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A holistic model for evaluating innovation in agro-industries through the intersection of internal and external factors

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Abstract

Purpose – In an increasingly competitive and technology-driven environment, innovation has become essential for agro-industries seeking to maintain competitiveness and adapt to dynamic markets. However, innovation assessment in this sector remains fragmented and often limited to isolated indicators. This study aims to analyze internal and external factors of innovation and to propose a holistic model for evaluating the degree of innovation in agro-industries.

Design/methodology/approach – A systematic literature review (SLR) was conducted following a structured and transparent protocol to identify innovation factors relevant to agro-industrial contexts. The identified factors were classified into internal and external dimensions and subsequently validated by sector experts to ensure practical relevance. A mathematical measurement model was then developed using the best–worst method (BWM), a multi criteria decision-making technique applied to weight the innovation factors and structure the evaluation framework.

Findings – The results identify innovation factors organized into internal and external dimensions that together form a holistic innovation evaluation model. The weighting process highlights the multidimensional nature of innovation in agri-industries, emphasizing the combined influence of strategic, organizational, technological, market-related and institutional factors. The proposed framework integrates these elements into a hierarchical structure linked to key performance indicators, enabling a strategic diagnostic of innovation performance.

Originality/value – This study develops a holistic and structured model for innovation evaluation in agri-industries, grounded in systematic evidence and expert knowledge. The application of the Best–Worst Method represents a methodological advancement in innovation measurement for the agri-food sector. The model was applied in an exploratory assessment involving seven agri-industrial firms, demonstrating its feasibility and diagnostic potential, while large-scale validation remains a future research stage.

Keywords Innovation, Agro-industries, Competitiveness, Performance measurement, Best–worst method

Paper type Research article

1. Introduction

Innovation has been widely recognized as a central driver of competitiveness, productivity, and long-term sustainability across economic sectors, including agri-food systems (Porter, 1990; OECD and Eurostat, 2018). In the context of agri-industries, innovation plays a strategic role not only in technological advancement but also in organizational development, market

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positioning, and adaptation to increasingly complex regulatory, environmental, and institutional environments. As agri-food systems face growing pressures related to food security, climate change, and global market integration, understanding how innovation is structured and operationalized within agri-industrial firms has become a critical research agenda (Klerkx, Jakku, & Labarthe, 2019).

In recent years, innovation in the agri-food sector has increasingly been analyzed through systemic, ecosystem-based, and capability-oriented perspectives, reflecting the growing complexity of technological, institutional, and market dynamics that shape firm competitiveness (Klerkx *et al.*, 2019; Triguero, Cuerva, & Sáez-Martínez, 2022; Orsatti, Quatraro, & Scandura, 2024). Rather than being driven solely by technological adoption, innovation performance in agri-industries has been associated with organizational capabilities, governance structures, collaboration networks, and alignment with innovation policies, particularly in emerging economies (Edquist & Zabala-Iturriagagoitia, 2012; Orsatti *et al.*, 2024). Contemporary studies emphasize that innovation outcomes depend on the interaction between internal firm-level resources and external conditions embedded in innovation ecosystems.

Despite the extensive literature on innovation measurement, most existing frameworks remain limited in their ability to capture the multidimensional and context-dependent nature of innovation in agri-industrial settings. Traditional indicators, such as R&D expenditure or patent counts, often fail to reflect organizational, managerial, and relational aspects that are particularly relevant in agri-food sectors characterized by heterogeneous technologies and strong institutional influences (OECD and Eurostat, 2018). More recent models, including innovation scoreboards, maturity models, and capability-based frameworks, offer broader perspectives but frequently focus either on internal organizational dimensions or on macro-level benchmarking, providing limited guidance for firm-level strategic decision-making (Triguero *et al.*, 2022).

In response to these limitations, international guidelines such as the Oslo Manual have expanded the conceptualization of innovation beyond technological outputs to include organizational, marketing, and process dimensions, as well as the role of external interactions (OECD and Eurostat, 2018). Additionally, contemporary innovation approaches, including open innovation, social innovation, and innovation ecosystem perspectives, highlight the importance of collaboration, knowledge flows, and institutional alignment in shaping innovation performance (Chesbrough, 2003, 2020; Bignetti, 2011). However, the operationalization of these concepts into structured and actionable measurement models applicable to agri-industrial firms remains an open challenge in the literature.

Within this context, there is a clear need for holistic innovation assessment models that integrate internal organizational capabilities and external environmental conditions while providing practical support for managerial decision-making. Such models should be theoretically grounded, methodologically transparent, and capable of translating complex innovation dynamics into structured diagnostic tools. In particular, weighting mechanisms that account for the relative importance of different innovation factors can enhance the strategic relevance of innovation measurement, especially in sectors where resource allocation decisions are constrained (Edquist & Zabala-Iturriagagoitia, 2012).

Although the proposed model is theoretically grounded and not geographically restricted, the agri-industrial context of Southern Brazil is used as a reference environment due to its high concentration of agri-industrial firms, technological intensity, and institutional diversity. This context provides a representative setting to discuss innovation dynamics in emerging economies, without limiting the model's applicability to other regions or sectors. The focus on this context allows for a more grounded discussion of innovation factors while preserving the generalizability of the proposed framework.

Based on these considerations, the objective of this study is to analyze internal and external innovation factors identified in the literature and to develop a holistic model for measuring innovation performance in agri-industries. To achieve this objective, a systematic literature review is conducted to identify relevant innovation factors, which are subsequently validated by experts in the sector. The Best–Worst Method is then applied to weight the validated factors and structure an integrated innovation evaluation model. By doing so, this study aims to contribute to the innovation measurement literature by offering a theoretically informed and operational framework tailored to the strategic needs of agri-industrial firms.

2. Literature review

2.1 Innovation and innovation measurement

Innovation has been widely studied across different disciplines, resulting in a diverse set of definitions, typologies, and measurement approaches. A foundational reference in this field is the Oslo Manual, published by the OECD, which defines innovation as the implementation of a new or significantly improved product, process, marketing method, or organizational method (OECD and Eurostat, 2018). The Oslo Manual also provides methodological guidelines for measuring innovation activities, emphasizing the importance of systematic data collection and the distinction between inputs, processes, and outputs.

Traditional innovation measurement approaches have largely relied on input-based indicators, such as R&D expenditure, or output-based indicators, such as patents and new product counts. Although these metrics remain relevant, they have been criticized for offering a fragmented view of innovation and for inadequately capturing organizational, strategic, and contextual dimensions of the innovation process (Crossan & Apaydin, 2010). Earlier editions of the Oslo Manual already acknowledged these limitations, highlighting the need for more comprehensive approaches to innovation measurement (OECD and Eurostat, 2005).

As a result, more recent studies argue for multidimensional and integrative frameworks capable of reflecting the complexity of innovation processes. Innovation is increasingly understood as a systemic phenomenon that extends beyond firm boundaries and is influenced by interactions among internal capabilities, external actors, and institutional environments. This perspective is particularly relevant in sectors characterized by complex production systems and interdependent value chains, such as agro-industries.

2.2 Open innovation and social innovation

The open innovation paradigm, introduced by Chesbrough (2003), represents a significant departure from closed, internally driven innovation models. Open innovation assumes that firms purposively manage knowledge inflows and outflows to accelerate internal innovation and expand markets for external use of innovation. In agro-industrial contexts, open innovation has been associated with collaboration among producers, suppliers, research institutions, universities, and governmental agencies, fostering collective learning and technological diffusion.

Recent studies highlight that open innovation practices are especially relevant for agribusinesses operating in dynamic, uncertain, and resource-constrained environments, as they enable access to external knowledge, reduce innovation risks, and enhance adaptive capacity (Chesbrough, 2020). Empirical evidence suggests that open innovation contributes to improved innovation performance and competitiveness when aligned with organizational capabilities, governance structures, and strategic objectives.

Complementary to open innovation, the concept of social innovation has gained prominence, particularly in sectors with strong social and territorial embeddedness. Social innovation refers to new solutions that address social needs while simultaneously creating new social relationships, forms of cooperation, or governance mechanisms. In the agri-food sector, social innovation is closely linked to rural development, cooperative models, and sustainability-oriented practices. Previous studies demonstrate that social innovation initiatives can enhance resilience, inclusiveness, and long-term value creation in agro-industrial systems (Bitencourt, Santos, Agostini, & Zanandrea, 2022; Castelo, Santos, da Silva, & Aquino, 2022).

The integration of open and social innovation perspectives reinforces the need for innovation assessment models that go beyond technological outputs and explicitly incorporate organizational, relational, and societal dimensions of innovation.

2.3 Innovation ecosystems and innovation policy in agro-industries

The ecosystem approach to innovation further extends systemic perspectives by emphasizing the interdependence among heterogeneous actors, including firms, universities, government agencies, financial institutions, and supporting organizations. Innovation ecosystems are characterized by co-evolutionary dynamics, shared value creation, and institutional coordination (Carayannis & Campbell, 2019). In the agri-food sector, ecosystem-based approaches are particularly relevant due to the strong influence of regulatory frameworks, public policies, and regional infrastructures.

Innovation policy plays a critical role in shaping agro-industrial innovation ecosystems by influencing access to funding, knowledge infrastructure, research collaboration, and technology transfer mechanisms. Studies on innovation policy in the agrifood sector highlight the importance of coordinated policy instruments that simultaneously address technological, organizational, and sustainability challenges (Klerkx *et al.*, 2019). These findings indicate that external institutional conditions are not merely contextual variables but constitutive elements of firms' innovation performance.

Despite these advances, existing innovation measurement frameworks often treat ecosystem-related and policy-related factors as background conditions rather than integral components of innovation performance. This limitation is particularly critical in agro-industries, where external dependencies, regulatory environments, and institutional arrangements strongly shape firms' innovation trajectories.

3. The proposed method

This study adopts a qualitative–quantitative methodological approach aimed at developing a holistic model for evaluating innovation in agro-industries. The research design is structured in three sequential and complementary stages: (1) a systematic literature review (SLR), (2) expert validation of the innovation factors identified, and (3) the development of a mathematical weighting model using the Best–Worst Method (BWM). This structure ensures theoretical robustness, methodological transparency, and analytical consistency, in line with contemporary research standards in innovation studies.

3.1 Systematic literature review

The first stage of the research consisted of a systematic literature review conducted to identify internal and external factors associated with innovation performance in agro-industrial contexts. The review followed an evidence-informed management approach, based on the guidelines proposed by Tranfield, Denyer, and Smart (2003), ensuring rigor, transparency, and replicability in the review process.

In order to enhance methodological transparency, the systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page *et al.*, 2021). Although this study does not aim to perform a meta-analysis, the PRISMA framework was adopted to structure the stages of identification, screening, eligibility, and inclusion of studies, thereby ensuring clarity and reproducibility in the selection process.

The review process comprised the following steps: definition of the research scope and guiding question; identification of relevant scientific databases; establishment of inclusion and exclusion criteria; screening of titles and abstracts; full-text eligibility assessment;

and synthesis of results. Peer-reviewed scientific articles were retrieved from internationally recognized databases, focusing on journals related to innovation, agribusiness, competitiveness, performance measurement, and management.

The inclusion criteria encompassed studies that addressed innovation drivers, innovation measurement models, competitiveness, and performance in agro-industrial or closely related contexts. Exclusion criteria included non-peer-reviewed publications, studies not aligned with the research scope, and papers lacking methodological clarity. No initial temporal restriction was imposed, allowing the identification of both seminal and contemporary contributions. The temporal cut-off of the review was defined as March 2022, corresponding to the completion period of the doctoral research that originated this study and ensuring a theoretically saturated and consolidated body of literature.

Following the PRISMA protocol, records were initially identified through database searches, duplicates were removed, and titles and abstracts were screened based on predefined criteria. Subsequently, full-text articles were assessed for eligibility, resulting in the final set of studies used for the identification and classification of innovation factors. A flowchart summarizing the stages of the systematic review process is presented in Figure 1.

Based on the synthesis of the selected studies, innovation factors were identified and classified into internal and external dimensions, reflecting organizational capabilities, strategic orientation, market conditions, institutional environments, and policy-related aspects relevant to agro-industrial innovation.

Although the systematic review was concluded in March 2022, the theoretical discussion and interpretation of results were complemented with more recent studies to ensure conceptual alignment with current debates on innovation in agri-food systems, open innovation, and innovation ecosystems. This approach allows the model to remain theoretically updated while preserving the methodological coherence of the review process.

3.2 Expert validation

The second stage of the research involved expert validation to assess the relevance, clarity, and practical adequacy of the innovation factors identified through the systematic literature review. Experts were selected based on predefined criteria, including professional experience in agro-industrial management, involvement in innovation-related activities, strategic decision-making roles, and sector-specific knowledge.

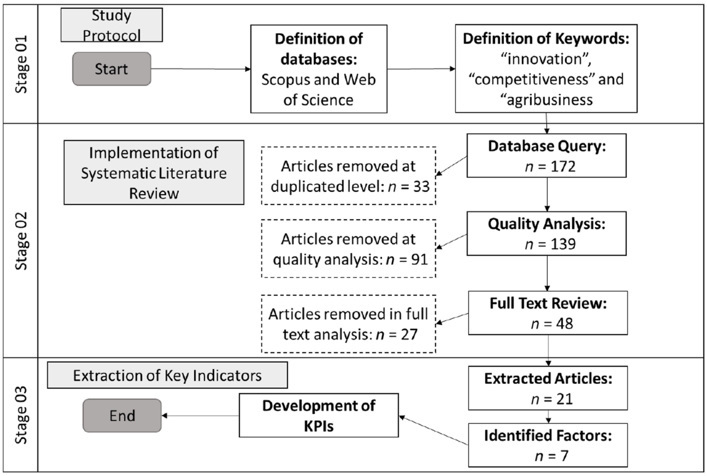

Figure 1. SLR execution protocol. Source: Authors' own work (2022)

The validation process was conducted through structured interviews carried out via digital communication platforms. The experts were invited to evaluate the set of innovation factors identified in the literature, providing feedback regarding their applicability, comprehensiveness, and relevance to the agro-industrial context. Importantly, the purpose of the expert validation was not to generate new factors, but to refine and validate those derived from the literature, thereby strengthening the content validity of the proposed model.

It is important to clarify that the expert interviews constitute a qualitative validation stage and are not part of the mathematical formulation of the Best–Worst Method. Instead, they provide the empirical foundation for defining the criteria to be weighted in the subsequent quantitative stage, ensuring alignment between theoretical constructs and practical realities of the sector.

3.3 Best–Worst Method (BWM)

The third stage of the methodology involved the application of the Best–Worst Method (BWM), a multi-criteria decision-making technique proposed by Rezaei (2015), to determine the relative importance of the innovation factors validated in the previous stages. The BWM was selected due to its methodological advantages compared to alternative approaches such as the Analytic Hierarchy Process (AHP), including a reduced number of pairwise comparisons, greater consistency of judgments, and improved robustness in weight estimation.

The BWM procedure consists of the following steps:

Identification of criteria: The innovation factors identified through the systematic literature review and validated by experts were defined as evaluation criteria.

Selection of the best and worst criteria: Decision-makers identify the most important (best) and the least important (worst) criteria among the set.

Best-to-others comparisons: The best criterion is compared with all other criteria using a predefined numerical scale.

Others-to-worst comparisons: All criteria are compared with the worst criterion using the same numerical scale.

Derivation of optimal weights: An optimization model is solved to obtain the weights that minimize inconsistency.

It is important to emphasize that the qualitative expert interviews and the Best– Worst Method represent distinct and complementary methodological stages. The interviews were employed exclusively to validate and refine the innovation factor identified through the systematic literature review, ensuring their relevance and applicability to the agri-industrial context. The Best–Worst Method was subsequently applied as a quantitative technique to weight the validated factors and structure the innovation evaluation model. Therefore, the interviews do not constitute an input to the mathematical formulation of the BWM, but rather a prior validation step that enhances the conceptual consistency and practical relevance of the criteria used in the weighting process.

3.4 Definition and role of key performance indicators (KPIs)

In this study, Key Performance Indicators (KPIs) are defined as measurable variables that operationalize innovation-related constructs, enabling the systematic assessment of innovation performance within agro-industrial organizations. KPIs translate qualitative and strategic dimensions of innovation into observable and comparable metrics, supporting analytical consistency and decision-making processes.

The use of KPIs in innovation assessment is aligned with contemporary performance measurement literature, which emphasizes that complex and intangible phenomena such as innovation require multidimensional indicator systems rather than isolated metrics (Neely, Gregory, & Platts, 2005; Kaplan & Norton, 2001). In this sense, KPIs serve not merely as monitoring tools, but as integrative elements that connect strategy, processes, and outcomes.

Within the proposed holistic model, KPIs are directly associated with the internal and external innovation factors identified through the systematic literature review and validated by experts. Internal KPIs capture organizational capabilities under managerial control, such as strategic orientation, process integration, human capital, innovation culture, and technological infrastructure. External KPIs reflect environmental and ecosystem-related conditions, including market dynamics, institutional support, innovation policies, collaboration networks, and regulatory frameworks.

The role of KPIs in the model is to enable the operationalization of the innovation factors within the Best–Worst Method (BWM). Each innovation factor is treated as a criterion represented by one or more KPIs, which are subsequently weighted through the BWM procedure. This approach allows for the aggregation of weighted KPIs into a composite innovation score, providing a structured diagnostic of the firm's innovation maturity rather than absolute benchmarking.

This KPI-based operationalization is consistent with recent studies advocating integrated performance measurement systems for innovation management, particularly in sectors characterized by complex value chains and strong external dependencies, such as agro-industries (Bititci, Carrie, & McDevitt, 1997; Neely *et al.*, 2005; OECD and Eurostat, 2018).

4. Results and analysis

The results of this study are structured according to the analytical stages defined in the methodology. First, innovation factors identified through the systematic literature review were classified into internal and external dimensions. Subsequently, these factors were validated by experts and weighted using the Best–Worst Method (BWM), resulting in a hierarchical and integrated innovation evaluation framework.

4.1 Identification of innovation factors

The systematic literature review resulted in the identification of a set of innovation factors recurrently associated with competitiveness and performance in agro-industrial contexts. Based on the synthesis of the selected studies, these factors were classified into two main dimensions: internal innovation factors and external innovation factors.

Table 1 presents the list of innovation factors identified in the literature.

4.2 Definition of factors

The identified factors express strategic innovation drivers. The interview process with semi-structured open questions was designed to improve a group's access to multiple interpretations and points of view on the topic under discussion: factors and their respective indicators capable of measuring the influence of strategic innovation drivers on the competitiveness of agro-industries. From the interviews carried out, it was possible to identify the experts' general idea regarding the influence of innovation on a company's competitiveness.

When conducting the interviews, when asked about the innovation factors selected in the RSL, they were generally confirmed and it was only suggested that they be grouped together to facilitate the approach, as it was evident that some factors could be considered an integral part from others. Figure 2 shows the division of internal and external innovation factors.

4.3 Weighting of innovation factors using the Best–Worst Method

After expert validation, the Best–Worst Method (BWM) was applied to determine the relative importance of the innovation factors. The BWM results provide a structured prioritization of factors based on expert judgments, allowing for the identification of the most influential drivers of innovation in agro-industrial contexts.

Table 1. List of innovation factors and their respective authors

Classification	Factor	Author
Internal	Human Capital	Brenes, Ciravegna, and Acuña (2020)
		Adenle; Manning, and Azadi (2017)
	Marketing	Brenes, Ciravegna, and Acuña (2020)
		Adenle, Manning, and Azadi (2017)
	Entrepreneurial Profile	Luo, Guo, and Jia (2017)
	Innovation Capacity/Investment in Innovation	Luo, Guo, and Jia (2017), Donner, Gohier, and de Vries (2021)
		Adenle, Manning, and Azadi (2017), Storer, Hyland, Ferrer, Santa, and Griffiths (2014)
		Leo, Neto, and Pacheco (2022), Peñalver, Conesa, and Nieto (2018)
		Raimundo, Batalha, and Torkomian (2017)
	Patents	Luo, Guo, and Jia (2017)
	Technologies	Luo, Guo, and Jia (2017), Guimarães, De Lara, and Trindade (2015)
		Fernandes, Ferreira, and Marques (2019)
		Raimundo, Batalha, and Torkomian (2017)
	New Business Models	Donner *et al.* (2021)
	Innovative Management	Jankelová *et al.* (2019)
	Information and Communication Technology	Abdullahi, Musa, and Abubakar (2021), Eze, Chinedu-Eze, Bello, and Inegbedion (2021)
		Manthou, Folinas, and Vlachopoulou (2005)
	P&D	Donner *et al.* (2021), Santos, Bignetti, and Silva (2017)
		Alarcón and Sánchez (2013)
	Market Research and Trends	Raimundo and Batalha (2015)
External	Subsidies and Financing	Corchuelo and Mesías (2017)
		Donner *et al.* (2021)
	Clusters Formation	Kundius (2011)
	Collaboration and Partnerships	Peñalver, Conesa, and Nieto (2018), Santos *et al.* (2017)
		Raimundo, Batalha, and Torkomian (2017),
		Volpentesta, Ammirato, and Della Gala (2013)
	Business Association	Ndyetabula, Sorensen, and Temu (2016), Santos *et al.* (2017)
	Public policy	Luo, Guo, and Jia (2017), Raimundo, Batalha, and Torkomian (2017)
	Partnership with Universities/ Institutional Support	Donner *et al.* (2021), Adenle, Manning, and Azadi (2017)
		Vesperi, Pianta, and Lucchese (2021)

Source(s): Authors' own work (2022)

The optimization process yielded consistent weight values for each factor, indicating a clear hierarchy of importance. Table 2 presents the weights obtained for the internal innovation factors, while Table 3 reports the weights associated with external innovation factors.

The results show that internal factors related to strategic orientation, process management, and human capital development tend to receive higher weights, reflecting their central role in fostering innovation capabilities. At the same time, external factors associated with institutional support, innovation policy, and ecosystem integration also present significant weights, underscoring the relevance of contextual conditions for innovation performance.

4.4 KPIs definition

After the factors were weighted, KPIs were created capable of actually measuring and evaluating performance based on strategic innovation drivers. Figure 3 presents the decision tree created to represent the internal innovation factors and their respective KPIs. Figure 4

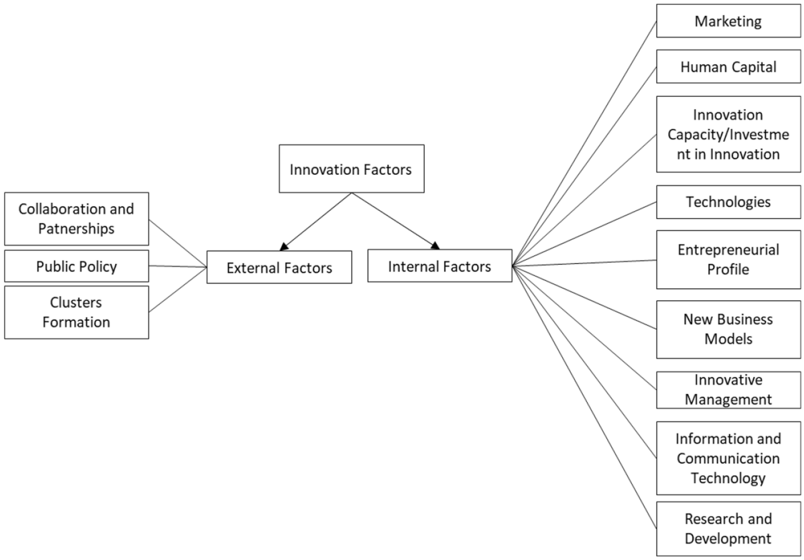

Figure 2. Innovation factors representation scheme. Source: Authors' own work (2022)

Table 2. Weights of external factors

Factors	Weights
Public Policy	0.3818
Collaboration and Partnerships	0.2920
Clusters Formation	0.3262

Source(s): Authors' own work (2023)

Table 3. Weights of internal factors

Factors	Weights
Marketing	0.1157
Human Capital	0.1150
Innovation Capacity/Investment in Innovation	0.0932
Technologies	0.1154
Entrepreneur Profile	0.1010
New Business Models	0.1331
Innovative Management	0.1001
ICT	0.1171
P&D	0.1093

Source(s): Authors' own work (2023)

presents the decision tree created to represent the external innovation factors and their respective KPIs.

From the systematic review of the literature and confirmation of the factors, it was possible to list which internal and external factors of innovation are relevant to leveraging the competitiveness of agro-industries. With the development of the holistic model and the

Figure 3. Decision tree of the internal innovation factors and their respective KPIs. Source: Authors' own work (2023)

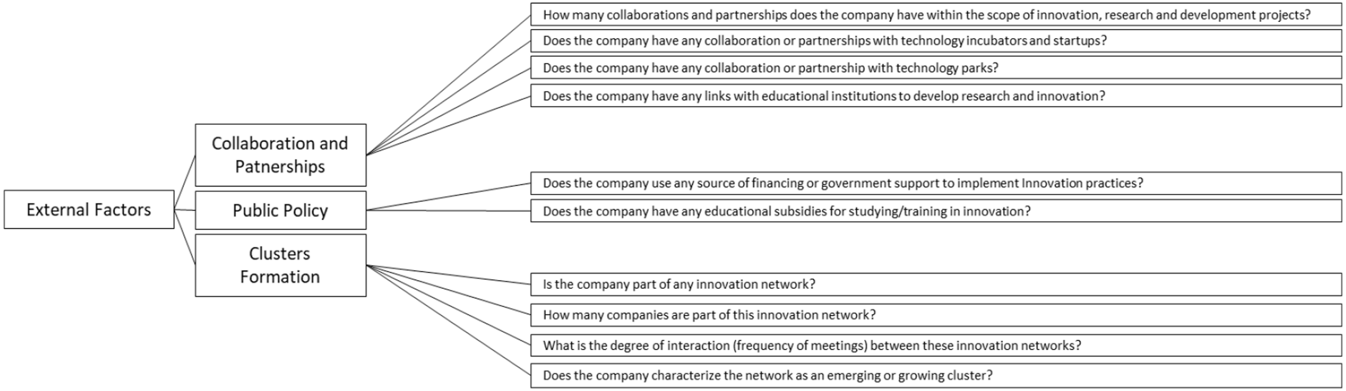

Figure 4. Decision tree of the external innovation factors and their respective KPIs. Source: Authors' own work (2023)

definition of its respective KPIs, it is possible to measure the degree of innovation. By quantifying this level of innovation, the agri-industry will be able to develop an action plan aimed at implementing innovative actions that are in line with its needs to remain competitive in the market.

The qualitative analysis of the global index, which measures the level of innovation, is presented in Table 4. This analysis facilitates discussions aimed at enhancing competitiveness through innovative factors. The evaluation of quantitative results and their interpretation into parameters is structured around four ranges, which classify the overall performance level.

This separation of performance levels shows the tendency that the company presents in relation to innovation, that is, its level of maturity in relation to the subject.

4.5 Application of the innovation performance measurement model

Based on the weight values assigned to each internal and external innovation factor, together with the defined key performance indicators (KPIs), it was possible to develop an application plan for the innovation performance measurement model.

Based on the weights assigned to internal and external innovation factors using the Best–Worst Method (BWM), along with the definition of the respective key performance indicators (KPIs), the model was operationalized to assess the innovation performance of agro-industrial firms located in southern Brazil.

For confidentiality and ethical reasons, the participating agri-industrial firms were anonymized and identified by letters from A to G. This procedure ensured data protection while allowing comparative analysis across firms with different organizational characteristics and innovation performance levels.

Data were collected through an online questionnaire administered to seven agro-industries. Innovation performance was calculated by combining the weighted scores of the factors with the responses obtained for each KPI. The results indicate that, overall, internal factors achieved higher performance scores than external factors, suggesting that agro-industries tend to prioritize internal actions as their primary pathway toward innovation (Tables 5 and 6).

Table 4. Performance levels

Performance levels (%)	Innovation performance
0% |———————— 25%	Unsatisfactory
25% |———————— 50%	Low
50% |———————— 75%	Regular
>75%	Robust

Source(s): Authors' own work (2022)

Table 5. Innovation performance by dimension (internal and external factors)

Agri-industry	Internal factors	External factors	Overall score
A	12.54	15.15	27.69
B	0.00	5.06	5.06
C	0.00	12.06	12.06
D	4.83	11.30	16.13
E	14.44	11.10	25.54
F	5.57	14.59	20.16
G	15.34	11.35	26.69

Source(s): Authors' own work (2023)

Table 6. Innovation performance by dimension (internal and external factors)

Agri-industry	A	B	C	D	E	F	G
Overall Innovation Performance (%)	46.59%	8.52%	20.29%	27.14%	42.97%	33.91%	44.91%

Source(s): Authors' own work (2023)

Among the internal factors, marketing, human capital, and R&D&I stood out as the most significant contributors to innovation performance. Conversely, external factors exhibited lower levels of performance, particularly those related to cluster formation and engagement with public policies supporting innovation. The overall analysis revealed that all evaluated agro-industries were classified at either an initial or low level of innovation maturity, regardless of firm size. These findings indicate that limited innovation performance is not necessarily associated with organizational scale or financial capacity, but rather with structural, strategic, and cultural shortcomings. The results highlight the need for more robust internal innovation strategies and stronger integration with external institutional support mechanisms.

From a managerial perspective, the model allows agri-industrial firms to translate innovation performance scores into concrete strategic actions. For instance, an agri-industry classified at a low innovation performance level can use the weighted results to identify priority areas for intervention. If internal factors such as marketing or human capital receive low scores, managers may focus on capability development, training programs, or market-oriented innovation initiatives. Similarly, weak performance in external factors, such as collaboration or public policy engagement, may indicate the need to strengthen partnerships with universities, industry associations, or public innovation support programs. In this sense, the model operates not only as a diagnostic tool but also as a decision-support instrument for innovation strategy formulation.

To illustrate the operational use of the proposed model, consider an agri-industrial firm classified at a low innovation performance level (below 50%), as observed in most cases in the exploratory application. After calculating the weighted innovation score, managers can identify the specific internal and external factors that most negatively affect overall performance. For example, if low scores are associated with internal factors such as human capital or innovation management, the model suggests prioritizing capability-building actions, including structured training programs, innovation-oriented leadership practices, and formalization of innovation processes.

Conversely, if external factors such as collaboration networks or engagement with public innovation policies receive low scores, firms may use the model to guide strategic decisions aimed at strengthening partnerships with universities, industry associations, or public funding agencies. In this sense, the model functions not only as a diagnostic instrument but also as a decision-support tool that translates innovation performance results into concrete strategic actions aligned with firm-specific needs.

4.6 Interpretation of results

The results reveal a low level of innovation maturity among the evaluated agro-industries, with a clear predominance of internally driven initiatives and limited engagement with external innovation ecosystems. The absence of firms classified at moderate or robust innovation levels underscores the need for more structured innovation strategies, stronger innovation-oriented organizational cultures, and greater utilization of institutional and policy-based support instruments, regardless of firm size.

5. Discussion

Rather than merely describing the relative importance of innovation factors, the results provide analytical insights into how innovation performance in agri-industries is structurally shaped by internal organizational capabilities and constrained by external institutional conditions. Unlike existing approaches that assess innovation through isolated indicators or unweighted frameworks, the proposed model offers a coherent structure that supports strategic diagnosis and decision-making at the firm level, particularly in agro-industrial contexts characterized by strong external dependencies and institutional influences.

The purpose of this study was to analyze the internal and external drivers of innovation and to propose a holistic model for measuring the degree of innovation in agro-industries. The results presented in the previous section support this objective and allow for a structured discussion based on recent literature on innovation measurement, competitiveness, and agribusiness systems.

The identification and classification of innovation factors reinforce the argument that innovation in agro-industries is inherently multidimensional and systemic. This finding aligns with contemporary perspectives that view innovation as emerging from the interaction between organizational capabilities and external environmental conditions, as described in the Oslo Manual 2018 (OECD and Eurostat, 2018) and by recent empirical studies highlighting systemic innovation dynamics (Wang *et al.*, 2022). The results demonstrate that traditional measures such as R&D expenditure or patent counts provide only a partial understanding of innovation performance.

When compared with existing innovation measurement frameworks, the proposed model presents relevant conceptual and operational advances. Traditional instruments such as innovation scoreboards and innovation radar models are primarily descriptive and often designed for macro-level benchmarking or visual diagnostics, offering limited guidance for firm-level decision-making. Capability-based innovation maturity models, although more organization-oriented, frequently focus on internal dimensions and neglect the role of external institutional and ecosystem-related factors. In contrast, the model developed in this study explicitly integrates internal organizational capabilities and external environmental conditions within a single analytical structure, supported by a formal weighting mechanism through the Best–Worst Method. This integration allows agro-industrial firms to assess innovation performance in a more strategic and actionable manner, addressing a gap identified in recent innovation measurement literature.

When compared with established innovation assessment frameworks, such as the European Innovation Scoreboard, innovation radar models, and capability-based innovation maturity frameworks, the proposed model presents important conceptual and operational distinctions. While scoreboards and radar models are primarily designed for macro-level benchmarking or visual diagnostics, they often lack explicit weighting mechanisms and firm-level operationalization. In contrast, the framework proposed in this study is specifically designed for organizational-level application and incorporates a structured prioritization of innovation drivers through the Best–Worst Method. This enables agro-industrial firms to move beyond descriptive assessments toward a more strategic and actionable evaluation of innovation performance.

The relative prominence of internal innovation factors in the Best–Worst Method results is consistent with recent research emphasizing the importance of strategic orientation, managerial practices, and human capital in enabling innovation capabilities (Zhang & Liu, 2022; Lee & Seol, 2021). Internal governance mechanisms, process integration, and organizational learning were among the most influential factors, suggesting that internal capabilities are central to fostering innovation in agro-industrial contexts characterized by operational complexity and knowledge-intensive processes.

At the same time, external innovation factors also exert significant influence, highlighting the importance of institutional and ecosystem-related conditions. These findings are supported by innovation systems research, which shows that public policies, regulatory environments, and collaborative networks shape firms' innovation trajectories and opportunities for knowledge exchange (Edler & Fagerberg, 2017; Capello & Lenzi, 2021a, b). In agro-industries, firms operate within complex value chains and are influenced by market volatility, supply-chain dynamics, and policy frameworks, all of which contribute to the external dimension of innovation performance.

The integration of internal and external dimensions into a single analytical framework represents a key theoretical contribution of this study. Unlike many existing innovation measurement models that focus exclusively on either firm-level capabilities or macro-level institutional factors, the model developed in this research explicitly captures their interdependencies. This holistic perspective is aligned with calls in recent literature for more comprehensive and context-sensitive approaches to innovation assessment, especially in sectors where organizational and environmental conditions co-evolve (Bruno, Crescenzi, Estrin, & Petralia, 2021; Adams, Bessant, & Phelps, 2006).

From a methodological perspective, the application of the Best–Worst Method enhances the analytical strength of the proposed model. By translating expert judgments into consistent weight values, the method provides a structured and replicable basis for prioritizing innovation factors. This addresses common critiques of subjectivity and lack of operationalization in innovation research (Marion & Fixson, 2021). The prioritized innovation factors provide clear guidance for decision-makers, supporting strategic planning and resource allocation in agro-industrial firms.

The results also underscore the relevance of the Brazilian agro-industrial context used for expert validation. Although the experts were drawn from a specific regional setting, the Southern region of Brazil is characterized by a high degree of technological intensity, industrial integration, and participation in global agri-food markets, making it a meaningful analytical reference for model development. It is important to note that the structure of the proposed model is designed to be adaptable to different agro-industrial segments and institutional environments, thereby enhancing its external validity.

The predominance of internal innovation factors observed in the results is consistent with recent empirical evidence suggesting that organizational capabilities, strategic orientation, and managerial practices play a central role in enabling innovation, particularly in sectors characterized by operational complexity and technological heterogeneity. Studies conducted in agri-food and manufacturing contexts indicate that firms with stronger internal governance structures and innovation-oriented cultures tend to achieve superior innovation outcomes, even in environments with limited external support (Lee & Seol, 2021; Zhang & Liu, 2022; Wang *et al.*, 2022). However, the relatively low performance observed in external innovation factors highlights a structural weakness in firms' engagement with innovation ecosystems, public policies, and collaborative networks. This finding reinforces arguments from innovation systems literature that emphasize the need for stronger institutional alignment and ecosystem integration to enhance innovation-driven competitiveness, especially in emerging economies.

Finally, it is important to emphasize that this study represents the first stage of a broader research agenda. The present article focuses on the conceptual design and methodological structuring of the innovation evaluation model. The empirical application and validation of the model at the firm level will be addressed in subsequent research, enabling further examination of its practical relevance and predictive capacity.

Despite its contributions, the proposed model presents limitations that should be acknowledged. The weighting of innovation factors relies on expert judgment, which, although methodologically supported by the Best–Worst Method, may reflect contextual perceptions specific to the agro-industrial environment analyzed. In addition, the empirical application involved a limited number of firms, which restricts statistical generalization. The model also assumes a relatively stable relationship between innovation drivers and performance, which may vary over time or across different institutional settings. These limitations do not compromise the conceptual validity of the framework but indicate opportunities for refinement through broader empirical testing and longitudinal analysis.

Overall, the discussion demonstrates that the proposed holistic model advances the literature on innovation measurement by integrating internal and external innovation drivers into a coherent and operational framework. This integration offers both theoretical contributions and practical insights for managers and policymakers seeking to enhance innovation-driven competitiveness in agro-industrial systems.

The practical and research implications derived from this study are consistent with recent empirical and conceptual works that emphasize the role of capability development, ecosystem engagement, and policy alignment in fostering innovation in agri-food sectors (Orsatti *et al.*, 2024; Wang *et al.*, 2022; Triguero, Córcoles, & Cuerva, 2013). By operationalizing these dimensions within a structured and weighted framework, the proposed model advances existing approaches and offers a theoretically grounded tool for both managerial decision-making and future empirical research.

6. Conclusion

The results and analyses presented in the previous sections provide the empirical and analytical foundation for the conclusions drawn in this section, linking the proposed innovation measurement model to its theoretical contributions and practical implications.

This study aimed to analyze the internal and external drivers of innovation and to propose a holistic model for measuring the degree of innovation in agro-industries. By integrating a systematic literature review, expert validation, and the application of the Best–Worst Method, the research responds to an important gap in the innovation literature, particularly regarding the need for comprehensive and context-sensitive assessment frameworks in agro-industrial systems.

The results confirm that innovation in agro-industries cannot be adequately understood through isolated indicators or exclusively firm-level perspectives. Instead, innovation performance emerges from the interaction between internal organizational capabilities, such as strategic orientation, managerial practices, and human capital, and external environmental conditions, including institutional frameworks, policy instruments, and innovation ecosystems. By explicitly incorporating these dimensions into a single analytical structure, the proposed model advances existing innovation measurement approaches and contributes to a more systemic understanding of innovation-driven competitiveness.

From a theoretical perspective, this study contributes to the literature by consolidating dispersed innovation factors into a structured and replicable framework tailored to the specificities of agro-industrial contexts. The integration of internal and external innovation drivers aligns with contemporary innovation system theories and addresses limitations identified in previous models that treat these dimensions separately. In this sense, the research strengthens the conceptual foundations of innovation measurement by emphasizing interdependencies rather than isolated effects.

Methodologically, the use of the Best–Worst Method represents an important contribution, as it enables the consistent weighting of innovation factors based on expert judgment. This approach enhances transparency and robustness in the prioritization of innovation drivers and offers a clear decision-support mechanism for managers and policymakers. The methodological structure proposed in this study can be replicated or adapted to different sectors and institutional environments, reinforcing its analytical relevance.

In practical terms, the proposed model provides agro-industrial firms with a diagnostic tool to assess their innovation maturity and to identify priority areas for strategic intervention. By highlighting the relative importance of different innovation drivers, the model supports more informed decision-making, resource allocation, and strategic planning aimed at enhancing competitiveness and long-term sustainability.

It is important to acknowledge the scope and limitations of the present study. This article represents the first stage of a broader research project focused on the development of an innovation evaluation framework. While expert validation was employed to structure and weight the innovation factors, the empirical application and validation of the model at the firm level were not addressed in this paper. This second stage of the research, which involves applying the model in agro-industrial organizations and analyzing its empirical performance, is currently being finalized and will be presented in a future article.

Future research may expand the empirical application of the model across different agro-industrial segments and geographical contexts, allowing for comparative analyses and further refinement of the innovation factors. Additionally, longitudinal studies could explore how changes in internal capabilities and external conditions influence innovation performance over time.

Overall, this study advances the field of innovation management in agro-industries by offering a holistic, structured, and adaptable model for measuring innovation performance. By bridging theoretical insights and methodological rigor, the research contributes to both academic debate and managerial practice, reinforcing the strategic role of innovation in fostering competitiveness within agro-industrial systems.

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