern aligns with our theoretical framework, where Perceived Value serves as the central cognitive mechanism translating innovation exposure into behavioral intentions.

Table 10 Mediation Analysis Results via Perceived Value

Model(X→M→Y)	Path	Coefficient	BootSE	BootLLCI	BootULCI	Significance
Tech. Innovation → PV → PRI	a (TI → PV)	0.789	0.018	0.754	0.824	Significant
	b (PV → PRI)	0.743	0.019	0.706	0.780	Significant
	Indirect (a*b)	0.586	0.023	0.542	0.632	Significant
	Direct (c')	0.149	0.051	0.049	0.249	Significant
Process Innovation → PV → PRI	a (PI → PV)	0.774	0.019	0.737	0.811	Significant
	b (PV → PRI)	0.743	0.019	0.706	0.780	Significant
	Indirect (a*b)	0.575	0.023	0.531	0.621	Significant
	Direct (c')	0.106	0.051	0.006	0.206	Significant
Packaging Innovation → PV → PRI	a (PKI → PV)	0.773	0.018	0.738	0.808	Significant
	b (PV → PRI)	0.743	0.019	0.706	0.780	Significant
	Indirect (a*b)	0.574	0.022	0.531	0.618	Significant

Model(X→M→Y)	Path	Coefficient	BootSE	BootLLCI	BootULCI	Significance
Conceptual Innovation → PV → PRI	Direct (c')	0.274	0.047	0.182	0.366	Significant
	a (CI → PV)	0.789	0.018	0.754	0.824	Significant
	b (PV → PRI)	0.743	0.019	0.706	0.780	Significant
	Indirect (a*b)	0.586	0.023	0.542	0.632	Significant
	Direct (c')	0.166	0.054	0.060	0.272	Significant

Note: N=2,016. Unstandardized coefficients are reported. Boot LLCI and Boot ULCI represent the lower and upper limits of the 95% bias-corrected bootstrap confidence interval based on 5,000 samples. The indirect effect is significant if the CI does not contain zero.

Moderation analysis examined how demographic factors condition the relationships in our model. The results (Table 11) provide comprehensive support for H3, revealing several important segmentation insights.

The moderation results reveal that innovation effectiveness is strongly contingent on consumer characteristics:

Gender Segmentation: Multi-group analysis revealed a significant gender difference in the impact of packaging innovation on purchase intention ($\Delta\chi^2 = 12.35$, $p < .001$). Specifically, the effect was significantly stronger in female consumers ($\beta = 0.341$, $p < .001$) than in male consumers ($\beta = 0.201$, $p < .01$). The effect size for female consumers was approximately 1.7 times that for male consumers, suggesting that

packaging innovation may have particularly strong marketing effectiveness when targeting the female market segment.

Age Paradox: Technological innovation effects increase with age, challenging assumptions that digital features primarily appeal to younger consumers.

Income Sensitivity: Conceptual innovations (e.g., organic, sustainable) show stronger effects among higher-income segments, indicating premium positioning opportunities.

Knowledge Dependency: Process innovations only significantly influence frequent drinkers, suggesting they require wine expertise to appreciate.

Education Effects: Highly educated consumers' purchase decisions are more strongly driven by value calculations.

These findings emphasize the need for precisely segmented innovation strategies rather than one-size-fits-all approaches.

Table 11 Summary of Moderation Effects

Moderator	Variable Tested	Analysis Method	Group / Interaction Term	Result	Support for H3?
Gender	PKI → PRI	MGA (SEM)	Male Group (n=1128)	β=0.201, p<.01	Supported
			Female Group (n=700)	β=0.341, p<.001	
			$\Delta\chi^2$ (1)	12.35, p<.001	
Age	TI → PRI	Mod. Regression	TI * Age	b=0.184, p<.001	Supported
Income	CI → PRI	Mod. Regression	CI * Income	b=0.156, p=.003	Supported

Education	PV → PRI	MGA (SEM)	Bachelor's & Below (n=1756)	β=0.682, p<.001	Supported
			Master's & Above (n=152)	β=0.801, p<.001	
			$\Delta\chi^2$ (1)	5.92, p=.015	
Drinking Frequency	PI → PRI	MGA (SEM)	Low Frequency (n=1236)	β=0.088, p=.112	Supported
			High Frequency (n=780)	β=0.192, p=.004	
			$\Delta\chi^2$ (1)	4.11, p=.043	
Note: MGA=Multi-Group Analysis; Mod. Regression=Moderated Regression; $\Delta\chi^2$ represents the chi-square difference test between constrained and unconstrained models.					

5 Discussion

Overall, our empirical results provide strong support to all hypotheses. The results demonstrate that innovation drives demand through multiple pathways, with effectiveness contingent on both the type of innovation and consumer characteristics. The hierarchical importance of innovation dimensions (Packaging > Conceptual ≈ Technological > Process) provides strategic guidance for resource allocation, while the mediation and moderation findings offer insights into the underlying psychological and demographic mechanisms.

Table 12 provides a comprehensive summary of hypothesis testing results, confirming the robustness of our theoretical model in explaining Chinese consumers' responses to wine innovations.

Table 12 Comprehensive Hypothesis Testing Summary

Hypothesis	Relationship Tested	Result	Support
H1	Innovation → PRI	Significant	Yes
H1a	TI → PRI	β= 0.149, p=0.003	Yes
H1b	PI → PRI	β= 0.106, p=0.030	Yes
H1c	PKI → PRI	β= 0.274, p<0.001	Yes
H1d	CI → PRI	β= 0.166, p=0.001	Yes
H2	PV mediates TI, PI, PKI, CI → PRI	All indirect effects significant	Yes
H3	Demographics moderate model paths	Multiple significant interactions	Yes

5.1 Theoretical Alignment with DOI Innovation Attributes

The strong support for H1 confirms our theoretical proposition that different innovation dimensions serve as distinct external stimuli that shape behavioral intentions. The hierarchy of influence—Packaging Innovation (β=0.274) > Conceptual Innovation (β=0.166) ≈ Technological Innovation (β=0.149) > Process Innovation (β=0.106)—directly reflects DOI theory's emphasis on innovation attributes. Packaging Innovation's dominance aligns with its high observability and compatibility with China's gift-giving culture, while Process Innovation's weaker effect corresponds to its lower trialability and higher complexity for average consumers.

The visual and symbolic nature of Packaging Innovation in China creates immediate social visibility (observability) that strongly influences subjective norms—a core TPB

construct. These finding challenges Western wine markets where production methods often carry more weight, revealing culturally distinct innovation adoption patterns.

Notably, PKI emerged as the strongest predictor (β=0.274, p<0.001). This aligns with the visual and symbolic nature of consumption in China, where packaging serves as a critical signal of quality, modernity, and environmental responsibility (Li & Hasan, 2025; Zhou & Bai, 2025). This effect is particularly potent within China's digital ecosystem, where the design of social commerce interfaces—including visual presentation and social proof—is known to significantly sway purchase decisions (Huang & Benyoucef, 2017). Innovations like lightweight bottles, eco-friendly materials, and AR-enabled labels are highly visible and easily communicable, enhancing both functional and social value. CI, particularly organic certification, low-alcohol, and eco-friendly production, also showed a very strong influence (β=0.166, p=0.001). This reflects a growing consumer consciousness around health, wellness, and sustainability, a trend accelerated by the COVID-19 pandemic (Sun et al., 2021; Qi & Ploeger, 2021). Consumers increasingly seek products that align with their personal values, and CI powerfully addresses this need.

TI (β=0.149, p=0.003) and PI (β=0.106, p=0.030), while significant, had comparatively smaller unique effects. This suggests that while appreciated, their benefits might be less immediately tangible or require more consumer education. The complexity of some technological features (e.g., blockchain) might slightly hinder adoption, as predicted by DOI theory (Rogers, 2003), though their strong correlation with PV indicates they significantly enhance value perception.

5.2 Perceived Value as Theoretical Bridge between TPB and DOI

The mediation results (H2) validate our core theoretical contribution: positioning Perceived Value as the cognitive mechanism that translates innovation attributes (DOI) into behavioral intentions (TPB). The significant indirect effects across all innovation

types (β=0.574-0.586) demonstrate that innovations are not adopted based on features alone, but through the value perceptions they generate.

Perceived Value serves as the 'missing link' that explains how external innovation characteristics become internalized as purchase motivations. This bridges the sociological perspective of DOI with the psychological focus of TPB, creating a more comprehensive theoretical framework for innovation adoption. This view is consistent with the TPB, where PV can be seen as a core component shaping Attitude Toward the Behavior (Ajzen, 1991, 2020). For Chinese wine consumers, the value derived from innovation is a composite of functional, social, emotional, and epistemic benefits.

This emphasis on value creation through innovation is not unique to China. Studies in mature markets like Italy also highlight the importance of perceived value and the role of certifications (e.g., organic, ISO 14000) in driving innovation adoption, albeit often driven more by export orientation and stringent regulatory environments (Stasi et al., 2016). Similarly, research in France, a classic Old World wine country, underscores the paramount importance of 'Region of Origin' as a key driver of perceived value and consumer choice, a value that innovative marketing strategies must carefully align with to be effective (Perroutyet al., 2006). However, a key differentiator in the Chinese context is the rapid integration of digital platforms (e.g., Douyin, Xiaohongshu) into the value perception process, which is less pronounced in traditional European markets. The significant role of information and purchase platforms in the PV construct highlights that the channel through which innovation is delivered and explained is itself a critical part of the value proposition in China's digital-first ecosystem. Within China’s digital-first ecosystem, information and purchasing platforms themselves constitute key components of value propositions. This finding echoes the work of Xie et al. (2014), who confirmed that online consumer reviews and managerial responses yield significant commercial value—given that such user-generated content and brand interactions serve as critical sources of information and foundations of trust for consumers to evaluate products and form perceived value. In the Chinese wine market, product reviews, sharing posts, and brand interactions on social commerce platforms

such as Douyin and Xiaohongshu function not only as channels for disseminating innovation-related information, but also as venues for value co-creation and validation, exerting a substantial impact on consumers' perceived value.

This study confirms the core mediating role of perceived value in the innovation adoption process, thereby enriching our understanding of the driving mechanisms of innovation. This finding echoes recent literature on consumer relationships; for instance, Hollebeek et al. (2022) emphasize the pivotal role of value in driving customer engagement and long-term loyalty. Future research could further explore whether and how different types of wine innovations (such as the four dimensions distinguished in this study) influence deeper-level consumer relationship constructs—such as brand engagement or repurchase behavior—through perceived value, so as to verify the relationship between innovation and value creation over a longer time horizon.

5.3 Demographic Moderators: Challenging Conventional Segmentation Wisdom

The ANOVA results provided powerful and consistent preliminary support for H3, revealing that the acceptance of innovation is profoundly shaped by consumer demographics. These results confirm our theoretical expectation, derived from DOI theory's adopter categories and TPB's background factors, that demographic characteristics systematically moderate how innovations are perceived and adopted across different consumer segments. This aligns with research on consumer innovativeness, which has established significant correlations between adoption tendencies and demographic profiles (Bartels & Reinders, 2011). This granular understanding is vital for effective market segmentation.

The significantly higher scores among female respondents across all constructs challenge any outdated notion that wine is a male-dominated domain in China. Women appear to be the primary drivers of innovation adoption, likely due to their roles as key household purchasers and their greater attunement to health, aesthetics, and storytelling

in products. This suggests marketing strategies should specifically target and resonate with female consumers.

Secondly, contrary to common assumptions that younger consumers are the most innovative, the results showed that older consumers (56+) held the most positive views. This cohort, likely with higher disposable income, more wine experience, and greater confidence, appears more open to premium and novel wine experiences (Barber et al., 2012). Younger consumers (18-25) were the least positive, possibly due to less knowledge, lower income, or stronger preferences for other beverages. This indicates that innovation should not solely target the youth market.

Moreover, the clear positive gradients associated with higher education and income are intuitive yet critical. They highlight that appreciating innovation often requires cognitive resources, cultural capital, and the financial means to act on positive perceptions (Chen & Shen, 2023). Innovation, at least initially, may be a strategy best targeted at the premium market segment.

Finally, the strong link between wine involvement (frequency of consumption) and positive perceptions of innovation validates the notion that familiarity breeds curiosity. Frequent drinkers seek novelty to avoid boredom and have the knowledge to appreciate subtle innovations in process or technology (Yuan et al., 2025). For novice drinkers, reducing complexity and enhancing trialability are key.

The strong support for H3 confirms DOI theory's premise that innovation adoption varies systematically across population segments. However, several findings challenge conventional marketing assumptions (see Table 13):

- Gender Revolution: The effect size for female consumers was approximately 1.7 times that for male consumers, suggesting that packaging innovation may have particularly strong marketing effectiveness when targeting the female market segment.

- Age Paradox: Older consumers' greater receptivity to Technological Innovation contradicts the youth-tech stereotype, reflecting their higher disposable income and wine experience.
- Knowledge Barrier: Process Innovation's dependence on wine drinking frequency validates the expertise threshold for appreciating technical innovations.

The Chinese wine market represents a unique scenario where traditional innovation adoption curves are inverted. Rather than following Rogers' (2003) classic early adopter profile, innovation acceptance here is driven by older, female, and experienced consumers—suggesting market-specific adoption patterns that demand customized theoretical models.

Table 13 Evidence-Based Consumer Segmentation for Wine Innovation

Segment	Innovation Priority	Communication Channel	Key Message
Female Professionals	Packaging & Conceptual	Social Commerce (Xiaohongshu)	"Elevate your lifestyle with sustainable luxury"
Experienced Drinkers (55+)	Technological & Process	WeChat Official Accounts	"Discover the story behind your wine"
High-Income Urbanites	Conceptual & Packaging	Premium E-commerce	"Values that match your standards"
Young Enthusiasts	Packaging & Technological	Douyin/Short Video	"The new way to experience wine"

5.4 Strategic and Global Implications for China's Wine Innovation Ecosystem

The findings of this study reveal that innovation has emerged as a central driver of competitiveness in the Chinese wine market, with important implications for both

domestic producers and international entrants. The dominance of Packaging and Conceptual Innovation demonstrates that Chinese consumers respond strongly to innovations that enhance symbolism, convenience, sustainability, and cultural resonance. This mirrors evidence from Old World markets that product cues can significantly shape value perceptions—such as the established importance of region-of-origin cues documented in France (Perroutyet al., 2006). However, in China these cues are increasingly complemented—or even superseded—by consumer-facing innovations in packaging and concept positioning. Firms seeking market growth should therefore invest in translating technical or process improvements into innovations that are legible, visible, and meaningful to consumers.

The demographic moderation results further highlight the emergence of distinct consumer segments whose responsiveness to innovation varies sharply. The greater receptivity of older and female consumers challenges traditional adopter stereotypes. This reinforces the need for tailored innovation strategies delivered through China's sophisticated digital ecosystems. Unlike in Italy, where innovation diffusion is strongly producer-driven—shaped by firm size, export orientation, and B2B collaboration (Stasi et al., 2016)—the Chinese model is fundamentally demand-pull. This aligns with Italian evidence showing the critical role of vertical collaboration in advancing eco-innovation (Muscio et al., 2017) but suggests that in China, the most powerful collaborations may be those between producers and digital platforms that directly mediate consumer perceptions.

Positioning these results within a global context reinforces the distinctiveness of China's innovation trajectory. Unlike Old World models such as France or Italy—where heritage, terroir, and producer authority dominate innovation narratives—or New World examples such as Chile and Argentina, where institutional actors and exogenous forces like foreign investment have historically shaped innovation paths (Kunc & Tiffin, 2008; Farinelli, 2013), China's ecosystem is defined by consumer-centric, digitally accelerated, and market-responsive innovation dynamics. In contrast to Italy's producer-driven model and Chile's institutionally supported model (Farinelli,

2013; Kunc & Tiffin, 2008), China's model is driven primarily by innovation's ability to elevate Perceived Value in the eyes of highly segmented, digitally networked consumers.

This creates an environment in which successful innovations combine cultural adaptation, aesthetic appeal, digital storytelling, and clear value communication. This reflects a broader shift towards leveraging digital platforms for experience-based value co-creation, a trend observed in how mobile technology engages younger consumers (Zhang et al., 2018). International producers seeking entry into China must therefore recalibrate conventional terroir-based or technical-quality narratives and instead prioritize innovations that resonate with local consumer identities and are optimized for digital channels. China's digitally mediated, consumer-driven paradigm may also signal the future direction of global wine markets as other countries confront similar shifts toward algorithmic targeting, online social validation, and hybrid product–experience value creation.

Ultimately, China represents neither a classic Old World nor New World innovation model, but a third paradigm—a demand-pull, digitally filtered, consumer-centered innovation ecosystem. This distinct structure underscores the need for a customized innovation playbook in China and suggests that insights from its market may increasingly inform the global evolution of innovation strategies in the wine industry.

In summary, the "digitally enabled, demand-pull" innovation paradigm in China revealed by this study is highly consistent in essence with the service-dominant logic advocated by Vargo and Lusch (2008). Within this logic, value is not solely created by enterprises and then delivered to consumers; instead, it is co-created through interactive processes in which consumers use products or services. China's digital platforms (e.g., social commerce platforms and content communities) have precisely provided an unprecedentedly rich array of scenarios for such interactions and value co-creation. Therefore, successful innovation entails not only the introduction of new technologies or concepts, but also the design of digital experiences that facilitate consumer interaction, participation, and dialogue, thereby maximizing value through co-creation

with consumers. This finding offers a new strategic perspective that transcends traditional product innovation thinking for wine enterprises in China and around the world.

6 Conclusions

This study has systematically investigated the impact of multidimensional innovation on wine demand in the rapidly evolving Chinese market. By integrating TPB and DOI, this research has developed and empirically validated a comprehensive framework explaining how different innovation types shape consumer behavior in China's increasingly digital and consumer-driven wine ecosystem.

The primary theoretical contribution of this research lies in its multidimensional conceptualization of wine innovation. By distinguishing four innovation dimensions—Technological, Process, Packaging, and Conceptual—the study demonstrates that these categories exert markedly different levels of influence on consumer purchase and recommendation intentions. Packaging Innovation emerged as the strongest driver, followed by Conceptual, Technological, and Process Innovations.

A second major contribution is the identification of Perceived Value as the central psychological mechanism mediating the relationship between innovation and consumer behavior. This finding bridges the sociological foundations of DOI with the psychological focus of TPB, revealing that innovations influence consumers not through technical features alone but through value perceptions constructed during evaluation.

Third, this study provides new evidence that innovation adoption patterns in China diverge sharply from conventional DOI assumptions. Older consumers (56+) exhibited stronger receptivity to innovation than younger groups, particularly toward technological improvements, and female consumers emerged as key drivers of

innovation adoption. These patterns support the development of market-specific rather than universal models of innovation diffusion.

The findings position China as representing a distinct third paradigm in global wine innovation—one that differs fundamentally from Old World producer-driven models and New World institutionally-driven approaches. China's wine market operates as a digitally-enabled, demand-pull ecosystem in which success depends on aligning specific innovation types with clearly segmented consumer demographics through digital platforms.

For industry practitioners, several strategic implications emerge. The demonstrated hierarchy of innovation effectiveness indicates that firms should prioritize packaging and conceptual innovations for mass-market appeal while deploying technological and process innovations for targeted high-value segments. The strong moderating effects of demographic variables underscore the limitations of one-size-fits-all innovation strategies and highlight the need for precision targeting based on age, gender, income, education, and involvement level.

Despite its contributions, the study contains several limitations that open valuable pathways for future research. First, the cross-sectional design identifies associations but does not establish causality; longitudinal designs would clarify how innovation perceptions and adoption evolve over time. Second, while online sampling effectively captures digitally engaged consumers, it may underrepresent less digitally active populations; mixed-method sampling would enhance representativeness. Third, reliance on self-reported behavioral intentions limits insight into actual purchasing behavior, suggesting the need for studies incorporating field experiments or transaction data.

Future research should examine additional mediating variables such as perceived risk, brand trust, or emotional value, which may further illuminate the psychological mechanisms underlying innovation adoption. Studies investigating cultural moderators—such as modern versus traditional values—could deepen understanding of

value-driven heterogeneity in innovation receptivity. Cross-national comparisons across Asia or other emerging markets would help determine whether China's innovation hierarchy and consumer patterns are generalizable or context-specific.

As China's wine market continues to mature, longitudinal research should track how the relative effectiveness of innovation types changes over time. Examining interaction effects among innovation dimensions (e.g., how packaging and conceptual innovations reinforce one another) would provide guidance for optimizing innovation portfolios. Research into price sensitivity across innovation types would also offer insight into how consumers reconcile value perceptions with willingness to pay.

Taken together, these research directions will further refine theoretical models of innovation adoption and support industry practitioners navigating an increasingly dynamic and innovation-driven marketplace. More broadly, the findings reaffirm that innovation is a powerful but nuanced strategic lever whose effectiveness in China is shaped by multidimensional attributes, psychological mediation processes, and demographic contingencies. As global wine markets move toward more consumer-centric and digitally integrated structures, the Chinese innovation paradigm identified in this study may foreshadow broader shifts in the global industry's future development.

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Appendix

Table 1A Detailed Demographic Profile

Variable	Category	Frequency	Percentage
Gender	Male	1128	55.952%
	Female	700	34.722%
	Prefer not to say	188	9.325%
Age	18-25	456	22.619%
	26-35	672	33.333%
	36-45	644	31.944%
	46-55	156	7.738%
	56 and over	88	4.365%
Education	Middle school and below	108	5.357%
	High school/vocational school	248	12.302%
	Junior college	684	33.929%
	Undergraduate course	824	40.873%
	Master's degree or above	152	7.54%
Occupation	Corporate staff	848	42.063%
	Student	400	19.841%
	Individuals/ freelancers	392	19.444%
	Civil service/public institutions	276	13.69%
	other	80	3.968%
	retire	20	0.992%
	＜3000	148	7.341%

Monthly disposable income (RMB)	3000-5999	596	29.563%
	6000-9999	672	33.333%
	10000-14999	324	16.071%
	15,000 and above	276	13.69%
Frequency of wine consumption	never	312	15.476%
	Occasionally (less than 1 time/month)	492	24.405%
	Sometimes (1-3 times/month)	432	21.429%
	Frequently (≥1 time per week)	396	19.643%
	Every Day	384	19.048%

Table 1B Complete Descriptive Statistics

Construct	N	Min	Max	Mean	Std.Dev.
Conceptual Innovation (CI)	2016	1	5	3.01	1.01
Packaging Innovation (PKI)	2016	1	5	3.06	1.03
Process Innovation (PI)	2016	1	5	3.01	1.03
Technological Innovation (TI)	2016	1	5	3.09	1.04
Perceived Value (PV)	2016	1	5	3.05	0.99
Purchase and recommendation willingness	2016	1	5	3.08	1.07

Table 1C Complete correlation matrix

	1	2	3	4	5	6
1. CI	1					

	1	2	3	4	5	6
2. PKI	.745**	1				
3. PI	.779**	.710**	1			
4. TI	.763**	.740**	.778**	1		
5. PV	.789**	.773**	.774**	.789**	1	
6. PRI	.735**	.745**	.710**	.727**	.743**	1

Note: Correlation is significant at the 0.01 level (2-tailed).

Table 1D Comprehensive ANOVA Results

Construct	Male(n=1128)		Female(n=700)		Prefer not to say(n=188)		F-value	p-value
	Mean	SD	Mean	SD	Mean	SD		
CI	2.569	0.899	3.505	0.843	3.787	0.906	81.356	0.000***
PKI	2.617	0.924	3.546	0.858	3.915	0.868	81.529	0.000***
PI	2.613	0.924	3.493	0.917	3.644	0.931	61.270	0.000***
TI	2.597	0.910	3.657	0.822	3.932	0.868	103.607	0.000***
PV	2.590	0.826	3.588	0.774	3.792	0.773	108.905	0.000***
PRI	2.609	0.948	3.556	0.906	4.128	0.818	90.486	0.000***

***P<0.001

Chapter 3 Navigating New Terroirs: An Integrated Analysis of Italian Wine Firms' Commercial Strategies, Innovation Trajectories, and Market Entry Potential in China

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Abstract

This study provides a triangulated assessment of the Italian wine sector's readiness to engage with the Chinese market. Using a proprietary 2024 survey of 387 Italian wine firms, we identify a marked strategic misalignment between Italian supply-side strategies and Chinese demand dynamics. Italian firms continue to rely on traditional channels such as Ho.Re.Ca. and Western social media, while the Chinese market is dominated by integrated e-commerce platforms (e.g., Tmall, JD.com) and social commerce ecosystems (e.g., Douyin). Innovation efforts likewise remain concentrated on enological techniques and packaging, with limited adoption of Industry 4.0 technologies. In contrast, Chinese consumers show strong preferences for digital traceability, interactive labels, and health-oriented innovations. Econometric analysis reveals that perceived barriers to innovation form a systemic latent construct which, together with firms' embeddedness in the domestic wine system, significantly predicts organizational resistance to change. The findings indicate that successful market entry requires a dual strategy of Digital Acculturation and Innovation Alignment.

Keywords: Strategic Misalignment, Digital Acculturation, Innovation Alignment, Wine Internationalization, China Market Entry

1 Introduction

The strategic challenge of entering new markets often lies in aligning a firm's internal capabilities with the specific demands of the foreign ecosystem. This challenge is acutely felt by Old World wine producers, such as those in Italy, as they target the complex and rapidly growing Chinese market. China has not only ascended to become a top global wine consumer but has also forged a unique digital-first marketplace, fundamentally distinct from traditional European models (Asia Beverage Media Group, 2021). Many Western businesses are eager to better understand Chinese consumer culture in order to tap into the growing Chinese market comprising 1.4 billion consumers. When it comes to export opportunities and market penetration by Western companies, e-commerce and social media platforms play an increasingly significant role (McQueenie et al., 2024). The Chinese wine consumer's journey is increasingly mediated through integrated social commerce platforms like Douyin and Xiaohongshu, where discovery, community engagement, and transaction converge (Liu & Mu, 2021; Zhang & Benyoucef, 2016). (Du & Morrish， 2025).The short video sharing platform Douyin, which is better known outside of China as TikTok, is regarded by many marketing advisories as one of the most significant platforms businesses should consider (McQueenie et al., 2024). Concurrently, Chinese consumer values are evolving, showing strong inclinations toward innovations that guarantee authenticity (e.g., blockchain traceability)(Kang at al., 2023; Ismailvo & Mammadzada, 2025), offer immersive experiences (e.g., AR/VR), and align with health and wellness trends (Liu & Murphy, 2007). Extant literature has provided valuable but segmented insights into this multifaceted scenario. One strand of research has examined innovation dynamics in the wine sector, emphasizing the role of firms' absorptive capacity and collaborative networks, while also pointing to structural rigidities and the relative insularity of traditional wine-producing regions such as Italy (Stasi et al., 2016). In parallel, a substantial body of literature has analyzed the distinctive features of Chinese consumers

and the architecture of China's digital marketplace (Somogyi et al., 2011), identifying online marketing and platform-based strategies as transformative forces for the industry (Asia Beverage Media Group, 2021). Wine marketing scholarship has further highlighted the enduring importance of terroir, brand heritage, and distribution channels (Atkin & Thach, 2012; Capitello et al., 2014), while studies on industry innovation have predominantly concentrated on technological adoption in viticulture and vinification, alongside the influence of firm size and regional networks. Concurrently, a growing body of research has begun to unravel the unique characteristics of the Chinese wine market, emphasizing the centrality of e-commerce, social media, and a growing interest in wine education and provenance (Liu & Murphy, 2007). However, few studies have undertaken an integrated, data-driven examination that directly contrasts the internal capabilities and strategies of Old World producers with the specific, empirically-grounded demands and behaviors of the New World consumer：How do the channel structures of Italian firms align with Chinese purchasing habits? To what extent does the innovation portfolio of Italian wineries resonate with the preferences of Chinese consumers? What internal barriers hinder the necessary adaptation?

To answer these questions, we leverage a unique 2024 dataset from a survey of 387 Italian wine companies. The Chinese consumer data, against which the Italian firm data is benchmarked, is drawn from the study carried out by Wang et al. (2025). This dataset comprises 2,016 valid responses from Chinese consumers, collected via an online survey using purposive and quota sampling to reflect the demographics of the potential wine-buying population. Our analysis is structured around a comparative framework that juxtaposes firm-level data on channels and innovation with consumer-level data from China. We first benchmark Italian channel strategies and innovation portfolios against Chinese market realities. We then employ a Structural Equation Model (SEM) to statistically validate the latent constructs of "Innovation Barriers" and "Wine System," and to examine their influence on "Organizational Change".

Our findings reveal a significant strategic disconnect, which we frame as a dual misalignment in channel architecture and innovation priorities. To fill this gap, this

study's core theoretical contribution is the development of an integrated strategic framework for market entry, built on the twin pillars of "Digital Acculturation"—the process of adapting to China's unique digital ecosystem—and "Innovation Alignment"—the re-orientation of R&D towards Chinese consumer values. This framework provides an actionable roadmap for firms and contributes a novel model to the literature on international marketing and agricultural innovation systems.

2 Literature Review

2.1 The Supply-Side Perspective: Firm Innovation, Collaboration, and Capability Constraints

Innovation is widely recognized as a critical driver of competitiveness in the wine industry. Research on Italian wineries reveals a distinctive pattern of innovation adoption, heavily influenced by firm-internal capabilities and constrained by structural and collaborative factors. Italian wine firms actively innovate, but their efforts are often concentrated in traditional areas such as winemaking techniques, packaging, and energy efficiency (Stasi et al., 2016). This aligns with a focus on process and product innovation aimed at enhancing quality and reducing costs. A more nuanced understanding emerges from the literature on eco-innovation, which distinguishes between Cleaner Production (CP) strategies that prevent pollution at the source (e.g., precision viticulture to reduce chemical inputs) and End-of-Pipe (EoP) solutions that manage waste and emissions after they are generated (Frondel et al., 2007; Horbach et al., 2017). Italian firms, particularly SMEs, often engage in incremental CP innovations within their existing knowledge domains but show limited adoption of disruptive digital or radical environmental technologies (Muscio et al., 2017).

The adoption of more complex innovations is constrained by limited absorptive capacity—the firm's ability to identify, assimilate, and apply external knowledge (Cohen & Levinthal, 1990; Camisón & Forés, 2010; Roberts et al., 2012). Studies

consistently find low levels of collaboration between Italian wineries and external knowledge sources such as universities, research centres, and technology companies (Muscio et al., 2017). This collaborative insularity creates a "capability trap" (De Haas et al., 2025), where firms recognize external market challenges (e.g., the need for digital traceability) but lack the networks and internal expertise to develop the necessary new competencies.

The prevalence of small, family-run businesses in the Italian wine sector exacerbates these challenges. These firms face significant resource constraints, high perceived costs of innovation (R&D, technology acquisition), and a scarcity of technical human resources. This context fosters a risk-averse culture and a reliance on established, traditional knowledge over externally sourced R&D. Consequently, the innovation trajectory of Italian wine firms is not merely a function of market opportunity but is deeply shaped by an internal capability system characterized by traditional focus, limited openness, and significant structural barriers.

2.2 Channel Architectures Innovation: A Paradigm Clash between Linear and Integrated Ecosystems

A second critical strand of literature examines innovations in marketing and distribution channels, revealing a fundamental divergence between European and Chinese models.

The Traditional European Model: In established European markets like Italy, the channel structure is relatively linear and segmented. It revolves around core physical and relationship-driven channels: the Ho.Re.Ca. (Hotel, Restaurant, Caf é) sector (Muscio et al., 2013), specialized wine retail, and direct-to-consumer (DTC) sales through winery visits (Fiore, 2016). Digital channels, such as company websites and Western social media (Instagram, Facebook), are often used primarily for branding and communication, playing a supplementary role to the core offline sales infrastructure. This model emphasizes controlled brand presentation, personal relationships, and a clear separation between marketing, distribution, and sales functions.

The Digital-First Chinese Ecosystem: In stark contrast, the Chinese market operates on a fundamentally different integrated social commerce paradigm (Zhang & Benyoucef, 2016; Goretti, 2022). Here, the consumer journey—from discovery and education to community engagement, transaction, and post-purchase sharing—is seamlessly woven within a few dominant digital platforms (Hu et al., 2024). Platforms like Douyin (TikTok) for short-video marketing and live-streaming sales, Xiaohongshu (Little Red Book) for user-generated lifestyle content and reviews, WeChat for omnipresent communication and mini-program e-commerce, and Tmall/JD.com for trusted transactional marketplaces form an interconnected ecosystem (Asia Beverage Media Group, 2021). This model is digitally native, platform-centric, and socially driven. As Du and Morrish (2025) note, these platforms have become the primary source of wine information for young Chinese consumers, surpassing traditional advertising. This type of innovation creates a channel architecture that is circular and integrated, presenting a profound adaptive challenge for firms accustomed to the linear, segregated Western model.

2.3 The Demand-Side Perspective: Chinese Consumer Values and Innovation Preferences

Understanding the Chinese wine consumer requires moving beyond demographics to psychographics and the specific value drivers that shape purchase decisions. Chinese consumers, especially the younger, urban, and increasingly sophisticated demographic, seek value that is multifaceted (Somogyi et al., 2011). This perceived value encompasses functional value (quality, authenticity), social value (status, gift-giving), emotional value (experience, enjoyment), and epistemic value (novelty, knowledge) (Zeithaml, 1988). Innovations are evaluated based on their contribution to these value dimensions.

Empirical research on the Chinese market reveals a clear hierarchy in how different innovations influence purchase intention, mediated by their impact on “Perceived

Value" (Peng & Huang, 2025). The first is "Packaging Innovation" which shows the strongest direct influence. Innovations in design, eco-materials (lightweight bottles), and interactive features (AR labels) provide high observability and potent social and emotional value, crucial for gifting and self-expression. Secondly, "Conceptual Innovation" pertaining to core product philosophy—such as organic, low-sugar, or sustainable wines—resonates deeply by aligning with health and environmental consciousness, enhancing compatibility with personal values and generating functional and emotional value. Thirdly, "Digital Innovation" includes blockchain traceability, NFC tags, and VR experiences. It addresses the critical need for authenticity and trust (combating counterfeiting), providing strong functional value and reducing perceived risk. Its adoption depends on reducing perceived complexity. Fourthly, "Process Innovation" related to winemaking techniques (e.g., specific fermentation methods), has a more muted effect. Its benefits are less observable and trialable to the average consumer, requiring more expertise to appreciate, thus contributing less directly to "Perceived Value" for mainstream segments.

This demand-side profile indicates a market that rewards innovations offering verifiable trust, experiential engagement, social currency, and alignment with lifestyle trends—a profile that often diverges from the traditional, product-centric innovation focus of Old-World producers.

2.4 Synthesis and Research Gap: Toward an Integrated Supply-Demand Analytical Framework

The three literature strands reviewed— (1) the supply-side model of Italian firm innovation (constrained, traditional, insular), (2) the divergent channel paradigms (linear vs. integrated digital ecosystems), and (3) the demand-side model of Chinese consumer values (driven by multi-faceted perceived value and distinct innovation preferences)—are well-developed in isolation. They converge on a critical, yet under-explored, research gap.

While we understand that Italian firms have specific innovation capabilities and collaborative constraints (Muscio et al., 2016), and we know the Chinese market has a unique digital channel structure (Zhang & Benyoucef, 2016; Goretti, 2022) and consumer value system (Peng & Huang, 2025), the existing literature lacks a unified, empirically grounded framework that directly and quantitatively contrasts these supply-side realities with demand-side expectations. Most studies remain siloed within a single perspective (e.g., firm innovation, consumer behaviour, or channel analysis) or offer qualitative, generalized comparisons.

This fragmented understanding leads to a key theoretical and practical shortcoming: an inability to systematically diagnose the precise points of strategic misalignment. The Chinese context, characterized as a digitally-enabled, demand-pulled innovation paradigm (in contrast to producer-pushed or institutionally-driven models), makes this integrated analysis especially urgent (Li & Wang, 2023).

Therefore, this study is built on the logic of integrating these three strands by juxtaposing firm-level data on Italian capabilities (innovation portfolios, channel structures, collaborative barriers) with consumer-level data on Chinese preferences (value drivers, innovation acceptance, channel behavior). This research moves beyond stating that "markets are different." It aims to precisely identify how and where these disconnects occur—in channel architecture versus innovation priorities—and how internal capability and collaboration barriers perpetuate them. This research offers a strategic framework to enhance the competitiveness of the Italian wine industry in a pivotal global market.

This study proposes and tests the following core hypotheses, which posit a fundamental strategic misalignment between the capabilities of Italian wine firms and the demands of the Chinese market, rooted in a systemic lack of collaborative capacity.

H1 There is a significant strategic misalignment between the channel structures employed by Italian wine firms and the channel preferences and behaviors of Chinese wine consumers, creating a major barrier to effective market entry and brand visibility.

H2 There is a significant divergence between the innovation priorities of Italian wine firms and the innovation preferences of Chinese consumers, leading to a suboptimal value proposition in the Chinese market.

H3 Italian wine firms operate within a collaborative ecosystem characterized by high insularity, with limited ties to external knowledge sources (e.g., universities, technology firms), and perceive significant innovation barriers (e.g., high costs, lack of expertise, knowledge gaps).

H4 Both the systemic "Innovation Activities Barrier" and the degree of embeddedness in the "Wine System" are significant predictors of a firm's "Organizational Change" capacity (or resistance thereto). Specifically, higher perceived barriers and lower systemic integration predict greater organizational resistance to change.

3 Methodology

3.1 Research Design and Comparative Framework

This study employs a comparative research design to diagnose the strategic alignment between Italian wine producers and the Chinese market. The core of our methodology is the juxtaposition of supply-side data from Italian firms with demand-side data from Chinese consumers. This direct, quantitative comparison allows us to move from general observations about market differences to a precise identification of strategic gaps in channels and innovation. The analysis is structured to first benchmark Italian capabilities against Chinese realities, then to analyze the internal barriers that constrain Italian firms' adaptability, and finally to model the systemic nature of these barriers.

This study is based on primary data collected through a comprehensive survey administered to Italian wine companies in early 2024. The survey was designed to capture a wide range of firm characteristics, including operational structure, basic financial information, marketing activities, innovation adoption, and internationalization efforts. To ensure a robust and representative sample of Italian wine

firms, the sampling frame was meticulously constructed by integrating two complementary, sector-specific databases to achieve broad coverage: the membership directory of the Associazione Italiana Sommelier (AIS) and the commercial database from Beverfood. The AIS list provided access to wineries actively engaged in promotion and quality circles, while the Beverfood database ensured coverage of a wide spectrum of businesses within the Italian wine industry. From this integrated frame, firms were randomly selected and invited to participate.

Data collection employed a dual-mode approach to maximize response rates and diversity. The primary instrument was a web-based questionnaire administered via the SurveyMonkey platform, yielding 313 completed responses. To mitigate the common challenge of low online response rates in firm surveys and to capture insights from producers who may be less digitally inclined, this was supplemented with 74 in-person, structured interviews conducted at the Vinitaly trade fair in 2024. This combined strategy resulted in a final sample of N = 387 complete and valid responses from Italian wine companies. We acknowledge a moderate overall response rate and have proactively addressed potential non-response bias. First, the sampling frame itself, built from two major industry sources, ensures that the population of interest—from small traditional wineries to larger, more innovative firms—was comprehensively mapped, reducing coverage error. Second, the dual-mode collection method helped reach different segments of the population. Third, key structural characteristics of the responding firms (e.g., the predominance of SMEs, with 74.4% of non-exporters having a turnover below €1 million) align with the known profile of the Italian wine sector, suggesting the sample is representative of the industry's core. While bias cannot be entirely ruled out, these measures, along with the use of appropriate controls in our analysis, bolster confidence in the data's validity for examining the strategic postures of Italian wine firms. For the Structural Equation Modeling analysis focusing on latent constructs, the valid sample size was N=344 after listwise deletion of missing data on the relevant scale items.

The demand-side benchmark for this comparative analysis is derived from a parallel, large-scale study titled "How Does Innovation Shape Wine Demand in China?" (Wang et al., 2025). This dataset provides a robust empirical profile of contemporary Chinese wine consumer preferences, behaviors, and innovation receptivity. Data were collected via an online survey administered through the professional platform Wenjuanxing in 2024, employing purposive and quota sampling to ensure representation of key demographic segments within China's urban, wine-consuming population. The final sample comprises N = 2,016 valid responses.

The sample is strategically composed to reflect the core market demographic: it is predominantly male (55.95%), with the largest age cohorts being 26-35 (33.33%) and 36-45 (31.94%). Respondents are highly educated (74.8% hold a college degree or higher) and fall primarily within the middle-income brackets (62.9% with a monthly disposable income between RMB 3,000 and 9,999). The survey instrument captured detailed metrics on consumer preferences across four key innovation dimensions (Digital, Process, Packaging, Conceptual), their perceived value of these innovations, and their resulting purchase and recommendation intentions, measured via validated multi-item scales (overall Cronbach's $\alpha = 0.959$). This dataset serves as the critical empirical ground against which the supply-side strategies and innovation portfolios of Italian firms are benchmarked, enabling a precise, data-driven diagnosis of strategic alignment or misalignment (see Table 14 for details).

Table 14 Data Sources and Sample Profiles

[Table14 around here]

3.2 Methodology and measures

The analysis utilizes both descriptive and inferential statistics, drawing on different sections of the survey. The variables and corresponding analytical techniques are outlined in Table 15.

Table 15 Variables and Analytical Methods

[Table 15 around here]

To empirically test the hypothesized relationships and validate the measurement model, we employed Structural Equation Modeling (SEM) using the lavaan package in R (Rosseel, 2012). The analysis proceeded in two stages, following established guidelines (Anderson & Gerbing, 1988; Kline, 2023). First, we assessed the reliability of the multi-item scales for the three latent constructs—'Innovation Activities Barrier' (11 items), 'Wine System' (3 items), and 'Organizational Change' (2 items)—using Cronbach's alpha. A value above 0.70 is considered acceptable (Nunnally, 1978). Second, we conducted a Confirmatory Factor Analysis (CFA) to evaluate the measurement model. The model specified the three correlated latent factors, each indicated by their respective observed variables. Model parameters were estimated using the Maximum Likelihood (ML) method. To assess the model's goodness-of-fit, we report multiple standard indices (Hu & Bentler, 1999): the Chi-square statistic (χ^2), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA) with its 90% confidence interval, and the Standardized Root Mean Square Residual (SRMR). Conventional thresholds (CFI/TLI > .90, RMSEA < .08, SRMR < .05) were used to indicate acceptable fit.

Finally, after confirming an adequate measurement model, we tested the structural model (path analysis) to examine the influence of 'Innovation Activities Barrier' and 'Wine System' on 'Organizational Change'.

The analytical procedure followed four sequential stages:

- Descriptive Benchmarking: Profiling the current state of Italian firms and contrasting it directly with Chinese consumer data.
- Gap Analysis: Identifying and interpreting the strategic implications of disparities between Italian capabilities and Chinese market demands.

- Barrier Analysis: Examining the internal and external constraints on Italian firms' adaptability
- Path Analysis: Using SEM to validate the underlying structure of innovation barriers and their systemic influence.

This mixed-methods approach provides a holistic view, moving from "what is" to "why it is" and finally to "what can be done."

While the datasets are robust and fit for the purpose of this comparative analysis, certain limitations should be acknowledged. The sample of Italian firms, though representative of the sector's SME-dominated structure, may under-represent the strategies of the very largest producers. The Chinese consumer sample, while large and diverse, is based on an online survey, which may skew towards more digitally-engaged segments of the population. Furthermore, the cross-sectional nature of the data provides a detailed snapshot but cannot establish causal relationships over time. Additionally, while our sample size (N=387) is adequate for the SEM analysis conducted, following recommendations for model complexity (Kline, 2023), it constrains our ability to test more complex models with numerous latent variables or paths. Despite these limitations, the triangulation of two large, parallel datasets offers a unique and powerful basis for identifying critical strategic misalignments.

4 Results

4.1 Channel Architecture: A Fundamental Misalignment

The analysis reveals a stark contrast between the channel structures of Italian firms and the digital ecosystem of the Chinese market. Italian wineries are heavily reliant on traditional, offline channels, with Ho.Re.Ca. (63.71%), specialized retail (59.64%), and direct sales at the winery (55.84%) forming the core of their model. Their digital presence is secondary and Euro-centric, dominated by Instagram (67.51%) and

Facebook (65.99%), with a negligible presence on key Chinese platforms like Douyin (3.05%) and Xiaohongshu (1.02%).

In direct contrast, the Chinese consumer journey is digitally native. For discovery, consumers rely on social platforms like Douyin (40.68%) and WeChat (40.87%), and for purchase, they favour comprehensive e-commerce (Tmall/JD.com: 42.06%) and social commerce/live streaming (40.28%). (For a detailed comparative table, see Appendix, Table A1).

This channel misalignment represents a critical vulnerability for Italian firms and a structural mismatch with the characteristics of Chinese demand. Italian producers' reliance on a physical, relationship-driven distribution model renders them virtually invisible in the digital environments where Chinese consumers discover and purchase wine. The lack of a meaningful presence on platforms such as Douyin and WeChat constitutes a substantial barrier to market entry and brand building, fundamentally constraining their competitive potential in China. This stark contrast empirically confirms H1, demonstrating a significant strategic misalignment in channel architecture that acts as a major barrier to market entry.

4.2 Innovation Priorities: A Divergence in Value Proposition

Italian wineries demonstrate a clear innovation focus, but it is concentrated on traditional areas: Marketing & Packaging (37.31%), Energy Efficiency (35.53%), and Wine Aging (35.03%). Their adoption of digital technologies crucial for the Chinese market is exceptionally low (Blockchain: 5.58%; AR/VR: 1.27%).

Conversely, Chinese consumers show strong positive inclinations toward innovations that provide digital trust (Blockchain traceability: 44.05%), immersive experiences (AR labels: 41.07%), and health benefits (low-sugar wine: 42.66%). (See Table A2 in the Appendix for the full innovation alignment matrix).

The innovation priorities of Italian firms are inwardly focused on perfecting the product from a traditional enological standpoint. However, the Chinese consumer seeks

additional layers of value: verifiable trust, engaging storytelling, and alignment with wellness trends. The major misalignment in digital and health-oriented innovations signifies a failure to communicate value in a language the market understands, leaving a key competitive advantage untapped. This divergence in innovation priorities directly supports H2, highlighting a suboptimal value proposition for the Chinese market.

4.3 Collaboration and Barriers: The Root of Strategic Inflexibility

The data points to an insular innovation system. A significant majority of firms report no collaboration with universities (78.93%), other wineries (81.98%), or IT companies (91.62%). The most significant barriers are high costs (R&D, Energy) and a lack of human resources, compounded by "softer" knowledge gaps regarding foreign markets and technical expertise.

The lack of collaboration and the high perceived barriers suggest the presence of a "capability trap." Italian SMEs, in particular, are aware of the market challenges but are isolated from the knowledge networks (universities, tech firms) necessary to develop new capabilities. This pattern of insularity and perceived constraints points to a potential systemic root cause of the strategic inflexibility observed in channels and innovation, a relationship that is statistically tested in the following section. The high rates of non-collaboration and the significant perceived barriers detailed here provide clear evidence for H3.

4.4 Descriptive Statistics and Scale Reliability

Prior to model testing, we examined the descriptive statistics and scale reliability for the key latent constructs. Table 4.4a presents the means and standard deviations for all observed items. The perceived severity of innovation barriers ranged from moderate to low (Means: 1.36 to 2.06). Respondents felt most integrated into the local wine system (M = 2.26) and perceived moderate levels of organizational resistance to change (M = 1.78).

As shown in Table 3, the reliability coefficients (Cronbach's alpha) for all three constructs were excellent, far exceeding the 0.70 threshold (Innovation Barrier $\alpha = .967$; Wine System $\alpha = .935$; Organizational Change $\alpha = .811$), confirming high internal consistency.

Table 16 Descriptive Statistics and Reliability for Latent Constructs (N=344)

[Table 16 around here]

The hypothesized three-factor measurement model was tested via CFA. The model demonstrated an excellent fit to the data: $\chi^2(101) = 280.5$, $p < .001$; CFI = .981; TLI = .978; RMSEA = .052 [90% CI: .044, .060]; SRMR = .028. All practical fit indices met or exceeded the recommended thresholds, indicating the model provides a very good representation of the observed data covariance structure.

4.5 Structural Equation Model Results: Validating Constructs and Pathways

4.5.1 Confirmatory Factor Analysis (CFA) Results

All standardized factor loadings for the three latent constructs were statistically significant ($p < .001$) and substantively high (ranging from .825 to .951), as presented in Table 17. This confirms that each observed variable is a strong and reliable indicator of its intended latent construct, demonstrating excellent convergent validity. For the 'Innovation Activities Barrier' construct, loadings were uniformly high (>.82), with 'Difficulty Finding Technical Expertise/Services Locally' ($\lambda = .873$) and 'Difficulties in Collaborating...' ($\lambda = .879$) among the strongest indicators.

Table 17 Confirmatory Factor Analysis Results (Standardized Loadings)

[Table 17 around here]

4.5.2 Path Analysis: The Impact of Barriers and System Perception on Organizational Change

Following the validation of the measurement model, we tested the structural relationships. The path model, which specified 'Innovation Activities Barrier' and 'Wine System' as predictors of 'Organizational Change', also showed excellent fit (indices identical to the CFA model, as it is a just-identified structural model).

The results of the path analysis (see Figure 5 and Table 18) reveal that both hypothesized antecedents significantly predict 'Organizational Change'. Perception of belonging to a cohesive 'Wine System' has a strong, positive association with 'Organizational Change' ($\beta = 0.503$, $p < .001$). This suggests that firms that feel integrated into a dynamic and innovative local industry network are more likely to report positive organizational change dynamics. The 'Innovation Activities Barrier' construct also has a significant, but comparatively weaker, positive effect ($\beta = 0.281$, $p < .001$). This model provides strong statistical support for H4, confirming that both the systemic innovation barrier and a firm's embeddedness in the wine system are significant predictors of its organizational capacity for change (or resistance to it).

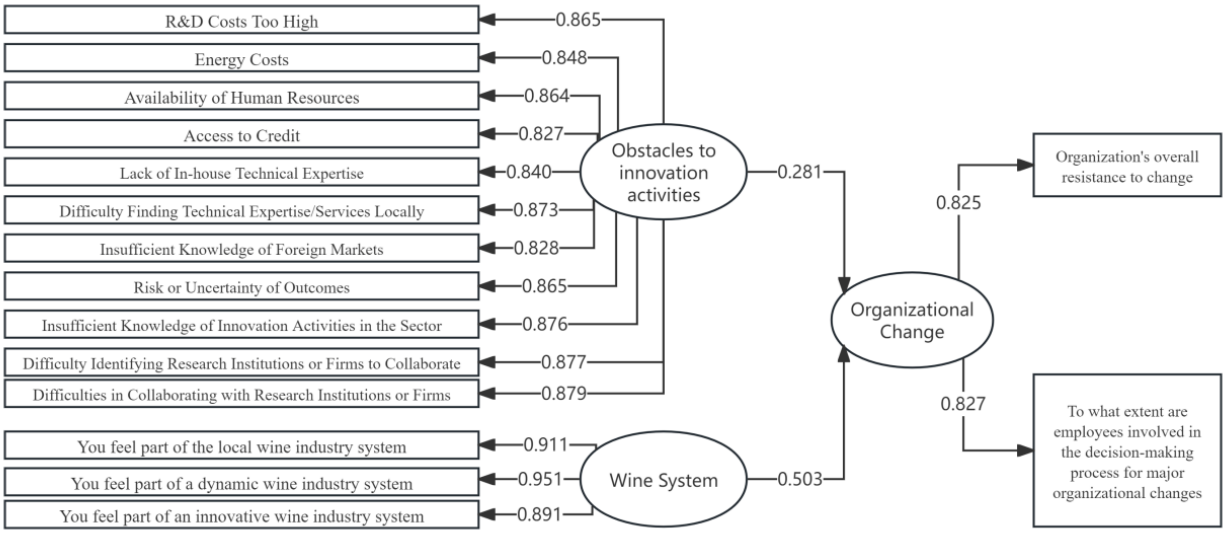

Figure 5 Structural Equation Model with Standardized Path Coefficients

Source: Author's analysis of survey data

Table 18 Path Analysis Results

[Table 18 around here]

The SEM analysis provides robust statistical validation for several key arguments. First, the high reliability and strong factor loadings confirm that the ‘Innovation Activities Barrier’ is a coherent, systemic latent construct, with collaboration and knowledge-based obstacles being its core indicators. This moves beyond treating barriers as a simple list.

Second, and crucially, the path analysis reveals the mechanism through which these systemic barriers influence firm adaptability. The significant path from ‘Innovation Activities Barrier’ to ‘Organizational Change’ empirically demonstrates that these perceived obstacles directly contribute to organizational inflexibility. However, the stronger path from ‘Wine System’ to ‘Organizational Change’ highlights a critical nuance: a firm‘s embeddedness within a supportive and innovative local ecosystem is an even more powerful driver of its capacity for change than the absence of barriers alone. This underscores that overcoming strategic misalignment requires not only mitigating internal and external obstacles but also actively fostering systemic connectivity and a shared sense of industry dynamism.

5 Discussion and Strategic Framework

The findings of this study reveal a profound strategic disconnect between the Italian wine sector and the Chinese market. To fully articulate the implications of this disconnection, we structure our discussion around the three central, interlinked themes of our analysis: channel strategies, innovation trajectories, and collaborative ecosystems.

5.1 Channel Architecture Misalignment and the Imperative for Digital Acculturation

Our results demonstrate that Italian firms are entrenched in a physical, relationship-driven distribution model (Ho.Re.Ca., specialized retail), with a digital presence that is an afterthought and confined to Western platforms. This stands in direct opposition to the Chinese market's platform-centric, socially-driven commerce model. This is not merely a difference in tool preference but a fundamental architectural mismatch. The Italian model is linear and segregated (marketing, then sales), while the Chinese model is integrated and circular (discovery, community, transaction).

To bridge this gap, we formally define and propose Digital Acculturation (Dey et al., 2020) as the strategic process through which a firm systematically integrates into a foreign market's digital ecosystem, adapting its business processes, marketing communications, and customer relationship management to the unique technological platforms, user behaviors, and cultural norms that define that ecosystem. This goes beyond simple translation or having a social media account; it requires a deep, operational immersion that acknowledges the paradigm clash (as outlined in section 2.2) between linear European and integrated Chinese channel architectures. For Italian wineries, this means moving from a token presence on WeChat to a coordinated strategy across Douyin for storytelling and live-streaming (Qu, 2022; Liu & Liang, 2024), Xiaohongshu for lifestyle branding and KOL marketing (Lu et al., 2020), and Tmall/JD.com for establishing transactional credibility (Changyi & Xiaoyu, 2024; Xia et al., 2024). This process aligns with recent calls for a more nuanced understanding of platformization in agri-food sectors (Klerkx et al., 2023).

5.2 Innovation Priority Misalignment and the Necessity of Innovation Alignment

The data reveals a second critical misalignment: while Italian firms innovate, they do so with an inward focus on enological perfection and cost efficiency. The Chinese consumer, however, values innovations that provide external, experiential value: trust (via traceability), engagement (via AR/VR), and personal wellness (via low-sugar

options). This divergence represents a failure in value proposition signaling. In a market where brand heritage is less known, trust must be engineered and the story must be told digitally.

Therefore, we posit that Innovation Alignment is the necessary corollary to Digital Acculturation. It involves the deliberate re-orientation of a firm's R&D and product development priorities to resonate with the specific value systems and consumption drivers (Somogyi et al., 2011) of the target market. This extends the traditional, internally-focused innovation patterns of Italian wineries (Stasi et al., 2016) towards a demand-pulled innovation paradigm (Li & Wang, 2023). For Italian firms, this means prioritizing "Trust-Tech" like Blockchain (which our data shows has a 44.05% consumer inclination vs. 5.58% firm adoption), "Experience-Tech" like AR labels, and "Wellness-Tech" like health-conscious formulations. This alignment directly addresses the multi-faceted perceived value (functional, social, emotional, and epistemic) sought by Chinese consumers, as discussed in section 2.3.

5.3 Collaborative Insularity as the Root of Strategic Inflexibility

The third pillar of our discussion addresses the root cause of the observed inflexibility. The documented lack of collaboration with universities, research centers, and particularly tech companies (91.62% report no collaboration), combined with high perceived barriers, creates a "capability trap." Firms recognize the external challenge ("lack of knowledge of foreign markets") but lack the external networks and internal absorptive capacity to develop the necessary new capabilities. The SEM analysis statistically validates that these barriers are not isolated but form a single, systemic construct, with the strongest loadings on collaboration and knowledge gaps (Difficulty Identifying Collaborative Partners, $\lambda = .877$; Difficulties in Collaborating, $\lambda = .879$). This finding empirically reinforces and extends the literature on absorptive capacity (Cohen & Levinthal, 1990) and open innovation in the Italian wine sector (Stasi et al., 2016). It demonstrates that collaborative insularity is not merely a descriptive trait but

a measurable systemic barrier that mediates external knowledge flows. Our results show that this insular ecosystem directly undermines a firm's dynamic capabilities (Teece, 2020)—specifically, its capacity to sense market shifts (e.g., Chinese digital trends) and to reconfigure internal resources—thereby explaining why the necessary strategic shifts have not occurred organically.

5.4 An Integrated Framework: Digital Acculturation & Innovation Alignment

The empirical confirmation of H1, H2, H3, and H4 reveals a coherent, multi-layered problem: a dual market misalignment (H1, H2) rooted in a systemic capability trap (H3, H4). To bridge the identified strategic misalignments and overcome the root barriers, a dual strategic framework is required, comprising (a) Digital Acculturation—the deep integration into China's digital ecosystem—and (b) Innovation Alignment—the reorientation of R&D towards Chinese consumer values. The successful implementation of this framework is contingent upon overcoming collaborative insularity. We therefore integrate these insights into a cohesive framework for market entry, presented in Figure 2. The framework posits that overcoming the strategic disconnect requires simultaneous action on two parallel pathways, which are both enabled by overcoming collaborative barriers.

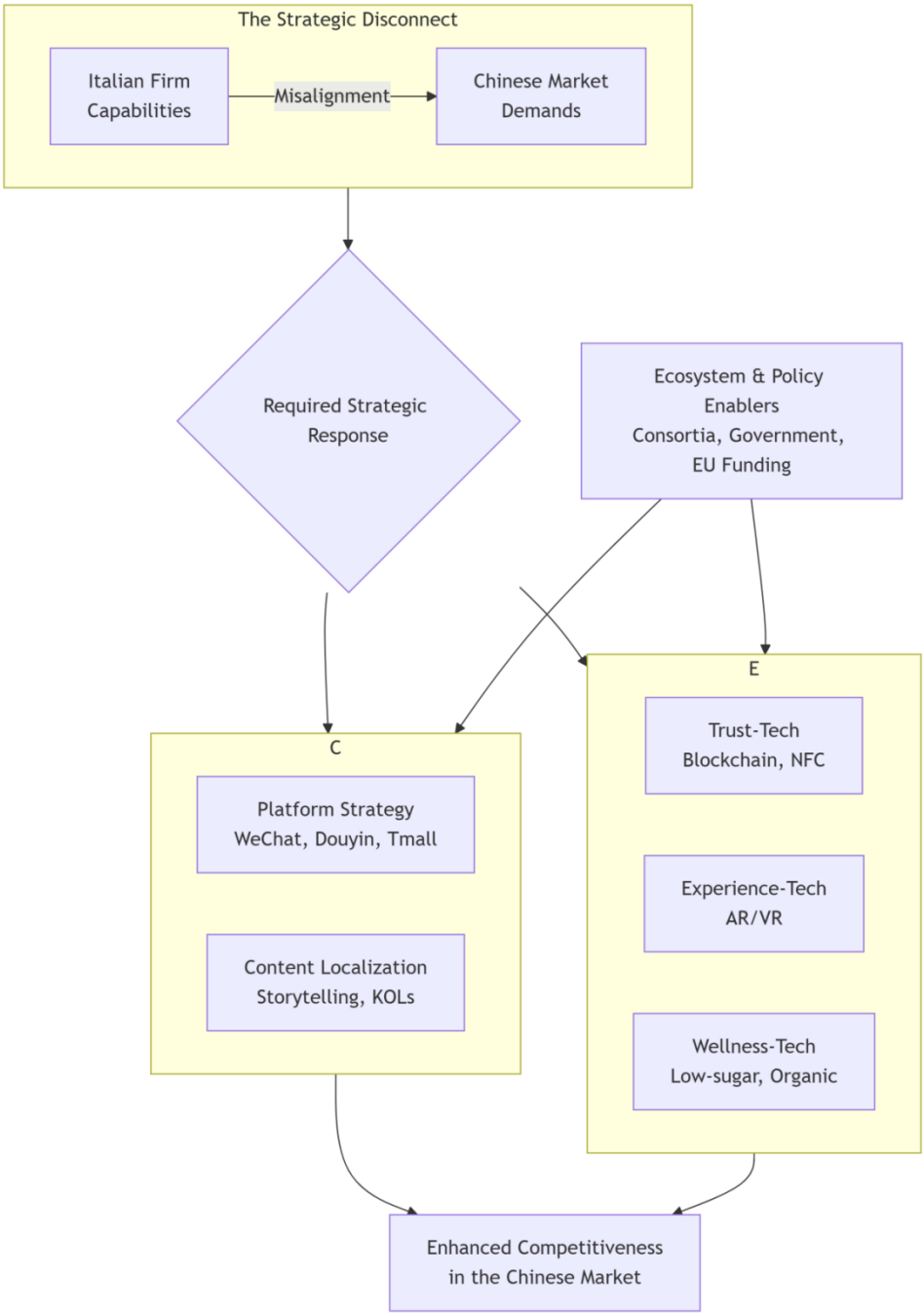

Figure 6 The Digital Acculturation and Innovation Alignment Framework for Market Entry

Source: Author's elaboration.

5.4.1 The Central Problem: The Strategic Disconnect

At the heart of the model lies the Strategic Disconnect, which this study empirically diagnoses as a fundamental gap between "Italian Firm Capabilities" and "Chinese Market Demands."

From the supply side, as documented in the Results, Italian firms are proficient in a traditional operational paradigm. This is characterized by a linear channel architecture reliant on physical, relationship-driven outlets (Ho.Re.Ca., specialized retail) and Western social media for communication. Their innovation trajectory is inwardly focused on product-centric and process improvements (enological techniques, packaging, energy efficiency), with minimal adoption of digital consumer-facing technologies.

From the demand side, in contrast, the Chinese market operates on a digitally-integrated ecosystem where platforms like Douyin, Xiaohongshu, Tmall, and WeChat converge discovery, community, and transaction. Chinese consumer values, as benchmarked in the study, demand innovations that provide verifiable trust (e.g., blockchain traceability), immersive experiences (e.g., AR/VR), and alignment with wellness trends (e.g., low-sugar wine). The disconnect is not trivial; it represents a profound strategic misalignment where the core capabilities of the supplier fail to meet the core values and behaviors of the target consumer, leading to invisibility in digital channels and a suboptimal value proposition.

5.4.2 The Dual Solution Pathways

To bridge this disconnection, the framework proposes two simultaneous and mutually reinforcing strategic pathways.

5.4.2.1 A. Digital Acculturation Pathway

This pathway addresses the channel architecture misalignment. “Digital Acculturation” is defined as the deep, operational process of integrating a firm’s marketing, sales, and customer relationship management into the unique digital ecosystem of the target market. It moves beyond mere presence to cultural and operational fluency. For Italian firms in China, this entails a “Platform Strategy” innovation: shifting resources from a peripheral presence on Western platforms to a core, coordinated strategy on dominant

Chinese super-apps. This involves mastering the mechanics and norms of key platforms. The most important platforms in China are: Douyin (TikTok Chinese version), Xiaohongshu (Little Red Book), WeChat and Tmall/JD.com. Douyin (TikTok Chinese version) is for short-form video storytelling, influencer collaborations (KOLs), and live-streaming commerce to drive discovery and impulse purchases. Xiaohongshu (Little Red Book) serves for seeding user-generated content, building lifestyle credibility, and leveraging in-depth reviews within a community of aspirational consumers. WeChat is a Chat APP similar to WhatsApp, but it's more complex. It serves for omnipresent customer service, private community building (via groups), and facilitating transactions through mini-programs. Tmall/JD.com are two famous online shopping malls in China: they are used to establish official brand storefronts, participate in major shopping festivals, and leverage the platforms' logistics and consumer trust for reliable fulfillment.

"Content Localization" is talking about adapting brand narratives and marketing content not just through language translation, but by aligning with local cultural codes, consumption occasions (e.g., gifting), and digital storytelling formats (e.g., livestream host interactions, short dramas).

5.4.2.2 B. Innovation Alignment Pathway

This pathway addresses the innovation priority misalignment. "Innovation Alignment" is the strategic re-orientation of a firm's R&D and product development efforts to resonate directly with the specific value drivers of the target consumer. It shifts innovation from a supply-pushed to a demand-pulled model. For Italian wineries, this means prioritizing:

First, "Trust-Tech": Integrating technologies like Blockchain and NFC tags to provide immutable proof of origin, authenticity, and supply chain integrity. This directly addresses the Chinese consumer's critical need for risk reduction and trust, especially for premium, imported products.

Second, “Experience-Tech”: Developing Augmented Reality (AR) labels or Virtual Reality (VR) experiences that bring the vineyard story to life, offer food pairing suggestions, or create shareable social moments. This enhances the emotional and epistemic value of the product.

Third, “Wellness-Tech”: Innovating on product formulation to align with health trends, such as developing low-sugar, low-alcohol, or organic wines. This taps into the growing functional and personal value sought by consumers.

5.4.3 The Foundational Enabler: Overcoming Collaborative Barriers

The two solution pathways are supported by a critical foundation: Overcoming Collaborative Barriers. The thesis’s SEM analysis empirically validated that perceived innovation barriers form a systemic construct and that a firm’s isolation from collaborative networks strongly predicts organizational resistance to change. Therefore, executing “Digital Acculturation” and “Innovation Alignment” is not feasible without addressing this root cause.

“Ecosystem & Policy Support” are important, because the individual SMEs, which dominate the Italian wine sector, often lack the resources and expertise for this dual transformation. The framework emphasizes the necessity of collective action and institutional support.

“Consortia & Industry Associations” can play a pivotal role by creating shared digital infrastructure (e.g., collective Tmall storefronts), pooling resources for cross-platform marketing campaigns, organizing trade delegations focused on digital skills, and facilitating knowledge exchange on Chinese market dynamics.

“Government & Policy”, they also play indispensable roles. Public agencies can support "market acclimation" programs that complement traditional R&D subsidies. This could include funding for digital skills training, grants for pilot projects in social commerce, and diplomatic support in navigating platform partnerships and regulatory environments.

In summary, Figure 2 visually encapsulates the study's core argument: The Strategic Disconnect (Problem) requires a dual transformation in Go-to-Market (Digital Acculturation) and Value Proposition (Innovation Alignment) strategies. The successful execution of this dual transformation is fundamentally dependent on breaking down collaborative insularity (Enabler) to build the necessary dynamic capabilities for competing in China's unique digital terroir.

In conclusion, this framework contributes to theory by moving beyond siloed analyses. It bridges the literature on international marketing by introducing Digital Acculturation as a digital-era complement to and operationalization of cultural adaptation, specifically for platform-dominated markets (Jean et al., 2020). Simultaneously, it advances innovation studies by framing Innovation Alignment as a strategic imperative driven by external consumer values rather than just internal R&D pipelines, addressing the supply-demand gap identified in section 2.4. Finally, it empirically extends the work on open innovation and SME internationalization (Monteiro et al., 2022) by quantifying how a closed collaborative system ("Wine System" perception having a $\beta = 0.503$ impact on change) directly inhibits the development of the dynamic capabilities needed for international competitiveness in complex markets like China.

Theoretically, this study provides a validated, integrated model that quantitatively links supply-side capabilities with demand-side preferences, a gap identified in the literature review. The concepts of Digital Acculturation and Innovation Alignment offer a novel lens for analyzing market entry in digitally advanced economies.

For managers, the framework provides an actionable roadmap. The findings are a clear call for a paradigm shift. Success in China requires Italian wineries to view themselves not just as producers of fine wine, but as creators of digital experiences and purveyors of verifiable trust. This is not a task for individual SMEs alone. It necessitates a systemic response, where consortia facilitate shared digital storefronts and pooled marketing resources, and where public policy supports "market acclimation" projects alongside traditional R&D funding. The journey to China is a journey into its digital and cultural terroir, and it requires a map this study provides.

6 Conclusions

This study has provided a novel, integrated analysis of the Italian wine sector's strategic posture towards the Chinese market. By systematically contrasting firm-level capabilities with consumer-level demands, we have empirically validated the strategic misalignments (H1, H2) and the systemic barriers (H3, H4) hypothesized at the outset. In response, this study's primary contribution is the development and proposition of the "Digital Acculturation and Innovation Alignment" framework, a novel model that provides a cohesive strategic roadmap for navigating such complex market entry scenarios.

we have moved beyond a generic acknowledgment of "market differences" to a precise diagnosis of strategic misalignments. The core findings reveal that Italian firms' proficiency in a traditional, offline channel model and a product-centric innovation paradigm is fundamentally mismatched with the demands of China's digitally-dominated, experience-driven market. This disconnect is further entrenched by a collaborative ecosystem that inhibits the development of the necessary digital and market-specific capabilities.

The primary theoretical contribution of this work lies in its integration of three critical, yet often siloed, domains: innovation studies, digital marketing, and international market entry strategy. We have demonstrated that these areas are not separate challenges but are intrinsically linked. A firm's innovation trajectory (e.g., prioritizing enology over digital traceability) directly impacts its value proposition, while its channel architecture (e.g., reliance on Ho.Re.Ca. over social commerce) determines its market visibility. Underpinning both is the firm's collaborative capacity, which our SEM analysis confirmed as a systemic barrier. In response, this study contributes the "Digital Acculturation and Innovation Alignment" framework, a novel model that provides a cohesive strategic roadmap for navigating such complex market entry

scenarios. This framework formally bridges the literature on agricultural innovation systems with that of international marketing in the digital age.

The proposed framework offers a clear, dual-pathway strategy for Italian wineries. It demands a paradigm shift: to succeed in China, firms must reconceive themselves not merely as producers of fine wine, but as creators of digital experiences and purveyors of verifiable trust and aligned values. This transformation, while challenging, is not optional but imperative for securing a competitive position in the global wine industry's most dynamic growth market. The journey into the Chinese market is a journey into its unique digital and cultural terroir, requiring a map that this study has sought to provide.

While this study offers significant insights, its limitations point toward valuable directions for future research. The first limitation concerns the cross-sectional nature of our data. While providing a detailed and valuable snapshot, this design cannot capture the dynamic, evolutionary processes of strategic adaptation or establish causal relationships over time. Second, the study's focus is exclusively on Italian firms. This limits the generalizability of the findings and the framework to other Old World wine-producing nations (e.g., France, Spain), which may face similar yet distinct challenges. Finally, while the Chinese consumer sample is large, its online recruitment may inherently skew towards more digitally-engaged segments, potentially under-representing consumers who discover wine through more traditional offline channels.

Future studies could build upon this work in several promising ways. First, longitudinal research tracking a cohort of firms as they implement (or fail to implement) strategies of Digital Acculturation and Innovation Alignment would provide deep insights into the adaptation process and the evolution of barriers. Second, a comparative analysis with firms from other wine-exporting countries would help identify which challenges are unique to the Italian context and which are more universal, thereby refining the proposed framework. Third, in-depth qualitative case studies of both successful and unsuccessful market entrants would illuminate the specific managerial practices, organizational changes, and partnership models that underpin effective strategy execution. Finally, exploring the role of generative AI and other emerging technologies

in facilitating content localization and personalized marketing within the Chinese digital ecosystem presents a compelling frontier for inquiry.

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TABLES

[TABLE 14]

Aspect	Italian Firm Data	Chinese Consumer Data
Source	UniFG 2024 Wine Enterprise Survey	The Impact of Innovation on Wine Demand in the Chinese Market (Wang et al., 2025)
Collection Method	Survey of Italian wine companies	Online survey
Sampling Technique	Targeted sampling across sizes and regions	Purposive and quota sampling
Sample Size	N = 387 complete responses	N = 2,016 valid responses
Key Characteristics	Dominated by SMEs (74.4% of non-exporters had <€1M turnover). Representative of the Italian industry structure.	Gender: 55.95% Male. Age: 26-35 (33.33%) & 36-45 (31.94%). Education: Bachelor's (40.87%). Income: RMB 6,000-9,999 (33.33%).

Source: Author’s elaboration based on survey data.

[TABLE 15]

Analysis Dimension	Key Variables & Measurement	Primary Analytical Method
Channel & Platform Analysis	Sales channels (Ho.Re.Ca., DTC, e-commerce) and social media usage (Facebook, WeChat, etc.), measured via multiple-choice questions.	Descriptive statistics (frequencies, percentages) for comparative benchmarking.
Innovation Analysis	Firm-side: Types of innovation adopted (winemaking, marketing, packaging) and "Vineyard 4.0" technology adoption (IoT, Blockchain, AR/VR).	Comparative analysis of adoption rates (firms) versus positive inclination (consumers; % of "Agree" + "Strongly Agree").

Analysis Dimension	Key Variables & Measurement	Primary Analytical Method
	Consumer-side: Preferences for innovations measured on a 5-point Likert scale (1=Strongly Disagree to 5=Strongly Agree).	
Collaboration & Barriers	Collaboration with actors (universities, suppliers) and perceived barriers rated on a 5-point Likert scale (1=Not Significant to 5=Very Significant).	Descriptive statistics (means, standard deviations).
SEM	Latent construct "Innovation Barriers" reflected by 11 observed variables (e.g., "R&D costs too high," "Lack of technical expertise").	Maximum likelihood estimation to validate the measurement model. Goodness-of-fit indices, standardized factor loadings, z-values, and p-values are reported.

Source: Author’s elaboration.

[TABLE 16]

Latent Construct & Items	Mean	Std. Dev.	Cronbach’s α
Innovation Activities Barrier			0.967
R&D Costs Too High	2.00	2.01	
Energy Costs	2.06	2.01	
Availability of Human Resources	2.03	1.99	
Access to Credit	1.71	1.79	
Lack of In-house Technical Expertise	1.36	1.53	
Difficulty Finding Technical Expertise/Services Locally	1.58	1.68	
Insufficient Knowledge of Foreign Markets	1.58	1.69	
Risk or Uncertainty of Outcomes	1.79	1.82	

Latent Construct & Items	Mean	Std. Dev.	Cronbach's α
Insufficient Knowledge of Innovation Activities in the Sector	1.41	1.53	
Difficulty Identifying Research Institutions or Firms to Collaborate With	1.53	1.65	
Difficulties in Collaborating with Research Institutions or Firms	1.49	1.61	
Wine System			0.935
Part of local system	2.26	2.00	
Part of dynamic system	1.95	1.77	
Part of innovative system	1.69	1.62	
Organizational Change			0.811
Organization‘s resistance to change	1.78	1.59	
Employee involvement in change	1.73	1.60	

Note: Scale for all items: 0 to 5. Cronbach's alpha for the full scale = 0.970.

Source: Author's analysis of survey data

[TABLE 17]

Latent Construct	Observed Variable	Std. Loading	S.E.	C.R.	P
Innovation Activities Barrier	R&D Costs Too High	0.865	0.108	18.407	<.001
	Energy Costs	0.848	0.108	19.053	<.001
	Availability of Human Resources	0.864	0.107	18.923	<.001
	Access to Credit	0.827	0.097	17.697	<.001
	Lack of In-house Technical Expertise	0.840	0.082	16.541	<.001
	Difficulty Finding Technical Expertise...	0.873	0.090	17.464	<.001
	Insufficient Knowledge of Foreign Markets	0.828	0.091	17.357	<.001
	Risk or Uncertainty of Outcomes	0.865	0.098	18.256	<.001

Latent Construct	Observed Variable	Std. Loading	S.E.	C.R.	P
	Insufficient Knowledge of Sector Innovation	0.876	0.083	17.079	<.001
	Difficulty Identifying Collaborative Partners	0.877	0.089	17.219	<.001
	Difficulties in Collaborating with Partners	0.879	0.087	17.185	<.001
Wine System	Part of local wine industry system	0.911	0.108	20.939	<.001
	Part of a dynamic wine industry system	0.951	0.095	20.405	<.001
	Part of an innovative wine industry system	0.891	0.087	19.283	<.001
Organizational Change	Organization‘s resistance to change	0.825	0.086	20.793	<.001
	Employee involvement in change decisions	0.827	0.086	20.092	<.001

Note: ML estimation. All factor loadings are significant at $p < .001$.

Source: Author's analysis of survey data

[TABLE 18]

Path	Standardized Estimate (β)	S.E.	C.R.	P
Organizational Change <--- Innovation Activities Barrier	0.281	0.056	5.017	<.001
Organizational Change <--- Wine System	0.503	0.051	9.917	<.001

Source: Author's analysis of survey data (2024)

Appendix

Table A1 Comparative Channel Analysis: Italy vs. China

Channel Type	Italian Firm Usage (Top Channels)	Chinese Consumer Preference (Willing/Very Willing)
Ho.Re.Ca.	63.71%	(Not directly measured as a retail channel)
Specialized Retail	59.64%	43.06% (Offline specialty stores)
Direct Sales (Winery)	55.84%	(Less applicable)
Online Store (Own Website)	32.23%	(Implied in brand interaction)
Comprehensive E-commerce	(Low via aggregators)	42.06% (Tmall, JD.com)
Vertical Wine E-commerce	20.81% (Aggregators)	43.65% (1919, Jiuxian)
Social E-commerce/Live Stream	2.53%	40.28% (Douyin Live, WeChat)

Source: Author's elaboration based on survey data.

Table A2 Innovation Alignment Matrix

Innovation Type	Italian Firm Adoption (Illustrative)	Chinese Consumer Positive Inclination	Strategic Implication
Marketing & Packaging	High (37.31%)	High (e.g., Modular Gifting: 38.89%)	Aligned

Sustainability (Process)	Medium-High (e.g., Energy: 35.53%)	Medium-High (e.g., Lightweight Bottle: 42.46%)	Aligned
Enological Techniques	High (e.g., Aging: 35.03%)	Lower (e.g., Clay Amphorae: 40.28%)	Partially Aligned
Digital Traceability (Blockchain/NFC)	Very Low (5.58%)	High (44.05%)	Major Misalignment
Digital Engagement (AR/VR)	Very Low (1.27%)	High (41.07%)	Major Misalignment
Health-oriented (Low-sugar)	(Not specifically measured)	High (42.66%)	Opportunity Gap

Source: Author's elaboration based on survey data.

Conclusions

This dissertation, through its tripartite structure, systematically investigates the complex interplay between digital transformation, multifaceted innovation, and market outcomes within the global wine industry. By sequentially addressing supply-side capabilities, demand-side perceptions, and their strategic integration, the three constituent papers collectively provide a holistic, evidence-based answer to the overarching research problem: how traditional wine producers can leverage innovation to navigate contemporary environmental and market challenges, particularly in dynamic growth markets like China. The following conclusion synthesizes the journey of these three papers, detailing how they sequentially answered the research questions and filled the identified gaps, their new findings and innovations, their dual theoretical and practical contributions, acknowledges their limitations, and proposes a roadmap for future research.

This dissertation makes a cohesive contribution by examining the sustainable digital transition through a dual, interconnected lens of supply and demand, thereby bridging traditionally separate theoretical streams. The logical progression across the three papers is deliberate: Paper I establishes the foundational firm-level link between digital technologies (Agriculture 4.0) and eco-innovation, grounding the inquiry in Porter's Hypothesis and Resource-Based View. Paper II deepens this by shifting to the demand side, introducing the Digital Acculturation framework—which integrates TPB and DOI—to explain how consumer acculturation to digital platforms shapes perceptions of sustainable product innovation. Finally, Paper III returns to the firm level to integrate these perspectives, demonstrating how the interaction between external digital infrastructure (TOE framework) and internal green knowledge shapes a firm's circular economy performance. Collectively, the thesis moves beyond examining technology adoption in isolation. Its core, integrative take-away is that the sustainable transition is co-driven by parallel technological logic on the supply side and socio-cultural logic on the demand side. It contributes to theory by 1) extending Porter's Hypothesis into the digital-agricultural context, 2) proposing a novel demand-side mechanism (Digital

Acculturation) for sustainable innovation diffusion, and 3) validating an integrated model where digital and green capabilities are synergistic antecedents to circularity.

The dissertation was structured to answer three sequential research questions, each paper designed to tackle a specific layer of the investigation, thereby addressing interconnected theoretical and empirical gaps.

Paper 1, “Digital Transformation for Eco-Innovation: Evidence from Agriculture 4.0 Adoption in Wine Firms,” addressed the first research question from a supply-side perspective: How does digital technology adoption influence the environmental innovation strategies of incumbent wine producers, and does it enable a ‘win-win’ outcome? The study hypothesized that the adoption of Agriculture 4.0 technologies (e.g., precision agriculture, IoT sensors, and management software) would act as a strategic enabler, shifting firms from reactive End-of-Pipe (EoP) solutions to proactive Cleaner Production (CP) strategies, ultimately supporting competitive upgrading into premium markets. This directly targeted the gap in literature that treated Agriculture 4.0 merely as a technological extension and overlooked its role in strategic differentiation within traditional industries like viticulture.

The hypothesis was rigorously tested using original survey data from 387 Italian wine firms. Employing econometric models (negative binomial regressions), the paper provided robust empirical proof. Results confirmed that Agriculture 4.0 adoption is strongly and positively associated with CP innovations, facilitating a preventive, efficiency-based approach to sustainability. Crucially, it demonstrated that digital adopters were significantly more likely to compete in premium and ultra-premium market segments. This provided concrete evidence for the "win-win" or Porter hypothesis, showing that digital transformation can simultaneously enhance eco-innovation and market positioning. The technology-specific heterogeneity analysis further revealed that precision farming, weather monitoring, and software tools were the most effective drivers, while blockchain and big data adoption remained low due to capability gaps. Thus, Paper 1 filled the gap by empirically validating digital transformation as a pathway for sustainable differentiation in a traditional sector, while

also uncovering the systemic barriers—high costs, knowledge gaps, and insular collaborative networks—that limit its full potential.

Paper 2, “How Does Innovation Shape Wine Demand in China?”, pivoted to answer the second research question from the demand-side perspective: How do different dimensions of wine innovation shape consumer purchase intentions in a key growth market, through what psychological mechanism, and how do demographics moderate these relationships? It hypothesized that innovation is not monolithic but multidimensional, with distinct effects. The study proposed a four-dimensional framework (Technological, Process, Packaging, and Conceptual) and posited that their influence on Purchase and Recommendation Intention (PRI) is mediated by Perceived Value (PV) and moderated by consumer demographics. This directly confronted gaps in prior research that treated innovation as a single construct, underspecified psychological mechanisms, and rarely tested demographic contingencies in integrated models.

Testing these hypotheses with a survey of 2,016 Chinese consumers using regression, mediation (bootstrapping), and moderation analysis, the paper yielded several groundbreaking findings. It confirmed a clear hierarchy of influence: Packaging Innovation was the strongest direct driver of PRI, followed by Conceptual, Technological, and finally Process Innovation. More importantly, it empirically identified Perceived Value as the central mediating mechanism, statistically validating that innovation attributes are evaluated through a cognitive appraisal of net benefits before shaping intention. Furthermore, moderation analysis challenged conventional wisdom: older and female consumers emerged as the most receptive segments to innovation, particularly to packaging and technological features, upending the stereotype of the young, male early adopter. Paper 2 therefore filled critical gaps by providing a nuanced, multidimensional framework for innovation, establishing PV as its core psychological conduit, and offering empirically grounded, counter-intuitive consumer segmentation for the Chinese market.

Paper 3, “Navigating New Terroirs: An Integrated Analysis of Italian Wine Firms' Channel Strategies, Innovation Trajectories, and Market Entry Potential in China,” performed the crucial integrative work to answer the third, synthetic research question: What specific strategic misalignments exist between the innovation capabilities of traditional producers and the expectations of the new market, what factors perpetuate this disconnect, and what integrated framework can bridge it? Its core hypothesis was that a fundamental dual misalignment exists—in channel architecture and innovation priorities—rooted in the collaborative insularity and organizational inertia of traditional producers.

The paper employed a novel triangulation method, directly juxtaposing the supply-side data from Paper 1 (Italian firms) with the demand-side insights from Paper 2 (Chinese consumers). This comparative diagnostic analysis empirically confirmed the hypothesized misalignments: a clash between Italy’s linear, offline channel model (Ho.Re.Ca., Western social media) and China’s integrated digital ecosystems (Douyin, Tmall); and a divergence between Italy’s product-centric innovation trajectory (enology, packaging) and China’s value-driven preferences (digital traceability, health-oriented concepts). To explain the persistence of this disconnect, Paper 3 used Structural Equation Modeling (SEM) on the Italian firm data, revealing that internal organizational inertia is statistically predicted by a latent construct of perceived innovation barriers and a firm’s deep embeddedness in local, insular networks. Synthesizing these findings, the paper constructed an original integrated strategic framework as its solution. It posits that successful market entry necessitates a dual transformation: Digital Acculturation (deep integration into China’s platform ecosystem) and Innovation Alignment (reorienting R&D towards Chinese consumer value drivers). Paper 3 thus filled the overarching gap of fragmented analysis by offering a data-driven, holistic diagnosis of strategic misfit and proposing a coherent framework to resolve it.

Collectively, the three papers generate several novel and significant findings. First, they establish that the digital-eco-innovation nexus is a viable and profitable strategic path

for traditional industries, with precision agriculture tools being particularly effective levers. Second, they reveal a demand-side hierarchy of innovation where packaging and conceptual innovations trump process and technological ones in influencing Chinese consumers, mediated by perceived value. Third, they uncover a counter-stereotypical adopter profile in China, identifying older, female, and experienced consumers as the primary targets for innovative wine products. Fourth, they provide empirical, quantitative evidence of a systemic strategic misalignment between Old World producer capabilities and New World market demands, diagnosing it at both channel and innovation levels. Fifth, they innovatively triangulate supply and demand data to move from generic market differences to precise strategic diagnoses. The core theoretical innovation is the development of the Digital Acculturation and Innovation Alignment framework, which synthesizes insights from international business, digital marketing, and innovation studies into a actionable model for market entry in digitally advanced economies.

This dissertation makes substantial contributions to multiple theoretical domains. It bridges siloed literature streams by integrating research on Industry 4.0/Agriculture 4.0, eco-innovation (CP vs. EoP), consumer behavior (TPB, DOI), and international marketing. To the eco-innovation and sustainability literature, it extends the Porter hypothesis into the digital age and traditional agricultural contexts, providing robust evidence that proactive environmental strategies can be enabled by technology and are competitively beneficial. For innovation adoption theory, it advances a multidimensional framework and solidifies the role of Perceived Value as a critical mediator, enriching the Theory of Planned Behavior. In international business and marketing, it introduces and elaborates the concepts of "Digital Acculturation" and "Innovation Alignment," offering a new lens for understanding market entry in platform-dominated economies, moving beyond cultural to digital and strategic adaptation. The SEM analysis in Paper 3 contributes to organizational theory by quantifying how systemic barriers and network embeddedness predict resistance to change, linking micro-level perceptions to macro-level strategic inflexibility.

The practical implications for industry stakeholders are direct and actionable. For wine producers, especially traditional SMEs, the research provides a clear strategic roadmap: invest in specific Agriculture 4.0 tools (precision viticulture, management software) for sustainable premiumization; for China, prioritize packaging and conceptual innovations, target marketing towards older and female consumers, and embark on the dual journey of Digital Acculturation (master Douyin, Xiaohongshu) and Innovation Alignment (develop traceability, wellness-focused products). For consortia and industry associations, the findings underscore the necessity of collective action to overcome systemic barriers—they should facilitate shared digital platform expertise, pooled marketing resources on Chinese platforms, and knowledge exchange programs to break down collaborative insularity. For policymakers, the research suggests a shift in support mechanisms: alongside traditional R&D subsidies, funding should be directed towards "market acclimation" programs, digital skills training for agricultural SMEs, and initiatives that foster connections between traditional wine clusters and technology providers or foreign market digital experts.

This research, while offering novel insights, is subject to methodological trade-offs that define the scope of its inferences. First, the cross-sectional design of the firm-level studies (Papers I and III) limits strong causal claims; although grounded in theory (e.g., Porter's Hypothesis, TOE) and controlled for key confounders, endogeneity concerns (e.g., unobserved managerial capabilities) cannot be fully ruled out. Second, potential sample biases exist: the Italian sample may under-represent large-scale industrial producers, while the Chinese consumer sample, collected online, skews toward digitally-engaged urban demographics. Third, findings are context-specific—the "twin transition" evidence is anchored in the Italian viticultural model, and the "Digital Acculturation" framework is tailored to China's unique platform ecosystem, necessitating validation in other settings. To bolster confidence in the results, robustness is sought through triangulation (supply-demand-integration perspectives), theoretical anchoring of models (TPB-DOI integration, SEM validation of constructs), and methodological checks (e.g., using Negative Binomial regression for overdispersed

count data). These checks mitigate concerns within the study's boundaries, affirming the internal consistency and theoretical contribution of the findings, which remain robust pathways for future longitudinal and comparative validation.

Building upon this foundation, future research should explore several promising avenues. Longitudinal and Causal Studies: Employing panel data or quasi-experimental designs to track firms' digital transformation journeys and their causal impact on export performance in markets like China would solidify the causal claims. Cross-Cultural and Comparative Extensions: Replicating the consumer study in other key growth markets (e.g., Southeast Asia, Africa) to test the universality of the innovation hierarchy and adopter profiles, and comparing the preparedness of other Old World nations (France, Spain) would enhance external validity. Qualitative Deep Dives: In-depth case studies of firms successfully implementing Digital Acculturation and Innovation Alignment could uncover the specific managerial practices, organizational changes, and partnership models that underpin successful execution. Expanding the Innovation Framework: Investigating the interaction effects between different innovation dimensions (e.g., how blockchain traceability enhances the value of conceptual "organic" claims) and incorporating emerging technologies like generative AI for hyper-localized content creation could refine the strategic framework. Integrating Objective Metrics: Future work could combine survey data with objective firm performance metrics (export volume, profitability) and digital footprint data (social media engagement, platform sales) to create a more comprehensive assessment of alignment and success. Finally, research could examine the role of policy intermediaries in facilitating the necessary ecosystem changes to overcome the collaborative barriers identified as so critical to organizational change.

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