INNOVATION IN THE WINE SECTOR DRIVEN BY CLIMATE CHANGE – AN INSIGHT INTO HUNGARIAN PRACTICES

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VALÉRIA LEKICS

HUNGARIAN UNIVERSITY OF AGRICULTURAL AND LIFE SCIENCES
DOCTORAL SCHOOL OF ECONOMICS AND REGIONAL SCIENCES

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HUNGARIAN UNIVERSITY OF AGRICULTURAL AND LIFE SCIENCES
DOCTORAL SCHOOL OF ECONOMICS AND REGIONAL SCIENCES

Head of the Doctoral School
PROF. DR. ZOLTÁN BUJDOSÓ

Supervisor
PROF. DR. IMRE FERTŐ
Doctor of THE HUNGARIAN ACADEMY OF SCIENCES

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Prepared by
VALÉRIA LEKICS

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Background and objectives of the research

The global ecological crisis, which is largely the result of human activity, is rewriting our future farming practices in many respects.

Viticulture and wine production are agricultural sectors that are heavily dependent on natural resources: the use of pesticides and fertilisers increases the concentration of greenhouse gases in the atmosphere and contributes to the destruction of living waters. Vineyard machinery releases pollutants into the atmosphere, and soil compaction damages soil life. Pesticides and their residues have a carcinogenic effect on humans. Wineries have significant water requirements and wastewater emissions, and their cooling needs also result in high electricity consumption (Bandinelli et al., 2020; SUSTAVINO, 2013) . While viticulture accounts for nearly one-third (27%) of the sector's carbon footprint, winemaking accounts for 73% (of which 23% is attributable to winemaking and 50% to bottling and packaging). The most widely accepted and common packaging material to date, the single-use glass bottle, raises serious ecological concerns (Navarro et al., 2017) . However, the sector is not only a partial contributor to today's global ecological crisis, but rather a victim of it. Vines are sensitive to increasingly frequent and extreme weather anomalies. Severe winter frosts are becoming less common, while early spring frosts are becoming more frequent, which is particularly harmful during bud break. The rise in average temperature increases the sugar content of the berries but reduces their acidity, shortening the growing season; the phenological phases are 'compressed', bringing forward the harvest date. Heat stress slows down photosynthesis, prolonged water stress causes quantitative and qualitative crop losses, and the reduction in carbohydrate reserves may also reduce crop yields in subsequent years. In addition to all this, new insect pests must also be dealt with in plantations (Király, 2017; Mesterházy et al., 2014) . Grape growing is therefore forced to adapt to a high degree due to the changed climatic conditions. On the one hand, the negative impact of their activities on the environment must be mitigated, and on the other hand, they must adapt to changing climatic conditions. Measures aimed at reducing the negative impact of operations are referred to as mitigation, while adaptation to climatic conditions is referred to as adaptation. Mitigation measures include the development of a carbon-neutral machine and vehicle fleet, wastewater treatment and water reuse to reduce the water footprint, the (re)use of by-products and end products, the use of renewable energy, the production of biofuels using by-products, and the choice of new packaging alternatives that reduce the weight of packaging materials and bottles. Adaptation measures include irrigation, mulching, and the planting of row cover crops to prevent erosion and regulate water management. We can also adapt to changing climatic conditions by planting grape varieties with longer growing seasons, better stress tolerance, lower heat requirements or greater resistance. We can expect an increase in the popularity of white wines with high acidity and less susceptibility to softening, as well as red wines with high alcohol content and rich colour (e.g. Balaton Uplands). The sector's adaptation to climate change is evidenced by the northward shift of grape-growing areas (north-eastern and north-western slopes, southern England and Canada) and their increasing altitude above sea level (Carroquino et al., 2020; Király, 2017) .

An increasingly broad segment of consumers is making environmentally/ethically responsible decisions, favouring local, healthy foods and thus sustainable food production (Benedek et al., 2020) . Environmental and health issues related to traditional production practices are increasingly becoming the focus of consumer interest. This segment of consumers emphasises the quality and safety of all foods, including wine products (Forbes et al., 2009) . Wines with geographical indications and organic labels are considered by consumers to be healthier and more environmentally friendly, which influences their consumer preferences and purchasing decisions as a value-adding factor (Bernabéu et al., 2008) .

Scarcer resources are reflected in higher energy prices, while stricter environmental and public health regulations are leading to the withdrawal of certain chemical substances from the market. Regulatory policies based on "command and control" measures cannot fully guarantee environmental protection (Triebswetter & Hitchens, 2005) , and in many cases involve costs that reduce the competitiveness of the industry (Testa et al., 2014) .

The search for sustainable solutions can spur innovation among industry players.

Innovation means introducing new products, services, sources of supply, production processes, organisational structures or conquering new markets (Schumpeter, 1934) . While its general definition is neutral in terms of the direction and content of change, eco-innovation brings about change in the direction of sustainable development: it contributes to reducing environmental impact and achieving ecologically sustainable goals (Rennings, 2000) . Sustainable businesses in the sector "are committed to ethical behaviour and contribute to economic development while improving the quality of life of their workforce, their families, the local and global community, and future generations" (Crals & Vereeck, 2004) .

This dissertation aims to explore the theoretical and practical implications of sustainable innovation in the wine industry and to promote understanding of its application, drivers and impacts in different contexts. Due to the growing importance of sustainable development and environmental protection, this area of research is of paramount importance for modern winemaking.

Figure 1 presents the conceptual model of the research, which examines the relationships between sustainable innovation and corporate performance. The research focuses on the toolkit of the sector's eco-innovation strategy. It analyses the human and social drivers of innovation and the impact of innovation on business performance. The model includes the following factors:

1. **Human capital / Social capital factors**
2. **Dynamic capabilities** (adaptive, absorptive, innovative, relationship-building capacity)
3. Managerial Entrepreneurial Orientation (MEO)
4. **Managerial commitment/attitude**
5. **Sustainable innovation** (product, marketing, organisational and process innovation)
6. **Business results**

The model assumes that companies' dynamic capabilities and managerial orientation strengthen the implementation of sustainable innovation, which has a positive impact on corporate performance.

Human and social capital factors

Human and social capital play a key role in sustainable innovation. Human capital includes the professional skills and knowledge of the company's employees, as well as leadership competencies. Social capital refers to the networks and relationships of trust that enable knowledge sharing and collaboration. The success of sustainable innovation depends largely on how a company manages and develops this capital.

Dynamic capabilities

Dynamic capabilities influence a company's adaptability and innovation potential. These include:

- **Adaptive capacity**: The ability to adapt quickly to market and environmental changes.
- **Absorptive capacity**: The ability to recognise, integrate and utilise new knowledge.
- **Innovation capacity**: The ability to continuously evolve and develop.
- **Networking capacity**: The management of the company's external and internal networks.

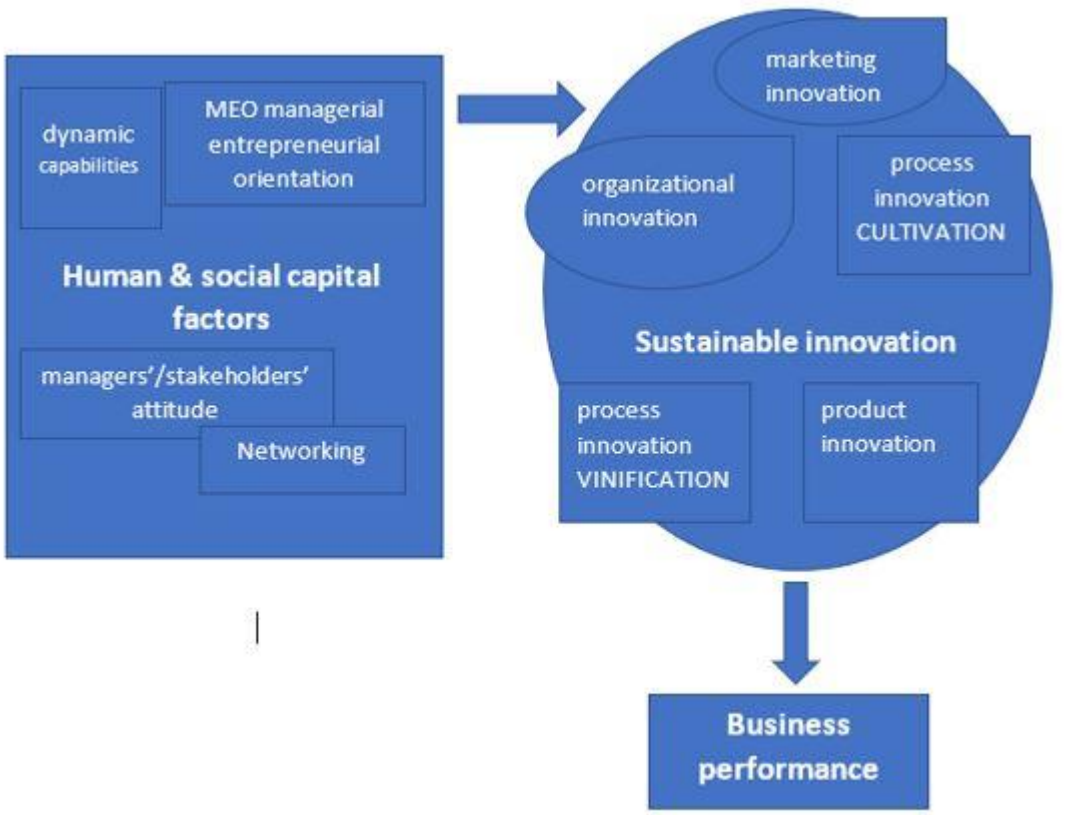
Entrepreneurial Orientation

A managerial entrepreneurial orientation refers to the strategic skills and attitudes that influence a company's innovation capabilities and strategic direction. Leaders of successful businesses proactively seek new opportunities, are open to innovation and are capable of dynamic management.

Sustainable Innovation

Our study distinguishes between four main types of sustainable innovation:

- **Product innovation**: Development of new, sustainable products
- **Marketing innovation**: Sustainable brand building and sales strategies
- **Organisational innovation**: Sustainable corporate management models
- **Process innovation**: Introduction of energy- and resource-efficient technologies



1. Figure: Research model
   Source: own compilation

Business Results

Sustainable innovation has a positive impact on business results:

- **Economic performance**: Revenue growth, market share expansion
- **Environmental performance**: Decreased carbon dioxide emissions, sustainable production processes

The model in Figure 1 provides a comprehensive framework for examining sustainable innovation and corporate performance.

We have formulated **specific research questions** (RQs) for our research objectives, to which empirical studies seek concrete answers:

RQ1: Systematic review of the literature

This objective served as the basis for Chapter 5.1 ("Sustainable innovation in the wine sector: A systematic review of the literature"): a detailed categorisation of the international literature on eco-innovation in winemaking (product, process, marketing and organisational innovations) and an in-depth analysis of the drivers, barriers and impacts.

- **Research Question 1.1:** What are the relevant types of eco-innovation (product, process, marketing, organisational) in the wine sector based on international literature, and what are their most common practices?
- **Research Question 1.2:** What are the main drivers (e.g. regulatory pressure, consumer demand, market competition) and barriers (e.g. resource constraints, technological constraints, knowledge gaps) influencing the introduction of eco-innovations in the wine sector?
- **Research Question 1.3:** What theoretical and empirical gaps can be identified in the literature on eco-innovation in the wine sector that require further research?

RQ2: Examination of eco-innovation practices in Hungary

A further aim of our research is to examine eco-innovation strategies and their application in detail in the Hungarian wine sector, which can be considered a representative case in Central and Eastern Europe. The research explores the characteristics and development trends of innovation activities in Hungarian wineries. We identify clusters of wineries based on their innovation strategies and performance results, taking into account their technological sophistication, environmental commitment and market orientation. We also explore the role of company size, resource availability and networks, with a particular focus on regional characteristics, thereby contributing to the sustainable development of the wine sector in a less researched region, Central and Eastern Europe.

- **Research Question 2.1:** How can Hungarian wineries be characterised in terms of their eco-innovation strategies and dimensions (product, process, marketing, organisational innovation)?
- **Research Question 2.2:** Can Hungarian wineries be classified into clusters based on their eco-innovation strategies and results?
- **Research Question 2.3:** What role do company size, resource availability and external networks play in the introduction of eco-innovation in Hungarian wineries?

RQ3: Analysis of the role of dynamic capabilities

Another objective of our research is to examine in detail the impact of managerial commitment, resource mobilisation and networking on the application of eco-innovation in the wine sector. In the course of our research, we explore the key organisational capabilities that determine the success of innovation. We

present SME strategies built on overcoming obstacles and exploiting sustainable innovation opportunities, including the areas of knowledge management, partnerships and resource optimisation.

- **Research Question 3.1:** To what extent does management commitment influence the introduction of eco-innovation in Hungarian wineries?
- **Research Question 3.2:** How does the dynamic capacity of wineries contribute to their eco-innovation activities?
- **Research Question 3.3:** What challenges do small and medium-sized enterprises face in developing dynamic capabilities for eco-innovation, and what successful strategies can be identified?

RQ4: Assessing the dual impact of eco-innovation

The aim of the research is to comprehensively evaluate the environmental and financial results of implemented eco-innovation, including the examination of direct and indirect effects. Detailed analysis of trade-offs and synergies between sustainability and profitability, with particular emphasis on short- and long-term impacts. The research identifies areas where environmental and economic goals can be reconciled and makes recommendations for resolving potential conflicts.

- **Research Question 4.1:** What are the direct and indirect effects of eco-innovation on the environmental performance of wineries?
- **Research Question 4.2:** How does eco-innovation affect the financial performance of wineries (e.g. revenue, cost reduction, market share)?
- **Research Question 4.3:** What synergies and trade-offs can be identified between environmental and financial outcomes related to eco-innovation, with particular regard to short- and long-term effects?

R5: Formulating and communicating feasible recommendations

A further aim of our research is to develop concrete strategies for wineries to apply eco-innovation, balancing costs and benefits. The recommendations cover the areas of technological investments, training and organisational development. We will prepare detailed policy recommendations to support eco-innovation, with a particular focus on the development of support schemes, training programmes and infrastructure. Our recommendations take into account the specific needs and opportunities of wineries of different sizes and types. Our goal is for the research to demonstrate the practical relevance of eco-innovation to industry stakeholders and decision-makers, thereby promoting the sustainable development of the sector.

- **Research Question 5.1:** What specific strategies can be recommended to wineries for the cost-effective and sustainable implementation of eco-innovation based on empirical results?
- **Research Question 5.2:** What policy measures could effectively support eco-innovation in the Hungarian wine sector, taking into account regional and company-specific characteristics?

Materials and methods

We conducted a survey of the innovation strategies of Hungarian winemakers as part of our primary research. Based on the theoretical model, the research questionnaire includes a human/social capital factor block, an innovation strategy block, an effectiveness block and an organisational characteristics block. We assigned variables to each factor to be measured, then formulated a question/statement for each variable, which had to be answered on a Likert scale ranging from 1 to 5. For the control variables, we asked single or multiple choice questions. We tested the questionnaire on a small group of wineries (6) and then sent it to the wineries in the form of an online GoogleForms questionnaire. We compiled a database of 837 businesses based on sectoral professional and regional wine tourism organisations and the wineries' websites. We received 234 completed questionnaires, representing a response rate of 27.9 per cent, which is

considered outstanding compared to the response rates of other studies in the wine sector (Doloreux & Frigon, 2019; Galati et al., 2017; Galbreath et al., 2016; Presenza et al., 2017) .

The questionnaire survey consisted of 77 questions. The questionnaire can be found in Appendix B of the dissertation, and the variables and descriptive statistics are presented in Table 1.

Table 1: Variables and descriptive statistics

Variable	Variable description	N	Average	Median	Standard deviation	Skewness	Peakiness	Min	Max	Abilities	Average ability
1.1_MEO-env	Commitment to sustainability	234	3.49	3	0.990	-0.23	-0.04	1	5	Management commitment	3.491
1.2_MEO risk	Financial, economic	234	3.46	4	1.069	-0.3	-0.64	1	5		
1.3_MEO-trust	relationship	234	4.48	5	0.713	-1.52	2.89	1	5		
1.4_MEO-indep	initiative	234	4.30	5	0.823	-	0.66	1	5	Managerial entrepreneurial mindset	
1.5_MEO-dilig	diligence	234	4.56	5	0.666	-1.4	1.47	1	5		
1.6_MEO-innov	idea generation	234	4.10	4	0.858	-0.8	0.54	1	5		
1.7_MEO-creat	creativity	234	4.17	4	0.805	-1.12	2.06	1	5		4.182
										DYNAMIC CAPABILITIES	
2.1_ADAC1	Innovation	234	3.06	3	0.969	-0.1	0.1	1	5		
2.2_ADAC2	Market adaptation	234	3.56	4	0.848	-0.1	-0.2	1	5	Adaptive capability	
2.3_ADAC3	Adaptation to the business environment	234	3.48	3	0.85	-0.2	0	1	5		3.372
2.4_ABSOC1	Recognition of external knowledge	234	4.16	4	0.670	-0.8	2.2	1	5		
2.5_ABSOC2	Integration of external knowledge	234	4.14	4	0.713	-0.7	1	1	5	Absorption capacity	
2.6_ABSOC3	Utilisation of integrated knowledge	234	3.85	4	0.807	-0.6	0.75	1	5		4.053
2.7_INNOC1	new working methods	234	3.15	3	1.110	0.1	-0.63	1	5		
2.8_INNOC2	New products, services	234	3.11	3	1.098	0.1	-0.7	1	5	Innovation capacity	
2.9_INNOC3	We are pioneers in the market	234	2.53	2	1.143	0.44	-0.5	1	5		2,936
2.10_NETCAP1	Coordination / Planning	234	3.45	4	1.061	-0.3	-0.6	1	5		
2.11_NETCAP2	Coordination / Reciprocity	234	3.51	4	0.973	-0.4	-0.2	1	5		
2.12_NETCAP3	Coordination / Cooperation	234	3.61	4	0.992	-0.3	-0.5	1	5		
2.13_NETCAP4	Interpersonal skills / Personality	234	4.41	5	0.720	-1.2	1.9	1	5		
2.14_NETCAP5	Interpersonal skills / Flexibility	234	4.29	4	0.781	-0.9	0.71	1	5		
2.15_NETCAP6	Interpersonal skills / Constructiveness	23	4.17	4	0.769	-0.9	1.1	1	5	Cooperation ability	
2.16_NETCAP7	Partner knowledge / Market	234	3.69	4	0.853	-0.2	-0.2	1	5		
2.17_NETCAP8	Partner knowledge / Product, Service	234	3.69	4	0.838	0	-0.4	1	5		
2.18_NETCAP9	Partner knowledge / Strengths, Weaknesses	234	3.56	4	0.898	-0.4	0.15	1	5		
2.19_NETCAP10	Internal communication / Formal relationships	234	3.15	3	1.169	-0.1	-0.8	1	5		
2.20_NETCAP11	Internal communication / Informal relations	234	3.62	4	1.034	-0.4	-0.5	1	5		
2.21_NETCAP12	Internal communication / Feedback	234	3.94	4	0.974	-0.8	0.3	1	5		3.761
2.22_ED1	Environmental dynamics / economic and social	234	3.06	3	1.023	0	-0.3	1	5		

Variable	Variable description	N	Average	Median	Standard deviation	Skewness	Peakiness	Min	Max	Abilities	Average ability
2.23_ED2	Environmental dynamics / natural	234	4.03	4	0.924	-0.8	0.07	1	5		
											INNOVATION NETWORK
3.1_Inter1	Innovation with raw material and technology suppliers	234	3.33	3	1.123	-0.4	-0.4	1	5		
3.2_Intra1	Innovation with other wineries, competitors	234	3.43	3	1.035	-0.4	-0.2	1	5		
3.3_Scien1	Innovation with universities and research institutes	234	2.60	3	1.139	0.19	-0.6	1	5		
3.4_Intra2	Innovation with customers and consumers	234	3.29	3	1.045	-0.2	-0.5	1	5		
3.5_Intra3	Innovation with sectoral professional organisations and professional associations	234	2.76	3	1.176	-0.1	-1	1	5		
3.6_Inter2	Innovation with consultants and knowledge-intensive business service providers	234	3.03	3	1.282	-0.1	-1	1	5		
3.7_Scien2	Innovation with knowledge gained from scientific and professional journals	234	3.23	3	1.131	-0.4	-0.45	1	5		
3.8_Scien3	Innovation contacts made at exhibitions, fairs and conferences	234	3.15	3	1.084	-0.2	-0.6	1	5		
4.1_MARKINN1	Certificate - organic	234	0.32	0	0.47	0.75	-1.45	0	1		
4.2_MARKINN2	Certificate - origin	234	0.70	1	0.46	-0.88	-1.23	0	1		
4.3_MARKINN3	Promotion, advertising	234	0.83	1	0.37	-1.8	1.25	0	1		
4.4_MARKINN4	Social media	234	0.88	1	0.33	-2.3	3.31	0	1		
4.5_MARKINN5	Short supply chain	234	0.78	1	0.42	-1.34	-0.19	0	1		
4.6_ORGINN1	Environmental manager	234	0.39	0	0.49	0.46	-1.81	0	1		
4.7_ORGINN2	HR manager	234	0.32	0	0.47	0.77	-1.41	0	1		
4.8_ORGINN3	Training, awareness raising	234	0.53	1	0.5	-0.1	-2.01	0	1		
4.9_ORGINN4	Innovation forums	234	0.50	1	0.5	-0.02	-2.02	0	1		
4.10_PROCINN1	Precision viticulture	234	0.35	0	0.48	0.65	-1.59	0	1		
4.11_PROCINN2	Integrated grape growing	234	0.56	1	0.5	-0.26	-1.95	0	1		
4.12_PROCINN3	Reduction in the use of agrochemicals	234	0.79	1	0.41	-1.41	-0.02	0	1		
4.13_PROCINN4	Recycling on plantations	234	0.79	1	0.41	-1.41	-0.02	0	1		
4.14_PROCINN5	Application of material, energy and water saving solutions	234	0.75	1	0.43	-1.18	-0.62	0	1		
4.15_PROCINN6	Reduction of greenhouse gas emissions	234	0.37	0	0.48	0.53	-1.73	0	1		
4.16_PROCINN7	Use of renewable energy	234	0.51	1	0.5	-0.05	-2.01	0	1		
4.17_PROCINN8	Green solutions in viticulture	234	0.83	1	0.38	-1.76	1.11	0	1		
4.18_PROCINN9	Green solutions in the cellar	234	0.32	0	0.47	0.8	-1.38	0	1		
4.19_PRODINN1	Green solutions in packaging	234	0.64	1	0.48	-0.57	-1.69	0	1		
4.20_PRODINN2	New grape varieties	234	0.41	0	0.49	0.37	-1.88	0	1		
4.21_PRODINN3	New wine varieties	234	0.59	1	0.52	0.08	-0.02	0	1		

Variable	Variable description	N	Average	Median	Standard deviation	Skewness	Peakiness	Min	Max	Abilities	Average ability
4.22_OTHER	Other	234	0.26	0	0.44	1.1	-0.8	0	1		
RESULT VARIABLES											
5.1_PERF	Increased efficiency, profitability	234	3.00	3	1.09	-0.14	-0.43	1	5	financial market performance variables	3.2
5.2_PERF	Increased sales	234	3.12	3	1.18	-0.3	-0.8	1	5		
5.3_PERF	New markets	234	3.21	3	1.1	-0.3	-0.5	1	5		
5.4_PERF	Export potential	234	2.35	2	1.39	0.52	-1.1	1	5		
5.5_PERF	Wines that have become more "branded"	23	3.44	4	1.12	-0.5	-0.2	1	5		
5.6_PERF	"Value-creating" image	234	3.78	4	1.08	-0.9	0.3	1	5		
5.7_PERF	Decreased water, energy and raw material requirements	2	2.58	3	1.13	0.29	-0.6	1	5	Operational sustainability result variables	2.6
5.8_PERF	Decreased waste production, gas and noise emissions	234	2.49	2	1.12	0.35	-0.6	1	5		
5.9_PERF	Sustainability integrated into management system	234	2.76	3	1.19	0.17	-0.8	1	5		
COMPANY CHARACTERISTICS											
6.3_COSINCE	Year of establishment		2003	2002	10.31	-0.41	0.28	1960		2020	
6.4.1_COSIZE	Enterprise size – number of employees		8	4	12.05	3.21	11.7	0	80		
6.4.2_AREA	Enterprise size – cultivated area (ha)		23.4	8	46.52	5.34	37.02	0	400		
6.4.3_VOL	Enterprise size – production volume (hl)		3731.78	300	24,052.54	10.6	119.1	1	300		
ENTREPRENEURIAL CHARACTERISTICS											
6.6_EDUC	Entrepreneur's qualifications		2.75	3	1.06	-0.58	-0.89	1	4		
6.7_GENDER	Gender of entrepreneur		0.18	1	0.38	1.72	0.97	0	1		
6.8_AGE	Entrepreneur's age		47.6	46	12.6	0.28	-0.38	21	78		

Source: own compilation

The statistics show that Hungarian winemakers have a strong commitment to the environment and an average entrepreneurial mindset. In terms of dynamic capabilities, the strengths of domestic wineries lie in recognising and integrating external knowledge and building informal networks. The primary source of innovation knowledge is relationships with competitors within the cluster. Most of the innovations implemented by wineries were focused on marketing and the production process; resource-saving, rational reorganisation and recycling process innovations are the most popular practices, resulting in cost efficiency. Wineries reported financial and market results more often as the benefits of their innovations than environmental and sustainability results.

Several quantitative methods were used in the dissertation, including principal component analysis (PCA), cluster analysis, semi-parametric binary models, and multivariate regression, all of which contribute to a thorough examination of the adaptation of eco-innovation and its impact on corporate performance.

To define eco-innovation strategies, we first performed a principal component analysis of the 22 innovation variables presented in Table 1. The aim of this step was to demonstrate that certain types of eco-innovation are closely related to each other and that the 22 eco-innovation variables can thus be classified into a limited number of eco-innovation dimensions. To determine the number of clusters, we performed a non-hierarchical K-means cluster analysis on these parameters, then applied Kruskal-Wallis tests to describe the relationship between each eco-innovation strategy and its determining factors. We used multivariate regression to examine how eco-innovation practices influence corporate performance.

This complex analytical approach allowed us to gain a deeper understanding of the relationships between eco-innovation practices and corporate performance, as well as to identify eco-innovative wine clusters with different eco-innovation profiles and performance characteristics. The results provide valuable insights for

both theoretical experts and practical decision-makers in understanding the strategic importance of eco-innovation.

Results

K1: Systematic review of the literature (Study 1)

We systematised the internal and external drivers of sustainable innovation (see Table 2) and the sustainable innovation practices of the sector (see Table 1), creating the framework for our empirical research.

Table 2: Drivers of sustainable innovation

Internal driving factors	External driving factors
• Owners' managers' awareness • Generational succession • Strategic approach in management • Cost reduction • Improving product and service quality • Risk avoidance: need for safety and security • Vision of a sustainable business • Minimizing ecological footprint • Tradition • Structural characteristics (size, corporate organization) • Absorptive capacity • Knowledge exchange • Quality and Environmental Management Systems • Voluntary certifications	• Market trends, consumer needs • Competition • Customer expectation • Industry initiatives • Export orientation • Government regulations (supportive) • Subsidies • Climate change • Networking and cooperation with customers, suppliers, research institutes, government organizations, marketing agencies • Supporting national wine strategy • Sectoral infrastructure

Source: own compilation

K2: Examination of eco-innovation practices in Hungary (Study 2)

In this study, we focus on two significant factors: the structural and organisational characteristics of the enterprise and the acquisition of external knowledge necessary for innovation. The relationship between company size and age and eco-innovation has been widely studied; the availability of resources, many years of experience, efficient cost management, agility, flexibility and risk appetite are some of the arguments for and against.

H1: The size of the enterprise has an impact on the uptake of eco-innovation.

H2: The age of the enterprise influences the adoption of eco-innovation.

Interactions with external actors, R&D partnerships and knowledge exchange have a positive impact on eco-innovation. The breadth and depth of these interactions can significantly influence the innovation performance of companies.

H3: Companies that engage in diverse and intensive interactions with external partners are more likely to adopt eco-innovation, as they have access to a wider range of knowledge and expertise (Galbreath et al., 2016; Muscio et al., 2013; Triguero et al., 2018).

The innovation variables were summarised by principal component analysis into seven factors that clearly distinguish wineries in terms of their innovation strategies (see Table 3). Cluster analysis distinguished

between an innovative cluster comprising 113 enterprises and a less innovative cluster comprising 121 wineries (see Table 3).

Table 3: Cluster analysis: average values of main innovation components for each cluster

Factors	Cluster 1	Cluster 2	Kruskal-Wallis (p value)	η^2	ε^2
COMMUNICATION	0.26	-0.25	0.0001	0.0103	0.0102
TAG	0.50	-0.47	0.0001	0.2072	0.2054
RESPONSIBILITY	0.35	-0.33	0.0001	0.0245	0.0243
LABOUR DEVELOPMENT	0.72	-0.67	0.0001	0.4310	0.4273
LOW-TECH	0.38	-0.35	0.0001	0.0788	0.0781
HIGH-TECH	0.60	-0.56	0.0001	0.3168	0.3141
PRODUCT	0.50	-0.47	0.0001	0.2154	0.2135
N	113	121			

Source: Authors' own work

Hungarian wineries also differ significantly in terms of innovation network building; the more innovative Cluster 1 makes more active use of all knowledge sources and has a larger number of employees, while its managers/owners are better educated and its cultivated area and production volume are slightly larger than those of the less innovative wineries in Cluster 2. The clusters do not differ in terms of age and gender (see Table 4).

Table 4: Cross-classification of clusters by innovation knowledge sources and organisational characteristics

Variables	Cluster 1	Cluster 2	Kruskal-Wallis (p value)	η^2	ε^2
Source of innovation knowledge					
Suppliers (materials and technology)	3.49	3.19	0.0415	0.0136	0.0135
Competitors	3.58	3.31	0.1045	0.0071	0.0070
Universities, research institutes	2.91	2.31	0.0001	0.0693	0.0687
Buyers, Consumers	3.42	3.17	0.0634	0.0105	0.0104
Sectoral professional organisations	3.10	2.45	0.0001	0.0710	0.0704
Knowledge-intensive advisory services	3.19	2.89	0.0630	0.0106	0.0105
Trade journals	3.45	3.03	0.0039	0.0317	0.0314
Exhibitions, fairs, conferences	3.46	2.86	0.0001	0.0764	0.0757
Organisation-specific variables					
Age of enterprise	21.6	18.8	0.0351	0.0095	0.0095
Number of contributors	9.78	6.31	0.0003	0.0544	0.0539
Cultivated area (ha)	30.24	17.04	0.0019	0.0397	0.0394
Production volume (hl)	4607.22	2914.70	0.0412	0.0089	0.0089
Contractor-specific variables					
Age	46.7	46.6	0.2421	0.0004	0.0004
Education	2.9	2.6	0.0435	0.0026	0.0026
No	0.175	0.175	0.9941	0.0038	0.0038

Source: Authors' own work

Our results show that the use of universities and research centres, professional organisations, scientific forums such as conferences, lectures or exhibitions as sources of innovation knowledge have a positive effect on

innovative cluster membership, but the size and age of the enterprise do not play a role in the introduction of eco-innovation practices (see Table 5). This means that we reject hypotheses 1 and 2 and confirm hypothesis 3.

Table 5: Logit models for determining innovative cluster membership

Source of innovation knowledge	**1**	**2**	**3**
Suppliers (materials and technology)	-0.010		-0.039
Competitors	-0.062		0.007
Universities, research institutes	0.351		0.303
Buyers, consumers	0.019		0.034
Sectoral professional organisations	0.368		0.344
Knowledge-intensive advisory services	-0.144		-0.208
Trade journals	0.10		0.153
Exhibitions, fairs, conferences	0.413		0.427
Age of enterprise		0.022	0.022
Number of employees		0.008	0.007
Cultivated area (ha)		0.006	0.007
Production volume (hl)		-0.000	-0.000
Age		-0.002	-0.001
Education		0.149	0.209
No	-3.016	-0.993	-4.192***
N	234	234	234
Pseudo R^2	0.113	0.032	0.139

Source: Authors' own work

K3: Analysis of the role of dynamic capabilities (Study 3)

Dynamic capabilities express the ability of companies to transform internal and external competencies in response to a rapidly changing environment (Teece et al., 1997) . In the wine sector, these capabilities are key to adapting to the effects of climate change and to effective resource management.

H1: Dynamic capabilities have a positive effect on eco-innovation in the wine sector (Arranz et al., 2020; Juan R. Ferrer et al., 2022; Galbreath et al., 2016; Teece et al., 1997)

Networking capabilities enable the establishment and maintenance of relationships with stakeholders, which are essential for accessing the knowledge, resources and collaboration opportunities necessary for eco-innovation (Pittaway et al., 2004)

H2: Networking capabilities positively influence the adoption of eco-innovation practices in the wine sector (Muscio et al., 2017; Pittaway et al., 2004; Silvestri et al., 2023) .

Managerial commitment to sustainability plays a central role in promoting eco-innovation, as it determines the strategic orientation of companies (Schaltegger & Burritt, 2018) and creates an organisational culture that supports the introduction of eco-innovation practices (Barba-Sánchez & Atienza-Sahuquillo, 2016; Ratten, 2018) .

H3: Managerial commitment to sustainability positively influences eco-innovation initiatives in the wine industry (Barba-Sánchez & Atienza-Sahuquillo, 2016; Kariyapperuma & Collins, 2021; Ratten, 2018; Schaltegger & Burritt, 2018) .

Effective knowledge management improves the ability of wineries to assimilate and apply environmental knowledge, which is essential for the successful introduction of eco-innovation (Cohen, W. & Levinthal, D., 1990)

H4: Knowledge management has a positive impact on the introduction of eco-innovation in the wine sector (Cohen, W. & Levinthal, D., 1990; Marco-Lajara et al., 2023; Martínez-Falcó et al., 2023; Martínez-Falcó, Sánchez-García, et al., 2024) .

Organisational characteristics such as size, age, ownership structure and availability of resources significantly influence how wineries adopt and implement innovation practices. Family-owned and cooperative wineries tend to show greater commitment to sustainability due to their deep-rooted traditions, responsible management and the prominent role of local communities (Kariyapperuma & Collins, 2021; Ferrer et al., 2024).

H5: Ownership structure moderates the relationship between management commitment and eco-innovation, in that family-owned and cooperative-based businesses show a stronger eco-innovation relationship due to their long-term sustainability orientation (Ferrer et al., 2024; Kariyapperuma & Collins, 2021; Carchano et al., 2024).

Table 6: Results of the binary model

Variable	PROCESS1	PROCESS2	PROCESS3	PROCESS4	PROCESS5	PROCESS6	PROCESS7	PROCESS8	PROCESS9
Adaptive	0.314	0.084	-0.396**	-0.649**	-0.257	0.336	0.169	-0.466***	0.095
Absorption	0.780	0.172	1.081	0.461	0.714	0.812***	0.476	0.247	0.322
Network	-0.851***	-0.073	-0.160	0.338	-0.305	-0.811***	-0.693	-0.489**	-0.359**
Knowledge exchange	0.701	0.193	0.989	0.400	1.260***	0.826***	0.383	0.997***	0.402
Management	0.283	-0.155	-0.074	0.223	0.281	0.349	0.308	-0.136	0.218
No	0.814*	-0.097	0.538	1.108	-0.112	-0.293	-0.285	0.964	-0.272
Education	-0.450	-0.002	0.405	0.700	0.083	-0.150	-0.362	-0.062	0.070
Cultivated area	0.005	0.014	0.032**	0.008*	0.006	0.004	0.021***	0.023**	0.002
Age of enterprise	-0.001	0.006	0.045	-0.035	0.018	0.017	0.035	-0.010	0.003
Ownership	0.382	-0.138**	-0.146	-0.515	-0.190	0.409***	0.359	0.194	0.318
N	233	233	233	233	233	233	233	233	233
Log-likelihood	-135.786	-139.286	-93.030	-106.989	-112.097	-136,525	-142,773	-87,986	-135,589

Source: Authors' own work

The factors influencing innovation and the strength of their impact are presented in Table 6.

H1 hypothesis can be accepted: Absorption capacity was generally identified as a key factor in the introduction of eco-innovation in the sample. Wineries with good absorption capacity are leading the way, for example, in reducing the use of agrochemicals, introducing energy and water saving measures, and reducing greenhouse gas emissions. The positive impact of adaptive capabilities was more evident in relation to more advanced eco-innovation measures, such as the use of information technology in production and efforts to reduce greenhouse gas emissions. 's H2 hypothesis was also confirmed: management commitment has a positive influence on the introduction of eco-innovations. The results confirm the key role of management commitment in promoting eco-innovation, particularly in the areas of greenhouse gas reduction and the use of renewable energy sources. Hypothesis H3 was partially confirmed: the role of network capabilities was mixed: it promoted eco-innovation related to resource recycling, such as the use of vine shoots and stumps,

but seemed to hinder more complex, technology-driven innovation, such as the reduction of greenhouse gases and the use of digital technologies in vineyard management. Hypothesis H4 was strongly supported: knowledge management has a positive impact on eco-innovation. Companies that actively collaborate with research institutes, suppliers and legislators have implemented more developments, further reinforcing the role of structured knowledge-sharing mechanisms (Martínez-Falcó et al., 2023). Hypothesis H5 was also supported: **The** ownership structure moderates the relationship between managerial commitment and eco-innovation. The gender of the manager also influences the uptake of eco-innovation: wineries managed by female managers were more likely to engage in resource recycling and cellar-level improvements.

K4: Assessing the dual impact of eco-innovation (Study 4)

In addition to environmental benefits, eco-innovation significantly improves economic performance by increasing profitability, market share and competitiveness.

H1: Eco-innovation has a positive impact on a company's environmental performance (Dahlan & Nurhayati, 2022; Rabadán et al., 2019) .

H2: Eco-innovation has a positive impact on a company's economic performance.

Eco-innovation enhances financial performance through increased market share and improved operational efficiency (.

H3: Organisational capabilities moderate the relationship between eco-innovation and corporate performance.

Companies with strong internal capabilities can realise greater economic and environmental benefits from their eco-innovation (Annunziata et al., 2018) .

H4: Stakeholder commitment mediates the relationship between eco-innovation and corporate performance.

The active commitment of the company and stakeholders enhances the effectiveness of eco-innovation strategies, resulting in excellent environmental and financial/economic performance (Pacheco et al., 2018) .

Principal component analysis of performance variables summarised the result variables in Table 1 into two factors: six variables were included in the market and financial component (output1), where improved profitability, higher turnover, market expansion and brand building had a strong impact. Three variables were included in the operational and sustainability component (output2), where improvements in resource efficiency, reductions in pollutant emissions and the integration of sustainability into the management system were the variables that loaded the component.

Table 7: Results of multivariate regression examining the impact of process innovation on company performance

	output1	output2
Process1	-0.071	-0.024
Process2	0.127	-0.084
Process3	0.055	0.132
Process4	0.018	0.080
Process5	0.108	0.086
Process 6	0.092	0.303***
Process7	-0.044	0.190
Process8	0.007	0.024
Process9	0.150	0.081
No	-0.027	-0.219
Education	0.009	0.036

	output1	output2
Size of cultivated area	-0.004	-0.001
Number of contributors	0.024***	0.009
Age of enterprise	0.010	-0.018
Constant	-21.010	34.443
N	233	233
R	0.1038	0.2569

Note: * p<.1; ** p<.05; *** p<.01

Table 7 shows that in the case of output2, which represents sustainability and operational efficiency results, process 6 and 7 innovation measures, i.e. reducing the use of petrol-powered machines and utilising renewable energy, have a significant impact, which further highlights the importance of targeted developments in achieving operational sustainability. Labour input has a positive impact on output1, which points to the importance of workforce development in promoting financial and market success. Hypotheses H1 and H2 can be partially accepted. However, the age of the enterprise has a negative effect on output2, suggesting that older enterprises may find it difficult to implement effective or sustainable developments, possibly due to organisational complexity or inertia.

Table 8: Results of multivariate regression examining the impact of organisational capabilities on entrepreneurial performance

	output1	output2
Management1	-0.137	0.98
Managers2	0.211	0.005
Managers3	0.081	0.177**
Adaptive1	0.132	-0.033
Adaptive2	0.233	0.005
Absorption1	0.213**	0.235**
No	-0.005	-0.311
Education	0.054	0.042
Cultivated area	-0.000	0.002
Age of enterprise	0.003	-0.023***
Constant	-8.339	44.090
N	233	233
R	0.2354	0.2039

Note: * p<.1; ** p<.05; *** p<.01

Table 8 shows that managerial commitment and creativity have a stimulating effect on environmental and operational performance, while risk-taking propensity has a stimulating effect on market and financial performance. We partially accept hypothesis H4. Adaptive capacity has a stronger impact on financial performance than on sustainability results. Companies that question traditional practices and respond flexibly to changing market conditions achieve better financial results. Absorptive capacity, i.e. the ability to recognise and utilise external knowledge, plays a significant role in both performance indicators. Control variables such as gender, education, size of cultivated land, and number of collaborators have little effect on financial performance, while company size is negatively correlated with sustainability outcomes, so we reject hypothesis H3.

Conclusions

K1: Systematic review of the literature (Study 1)

This dissertation analyses sustainable innovation in the grape and wine sector and the factors influencing it, and examines their impact on operational performance based on the available literature and research conducted among domestic wineries. Research into sectoral innovation strategies has been extremely extensive in terms of scope and subject matter over the past decade and a half, with the number of studies increasing year on year. Within the framework of a systematic literature review, we were able to synthesise the sustainable innovation practices of approximately 5,300 wineries worldwide.

The commitment of managers is key to integrating innovation into the overall structure of the company, but consumer expectations, export orientation, and economic incentives (Carroquino et al., 2020; Király, 2017), dynamic leadership skills (Dressler, 2020) , absorption capacity and knowledge exchange (Galbreath, J., 2016) are also relevant factors in the adoption of sustainable practices. Networking and regional and functional cooperation are crucial for development capacity in the wine ecosystem. Knowledge-sharing platforms and industry collaborations play a key role in the spread of sustainable practices (Elkington, 1998) .

However, owner/manager commitment is not only the main driving force, but also moderates or even enhances the impact of other factors on innovation. Consider, for example, that a lack of financial resources, a lack of information or inadequate legislation can significantly hinder sustainable development if there is a lack of managerial commitment, because businesses are not motivated to improve their environmental performance through other, more easily accessible or voluntary systems. The impact of eco-innovation is enhanced when customers are also involved in the development (Frigon et al., 2020) , for which short supply chains and cellar door sales provide an excellent opportunity. Innovation readiness is positively correlated with vertical (between actors in the sales chain) and horizontal (with competitors) cooperation, as well as with commitment to research and development (Stasi et al., 2016) .

However, the lack of financial resources and information, as well as the complexity of the regulatory environment, significantly hinder innovation (Carroquino et al., 2020; Király, 2017). Subsidies and legal regulations act as incentives in cases where owners and managers have little commitment to sustainability (Carroquino et al., 2020) .

Developments in the domestic sector – in line with international trends – are primarily focused on the process and, to a lesser extent, on the organisation. This is not surprising, given that we are talking about agricultural/food products, where the work process covering the entire year (the viticulture phase during the growing season, followed by the winemaking and storage phase) results in a finished product after bottling. On the other hand, the players in the sector in our country are predominantly family micro and small businesses. Among the innovations in the cultivation/production process, therefore, those that require less capital and often involve minor reorganisation are the most widespread, such as the use of vine shoot mulch and the application of live row cover. The proportion of digitalisation developments that require significant investment and are profitable for larger farms is therefore the lowest among process innovations. Since nearly 73% of the sector's carbon footprint comes from winemaking, and half of that comes from packaging (, it is not surprising that product innovation in the sector is focused on packaging with a more favourable carbon footprint (lighter bottles, bag-in-box) (et al., 2017) . Organisational innovation measures are less common among domestic wineries; training and awareness-raising through trade journals, presentations, courses and professional meetings provide an excellent opportunity for smaller businesses to acquire knowledge about sustainability and raise awareness.

Based on the results of the literature included in the systematic review, we obtained a mixed picture of the impact of sustainable innovation on corporate performance. Most studies report a positive impact on financial and environmental indicators, but there are also some that find no significant correlation (Guerrero-Villegas et al., 2018; Remaud et al., 2012) . This is understandable, as there are dimensions of effectiveness that are difficult to measure, and the analytical method used can also lead to discrepancies and distortions. Measurement difficulties may also arise from the fact that the impact of sustainable developments often only becomes apparent in the longer term. Consider, for example, measures introduced to preserve biodiversity

(e.g. living row cover, reduced use of agrochemicals), whose ecological results are not always immediate (except for improvements in soil water management) but often only become apparent after many years; with the establishment of insect populations that protect grapevines, the enrichment of soil biota , etc. Measuring the economic and social benefits is even more difficult, and there is no universally accepted measurement system.

K2: Examination of eco-innovation practices in Hungary (Study 2)

We were able to classify domestic wineries into two groups based on their sustainable innovation strategies; 113 wineries were classified as more innovative and 121 as less innovative. The companies in the innovative cluster have lively relationships with their partners, universities, research institutes and are active participants in scientific forums. Our findings are consistent with the literature, which emphasises the importance of external knowledge sources in promoting eco-innovation (Galbreath et al., 2016; Muscio et al., 2013; Triguero et al., 2018).

In terms of size dimensions, i.e. the number of contributors, the size of cultivated land and production volume, we can conclude that the wineries in the more innovative cluster are slightly older and larger than those in the less innovative cluster. Farmers in the more innovative cluster are better educated than those who are less committed to sustainable innovation. In terms of age and gender, the clusters do not differ from each other. Domestic research confirms the findings of international studies in this regard, namely that the organisational characteristics of wineries, such as size, age and education of managers, influence innovation activity. The so-called "innovation inertia" (Aylward, 2002) is a consequence of their lack of knowledge and relative inexperience in research and development issues (Carroquino et al., 2020; Muscio et al., 2013; Stasi et al., 2016).

The innovation capacity of larger, longer-established companies may be based on the financial and intellectual capital accumulated over the years; the combination of financial resources, knowledge and experience necessary for development. Our results suggest that wineries with greater access to financial resources and external knowledge are more likely to implement cutting-edge eco-innovation strategies, supporting the finding that resource availability determines innovation capacity (Frondel et al., 2008) .

Wineries in the more innovative cluster make more active use of universities and research centres, professional organisations, and scientific forums such as conferences, lectures, and exhibitions as sources of knowledge for their development than those in the less innovative group. These results confirm what has been reported in the international literature: knowledge exchange and information sharing within the organisation, as well as with partners and research institutes (Barba-Sánchez & Atienza-Sahuquillo, 2016; Chaminade & Randelli, 2020; Frigon et al., 2020; Marques et al., 2021; Ratten, 2018) by providing the necessary knowledge. Networking with competitors is a very common and important way of acquiring knowledge in both clusters; it is not uncommon for winemakers in a region, municipality, mountain community or even an entire wine region to work together and exchange knowledge on specific activities such as pruning, plant protection, or the DRS (mandatory return fee products) and EPR (extended producer responsibility for circular products) systems at professional events and presentations. Regularly convened joint wine competitions, wine reviews and festivals are also designed to deepen cooperation.

The results also highlight that regional innovation clusters are incubators for innovation. Wineries participating in regional clusters are in a more favourable position to adopt sustainable practices. This supportive role is consistent with the literature; Aylward (2007), Chaminade and Randelli (2020), and Giuliani (2013) also emphasise the importance of regional clusters in supporting innovation in the wine sector.

Our research found that Managerial Entrepreneurial Orientation (MEO), which excels in creativity, innovation and problem-solving skills, is an essential starting point for sustainability initiatives, in line with previous research (Schaltegger & Burritt, 2018).

Dynamic capacity, which expresses the ability to respond to a rapidly changing environment, is crucial for players in the resource-dependent wine sector. Businesses with better dynamic capabilities are able to manage environmental risks more effectively and integrate eco-innovation practices (Alonso & O'Neill, 2011; Arranz et al., 2020) .

Our research confirmed that the ability to acquire and apply new knowledge, i.e. absorption capacity, is crucial for the uptake of eco-innovation. This is in line with previous research on the role of absorption capacity in environmental innovation .

It has also been confirmed that flexible and strong personal relationships with business partners are essential for eco-innovation. We have seen that more formal partnerships (e.g. regular meetings) are less prominent, indicating that structured cooperation needs to be developed (Muscio et al., 2017).

Innovation knowledge exchange contributes most to sustainable initiatives in the case of interactions with professional associations and consultants. These results also confirm the importance of external knowledge in enhancing companies' eco-innovation capabilities, in line with previous studies (Maghssudipour et al., 2020).

K3: Analysis of the role of dynamic capabilities (Study 3)

Absorption capacity is a key factor in eco-innovation in the domestic wine sector. Wineries with good absorption capacity were more likely to adopt innovations such as reducing the use of agrochemicals, introducing energy- and water-saving solutions, and reducing greenhouse gas emissions. These results are consistent with previous research on the wine sector, which found absorption capacity to be critical for the integration of new technologies and sustainability practices, especially in regions facing environmental challenges (Frigon et al., 2020).

Adaptive capacities had a positive impact on more advanced, high-tech innovations, such as the use of information technology in viticulture or efforts to reduce greenhouse gas emissions. This indicates that the adaptive and transformative capacity of internal resources is not always sufficient to stimulate development, especially when capital investment is required. Studies of other wine regions, such as Spain and Australia, have also highlighted the varying importance of adaptive capacities, depending on the level of development of the sector and the availability of resources (Galbreath et al., 2016; Ferrer et al., 2022).

The role of network capabilities is complex; it favours relatively easy-to-adapt 'low-tech' practices but hinders more complex, technology-driven 'high-tech' innovation. This finding is consistent with previous research analysing the wine sector, which has shown that strong networks with external stakeholders, including research institutes and suppliers, enhance knowledge exchange and facilitate the uptake of incremental innovation (Dries et al., 2014; Muscio et al., 2017) . However, the conflicting interests or fragmentation of the Hungarian wine sector may explain the negative relationship between network building and disruptive innovation. Based on the example of Spanish wineries, networking skills play a decisive role in the spread of eco-innovation (Broccardo et al., 2023), but in emerging markets such as Hungary, these skills still need to be better aligned with specific innovation goals.

Management commitment has a particularly positive impact on reducing greenhouse gases and using renewable energy sources. Commitment to sustainability encourages long-term solutions: wineries whose managers prioritise sustainability are more likely to have initiated long-term developments. Our findings are consistent with the conclusions of the literature, which emphasises the role of committed leadership in integrating sustainability into business strategy (Galbreath et al., 2016; Kariyapperuma & Collins, 2021). In family- and cooperative-owned wineries, where long-term planning and community engagement are key determinants of business operations, management commitment to sustainability is consistent with both environmental goals and stakeholder expectations (Ferrer et al., 2024). Research findings from New Zealand and Spain also confirm that family ownership is associated with a higher degree of environmental responsibility and a stronger drive for innovation (Kariyapperuma & Collins, 2021; Ferrer et al., 2024).

The size and ownership structure of a winery significantly influence eco-innovation practices. Larger wineries with financial and operational resources were in a more advantageous position to implement certain capital-intensive innovation practices, such as energy-saving measures and reducing the use of agrochemicals. This finding is confirmed by the results of other studies, which show that larger companies have greater resource capacity to invest in sustainability initiatives (Presenza et al., 2017). Smaller wineries often face resource constraints that limit their ability to adopt costly innovations, even if they are more proactive and flexible in their decision-making than larger ones.

The ownership structure also has a significant impact on eco-innovation practices, with a positive effect found in the case of vineyard and cellar digitisation, the use of renewable energy and the reduction of carbon footprints. Family-owned wineries showed a stronger commitment to sustainability improvements than commercial companies. Our findings are consistent with previous research, which suggests that family-owned and cooperative wineries tend to prioritise sustainability due to their long-term and heritage-preserving approach (Ferrer et al., 2024; Kariyapperuma & Collins, 2021).

Interestingly, the gender of the manager also had an impact on the eco-innovation employed. Wineries managed by female managers favoured resource recycling, vineyard greening and digital viticulture solutions in their developments. Our observation is consistent with research showing that female managers place greater emphasis on environmental and social outcomes than their male counterparts, contributing to a holistic eco-innovation strategy (Roxas, 2021).

K4: Assessing the dual impact of eco-innovation (Study 4)

In our study, we examined the multifaceted impact of sustainable innovation on corporate performance and identified financial/market and environmental/sustainability outcomes. In line with previous research, eco-innovation emerges as a key driver of organisational competitiveness and environmental responsibility, with its effects mediated by key organisational capabilities and contextual factors (Almeida & Wasim, 2022; Tang et al., 2017).

Our findings confirm the dual value of eco-innovation, in line with previous studies that highlight its contribution to economic and environmental performance. On the one hand, financial and market benefits—such as increased profitability, market expansion, and improved brand value—highlight the role of eco-innovation in enhancing competitive advantage (. On the other hand, improvements in resource efficiency and reductions in greenhouse gas emissions emphasise the contribution of eco-innovation to environmental sustainability, confirming the findings of Dahlan and Nurhayati (2022) and Rabadán et al. (2019).

We have found that while financial performance is directly influenced by certain process innovation measures, environmental performance is influenced by a wider range of sustainable practices. This duality suggests that companies need to adopt a unique eco-innovation strategy tailored to their own needs and prioritise individual innovation measures in line with their strategic goals, whether the goal is to strengthen economic resilience or deepen environmental responsibility (Gu, 2023) .

Our analysis highlights the key role of organisational characteristics in mediating the relationship between eco-innovation and entrepreneurial performance. Managerial commitment has a dual effect: a strong commitment to environmental and social goals improves sustainability/operational outcomes, but can pose a challenge to financial performance in the short term. We have encountered this duality in previous studies (Hizarci-Payne et al., 2021; Tang et al., 2018) , which suggest that entrepreneurs with a long-term vision and a willingness to take risks are more likely to align their eco-innovation measures with their long-term goals. Absorptive capacity affects financial, market, sustainability and operational performance, confirming its strategic role in supporting sustainable innovation. Companies that are leaders in recognising and utilising external knowledge effectively integrate advanced practices and technologies, resulting in comprehensive performance improvements (Pacheco et al., 2018; Zhang & Zhu, 2019) . Although adaptive capacity has a more significant impact on financial performance, it remains crucial for maintaining flexibility and adapting to market dynamics, especially in the agricultural sector, where businesses face specific resource dependencies and environmental risks.

Scientific results and recommendations

In the research presented in this dissertation, we examined the role of sustainable innovation and eco-innovation in the wine sector, with a particular focus on the strategies employed by Hungarian wine businesses ( ) and their economic and environmental impacts. Below, we summarise the most important new scientific findings of the research.

1. Systematic examination of the role of sustainable innovation in the wine sector

One of the most important contributions of the dissertation is the systematic examination of sustainable innovation in the wine sector. Previous studies have mainly focused on the introduction of individual sustainable practices and their environmental impacts, but there has been a lack of a comprehensive approach that examines the economic, social and environmental aspects of innovation. Our research provides a comprehensive picture of the sectoral embeddedness of sustainable innovations, their motivational background and their role in market competition.

2. Development of a typology and clustering of eco-innovation

During the research, we developed a comprehensive typology of eco-innovation that allows us to systematise the sustainability strategies used by wineries. We identified four main categories of product, process, marketing and organisational innovation and presented their combinations in the case of wineries of different sizes and market positions.

During the empirical studies, we used cluster analysis to identify two distinct groups of entrepreneurs pursuing different eco-innovation strategies:

- **Innovative cluster**: wineries that have an extensive external knowledge network, strongly integrate eco-innovation solutions and proactively adapt to sustainability challenges.
- **Lagging cluster**: businesses with limited resources that rely less on external knowledge sources and tend to respond reactively to regulatory changes.

3. Exploring the relationship between sustainable innovation and corporate performance

The research empirically confirmed that sustainable innovation has a positive impact on the economic performance of wineries, but these effects vary depending on the innovation strategy:

- **Process innovations** (e.g. precision viticulture, use of renewable energy) have a significant cost-reducing effect in the long term, but due to their initial investment requirements, they can only provide a competitive advantage for larger wineries.
- **Marketing innovations** (e.g. green certifications, new sales channels) have a more direct impact on consumer preferences and the market position of businesses.
- **Organisational innovations** (e.g. introduction of environmental management) are mainly beneficial for businesses with long-term sustainability goals.

4. Exploring the links between businesses' network connections and innovation performance

One of the most important findings of the research is that it confirmed the decisive role of access to external knowledge sources in the development of eco-innovation strategies. Cooperation with universities, research institutes and professional organisations significantly increases the willingness to innovate and the successful application of sustainability practices.

5. Placing the eco-innovation strategies of Hungarian wineries in an international context

During our research, we found that the eco-innovation practices of Hungarian wineries differ from the trends in developed wine markets. While wineries in Western Europe and the New World tend to rely on high-tech innovations, in Hungary, low-tech solutions requiring less capital dominate.

This difference suggests that the effectiveness of innovation strategies depends largely on the regional institutional and market environment, as well as on support systems.

6. Policy recommendations for the development of sustainable wineries

Based on the results of the research, we have formulated specific policy recommendations to support the sustainability strategies of wineries:

- **Targeted support programmes**: developing support measures available to small and medium-sized enterprises to encourage eco-innovative developments.
- **Strengthening networking**: supporting cooperation between wine clusters, research institutes and businesses.

- **Shaping sustainability awareness**: introducing education and training programmes to promote eco-innovation.

In summary, the research has contributed significantly to a better understanding of sustainable innovation strategies in wineries and has provided practical guidance to industry players and decision-makers on how to promote sustainable development.

5. Policy recommendations for the sustainable development of the wine sector

Based on the results of the research, we have formulated specific policy recommendations to support the sustainability strategies of wineries:

- **Targeted support programmes**: developing tailored support measures for small and medium-sized enterprises to encourage eco-innovative developments
- **Strengthening networking**: supporting cooperation between wine clusters, research institutes and businesses, promoting high-level cooperation between actors in the wine industry value chain
- Developing forms of public-private cooperation to coordinate sustainability efforts
- **Shaping sustainability awareness**: introducing education and training programmes to promote eco-innovation
- **Developing a regulatory environment:** widespread dissemination of indicators appropriate for mitigation and adaptation strategies, tax breaks, subsidies and other incentives (e.g. non-repayable grants, low-interest loans for eco-innovative technologies, organic farming certificates) or the introduction of mandatory sustainability requirements. Regulatory frameworks that set clear environmental standards while allowing flexibility in compliance are considered optimal, as they encourage companies to adopt innovative solutions
- **Development of strategic frameworks: creation of a supportive national wine strategy**

In summary, the research has contributed significantly to a better understanding of sustainable innovation strategies in wineries and has provided practical guidance to industry players and decision-makers on how to promote sustainable development.

Scientific publications, informative articles and presentations on the topic of the thesis

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Valéria Lekics & Imre Fertő (2024): Vinnovation – Sustainability innovation in Hungarian Wineries, an Empirical Research, Tokaj Wine Congress. 27-30 October 2024 Sárospatak, Hungary (presentation)

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