



A Holistic Perspective on Quality

Organizational Culture, Sustainability
and the Future of Quality

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Background

The primary objective of the study was to systematically and comparatively understand the maturity of organisations across three fundamental dimensions of contemporary management: Quality Culture, the Integration of Quality and Sustainability, and perspectives on the Future of Quality. The intention was to capture not only implemented practices, but also trends, perceptions, and levels of preparedness for emerging challenges.

To achieve these objectives, a questionnaire was developed and structured into four complementary sections. The first section focuses on the sociodemographic characterisation of organisations, collecting essential information on country of origin, sector of activity, number of employees, turnover, number of sites, ISO 9001 certification, and degree of internationalisation. This characterisation enables the contextualisation of results and supports comparative analyses across different organisational groups. The subsequent sections explore specific dimensions of quality management in greater depth. Section 2 assesses Quality Culture, divided into five subdomains: leadership commitment, employee involvement, continuous improvement, customer focus, and open communication. Section 3 examines the integration between Quality and Sustainability, including sustainable practices, resource efficiency, sustainable design, and stakeholder engagement. Finally, Section 4 addresses the Future of Quality, analysing the strategic importance of quality, the role of technology, the culture of continuous improvement, proactive risk management, and workforce development.

The survey was conducted during the second half of 2025, and 396 responses were collected, of which 338 were considered valid and complete for statistical analysis, based on a rigorous validation process aimed at ensuring the reliability of the results.

The survey methodology was based on the dissemination of the questionnaire through multiple national and international contact networks. The geographical diversity of the sample (40 countries represented) was supported by the broad distribution of the survey, not only among members of the APQ, but also through databases of equivalent national associations, international partners, academic collaboration networks, and available international contact lists. The strong representation of countries such as Czech Republic, Portugal, China, and Spain also suggests the involvement of partner organisations and international quality networks, reinforcing the global nature of the study.

From an analytical perspective, the study adopts a cross-sectional observational design, using qualitative and Likert scales. Statistical analysis was carried out in R (version 4.5.1), using the tidyverse and knitr packages, as described in the report. Descriptive methods

and non-parametric tests were applied, namely the Kruskal–Wallis test and the Mann–Whitney U test, which are appropriate for comparing independent groups. The internal consistency of the scales was assessed using Cronbach's alpha, with values above 0.98 across all sections, demonstrating a high level of reliability of the measures.

Abstract

This report presents the statistical analysis of the data collected through the questionnaire conducted by the *Associação Portuguesa para a Qualidade*. The questionnaire aims to understand organizational culture in relation to Quality, Sustainability, and the Future of Quality.

The data were collected through a questionnaire organised into four main sections:

- **Section 1: Sociodemographic Characterization (A1):** Country, sector, organizational size, etc.
- **Section 2: Quality Culture (A2- 2.1 to 2.5):** Leadership commitment, employee involvement, continuous improvement, customer focus, and open communication.
- **Section 3: Integration of Quality and Sustainability (B- 3.1 to 3.5):** Integration, commitment to sustainable practices, resource efficiency, sustainable design, and stakeholder engagement.
- **Section 4: The Future of Quality (D- 4.1 to 4.5):** Strategic importance, technology, culture of continuous improvement, proactive risk management, and workforce development.

Index

Background	p. 3
Abstract	p. 5
Research Method	p. 7
Results	p. 8
Final Summary and Key Conclusions	p. 63
Perspectives for Future Work	p. 65
References	p. 66

Research Method

The statistical analysis of the data was carried out using the R programming language, version 4.5.1 (R Core Team, 2025). For data manipulation and visualization, the tidyverse (Wickham & Wickham, 2019) and knitr (Xie, 2017) packages were used.

As this study was conducted through a questionnaire, it is classified as a cross-sectional observational study. Given the nature of the variables involved, namely qualitative scales and Likert scales, statistical methods based on descriptive analysis were adopted, using observed frequencies together with bar charts and pie charts.

For the comparative analysis, non-parametric tests were employed, namely the Kruskal–Wallis test (for the comparison of k independent groups, where $k > 2$) and the Wilcoxon–Mann–Whitney test for two independent groups.

The decision rule adopted consisted of identifying statistically significant evidence for probability values (test p -values) below 0.05.

Results

A total of 396 responses were collected, of which only 338 contained complete information relating to the organizations.

Sociodemographic Analysis

Distribution by country of origin

From the distribution of responses by country, it can be observed that 40 countries are represented, as shown in **Table 1**.

Table 1 – Distribution of responses by country.

Country	Frequency (N)	Percentage (%)
CZECH REPUBLIC	103	30.47
PORTUGAL	63	18.64
CHINA	39	11.54
SPAIN	32	9.47
DENMARK	12	3.55
GERMANY	9	2.66
PERU	8	2.37
CAPE VERDE	7	2.07
SAUDI ARABIA	7	2.07
CYPRUS	6	1.78
BRAZIL	4	1.18
SLOVAKIA	4	1.18
UNITED KINGDOM	4	1.18
AUSTRALIA	3	0.89
AUSTRIA	3	0.89
HUNGARY	3	0.89
ALGERIA	2	0.59
CANADA	2	0.59
GREECE	2	0.59
INDIA	2	0.59
NORWAY	2	0.59
SLOVENIA	2	0.59
UNITED ARAB EMIRATES	2	0.59
ANGOLA	1	0.30
ARGENTINA	1	0.30
BELARUS	1	0.30
BELIZE	1	0.30
COLOMBIA	1	0.30
COSTA RICA	1	0.30
CUBA	1	0.30

Country	Frequency (N)	Percentage (%)
DOMINICAN REPUBLIC	1	0.30
ESTONIA	1	0.30
FINLAND	1	0.30
ITALY	1	0.30
JAMAICA	1	0.30
NEW ZEALAND	1	0.30
PANAMA	1	0.30
POLAND	1	0.30
SERBIA	1	0.30
TURKEY	1	0.30

Table 1 shows considerable geographical dispersion, covering 40 countries, with a total of 338 observations. However, a strong concentration can be observed in a small number of specific markets:

- **Predominance of the Czech Republic and Portugal:** These two countries together account for almost half of the sample (49.1%). The Czech Republic leads individually with 30.5% of responses, followed by Portugal with 18.6%.
- **Relevance of Spain and China:** China (11.5%) and Spain (9.5%) complete the group of the four most represented nationalities, together accounting for approximately 70% of all questionnaire responses.
- **Long tail distribution:** There is a broad range of countries (approximately 27 nations) contributing only 1 or 2 responses each ($\leq 0.6\%$ per country). This characteristic indicates that, although the questionnaire achieved global reach, the statistical analysis of subgroups for these countries individually may not be statistically significant.

This result may also be illustrated by the graph presented in **Figure 1**.

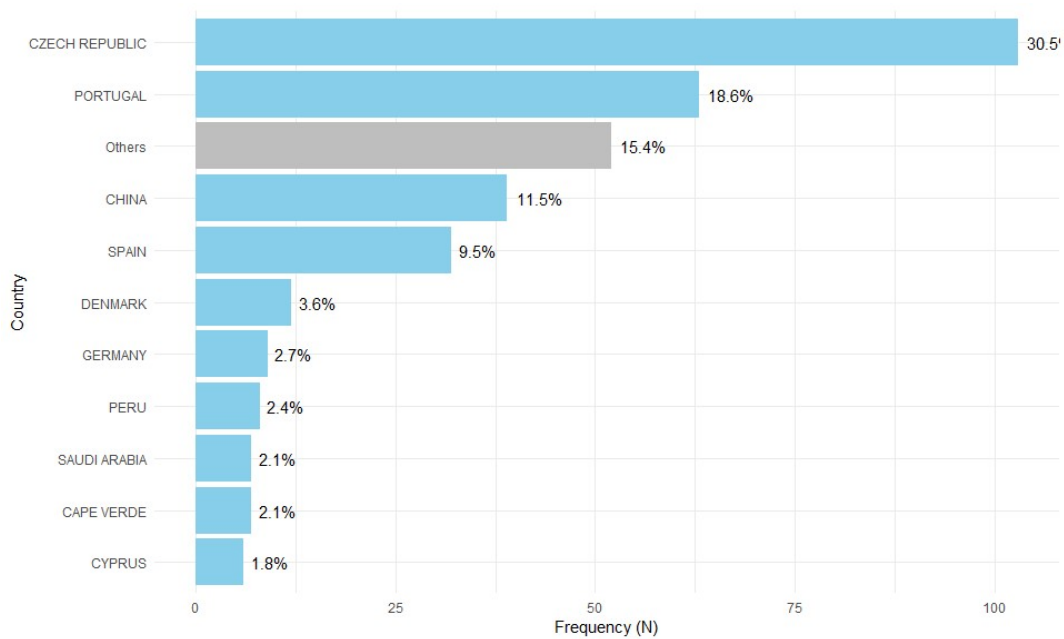


Figure 1 – Distribution by country of origin.

Distribution by sector of activity

Table 2 – Distribution of responses by sector of activity.

Sector	Frequency (N)	Percentage (%)
Industrial	153	45.27
Services	68	20.12
Other	26	7.69
Health and Social	22	6.51
Education	21	6.21
Commerce	11	3.25
Consulting	10	2.96
Public Administration	7	2.07
Extractive	5	1.48
Primary	5	1.48
Utilities	5	1.48
Environment	3	0.89
First Transformation	2	0.59

The sample reveals a clear predominance of organizations from the industrial and service sectors, with a significant concentration in the upper categories of Table 2:

- **Leadership of the industrial sector:** The industrial sector stands out as the main contributor to the sample, representing 45.3% of the total (153 observations).

This suggests that the results of the quality questionnaire are likely to be strongly influenced by manufacturing and material production processes.

- **Representation of the service sector:** The service sector emerges as the second most relevant group, accounting for 20.1% of responses. Combined with the industrial sector, these two segments represent 65.4% (almost two-thirds) of the analysed dataset.
- **Social and structural sectors:** A secondary balance can be observed between the areas of health/social care (6.5%) and education (6.2%), indicating moderate but notable participation from institutions in the non-commercial tertiary sector.
- **Fragmentation in the lower categories:** The remaining sectors (trade, consultancy, public administration, among others) show individually low frequencies, each accounting for less than 4%.

In graphical terms, these results may be illustrated by the charts presented in **Figure 2** and **Figure 3**.

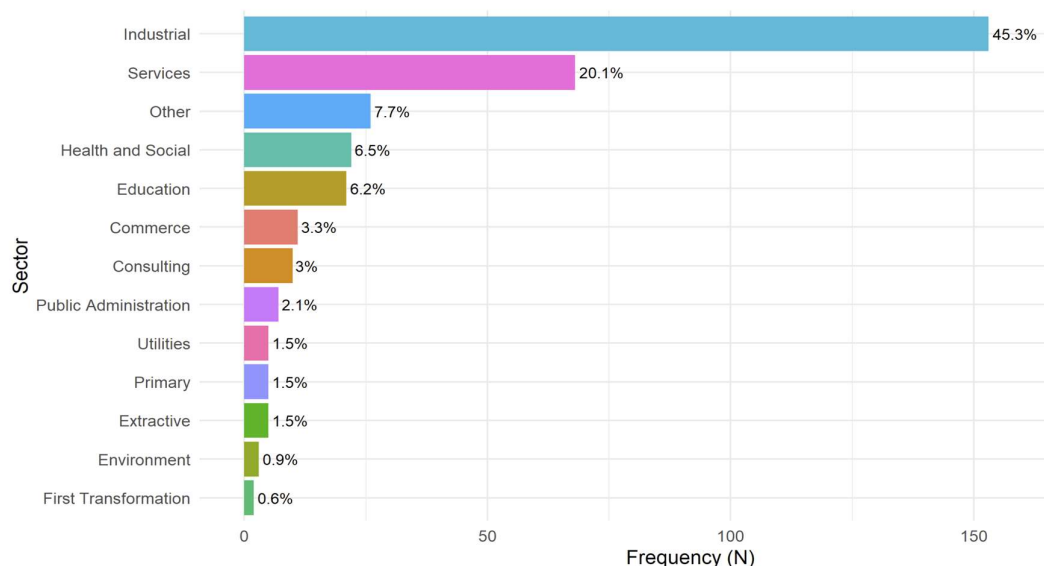


Figure 2 – Distribution by sector of activity.



Figure 3 – Distribution by sector of activity, with area proportional to absolute frequency (N).

Distribution by number of employees in the organization

Table 3 – Distribution of responses by number of employees.

Number of employees	Frequency (N)	Percentage (%)
11-50	61	18.1
51-250	90	26.6
250-500	51	15.1
>500	136	40.2
Total	338	100

The sample shows a marked skew towards large organizations, while still maintaining balanced representation across the intermediate size categories:

- **Predominance of large organizations:** The category with more than 500 employees is the most significant, representing 40.2% of the total sample (136 responses). This indicates that almost half of the data originates from large-scale corporate contexts, where quality management structures tend to be more robust and departmentalized.
- **Strong presence of medium-sized organizations:** The category of 51–250 employees constitute the second largest group (26.6%). When combined with the 250–500 employee category (15.1%), medium and upper-medium-sized organizations account for 41.7% of the sample.

- **Lower representation of small organizations:** The category of organizations with 11–50 employees is the least frequent (18.1%). The absence (or lack of mention) of micro-enterprises (1–10 employees) suggests that the questionnaire focused on organizations with at least a minimum level of operational structure.

The sample is predominantly composed of organizations with more than 50 employees (81.9%), which gives the report a perspective focused on entities with medium to high organizational complexity.

These results are illustrated in the chart presented in **Figure 4**.

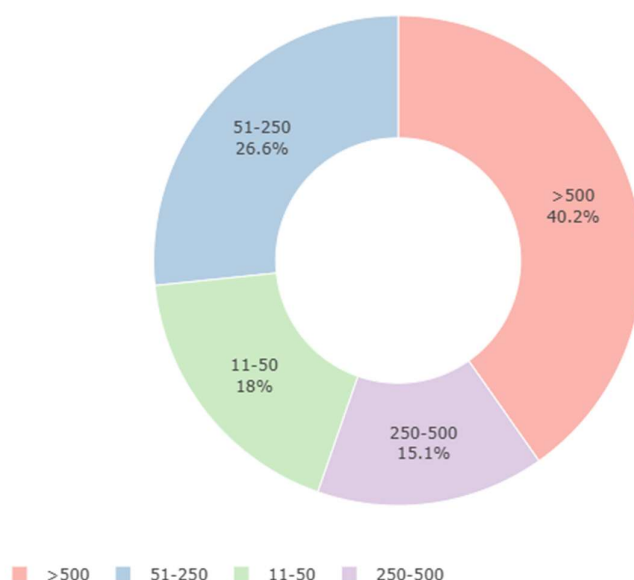


Figure 4 – Distribution by organization size.

Analysis of Exposure to the International Market

Table 4 – Distribution of responses by percentage of activity in the international market.

International Market	Frequency (N)	Percentage (%)
None - 0%	42	12.5
Less than 25%	134	39.9
Between 25% and 50%	35	10.4
Between 50% and 75%	54	16.1
Higher than 75%	71	21.1
Total	336	100

The data reveal a sample with a strong international presence, albeit with markedly different levels of intensity:

- **Predominance of low export intensity:** The most frequent category comprises companies with less than 25% of turnover derived from international markets (39.9%). This suggests that, although most organisations have already initiated some degree of internationalisation, the domestic market remains their primary focus.
- **Strong segment of highly internationalised firms:** A significant finding is that 21.1% of companies (71 organisations) have an international dependence exceeding 75%. This group represents either highly competitive global firms or organisations operating within international niche markets.
- **Inverted “U-shaped” distribution:** Interestingly, the sample is concentrated at the extremes: companies either export very little (below 25%) or export significantly (above 75%). The intermediate category (25% to 50%) is the least represented, accounting for only 10.4%.
- **Purely domestic organisations:** Only 12.5% of companies have no international presence. This indicates that approximately 87.5% of the sample is, to some extent, connected to external markets.

This distribution is illustrated in the chart presented in **Figure 5**.

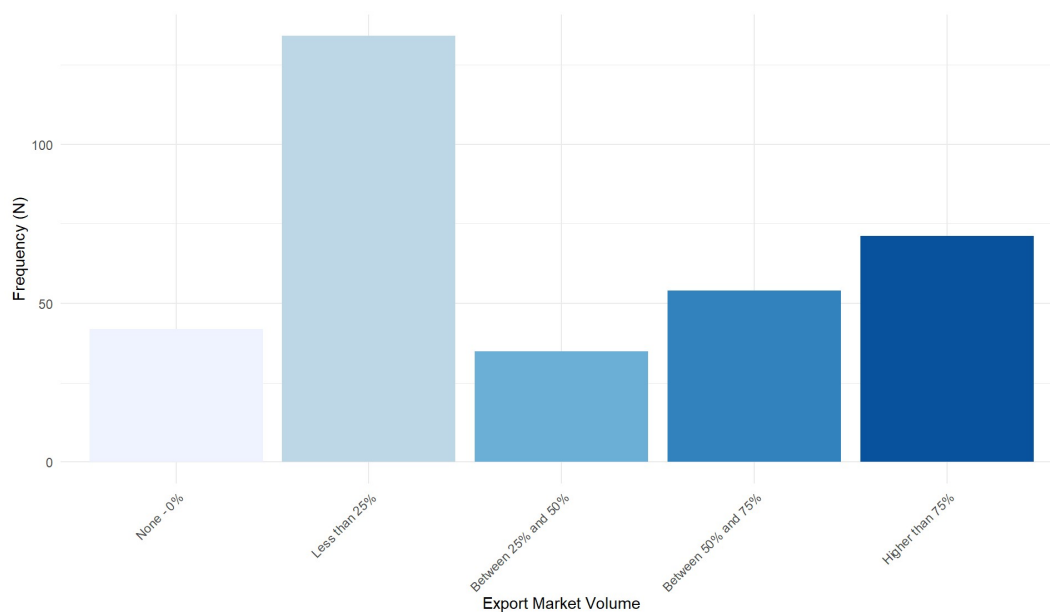


Figure 5 – Distribution by percentage of activity in the international market.

Analysis of Annual Turnover (US\$)

Table 5 – Distribution of responses by annual turnover.

Annual Turnover	Frequency (N)	Percentage (%)
less 0.5M	24	7.3
0.5-5M	70	21.2
5-10M	41	12.5
10-50M	79	24.0
More than 50M	115	35.0
Total	329	

The results indicate a sample predominantly composed of organizations with strong financial capacity:

- **Predominance of high-revenue organizations:** The category with an annual turnover exceeding 50M is the most significant, representing 35% of the sample. When combined with the 10–50M range (24%), it is evident that almost 60% of organizations report annual revenues above 10 million.
- **Relevant mid-sized segment:** The 0.5–5M category emerges as the second largest individual group (21.2%), indicating that, despite the prominence of large organizations, there is a solid core of small and medium-sized enterprises (SMEs) contributing to the dataset’s diversity.
- **Scarcity of micro-enterprises:** Only 7.3% of organizations report a turnover below 500,000 (0.5M). This reinforces the idea that the questionnaire predominantly reached established organizations with formal market structures.
- **Bimodal distribution:** An interesting pattern is observed: the sample is concentrated at the extremes of the medium-to-large scale (0.5–5M and >50M), while there is a marked decrease in the intermediate 5–10M range (12.5%).

These results are illustrated in the chart presented in **Figure 6**.

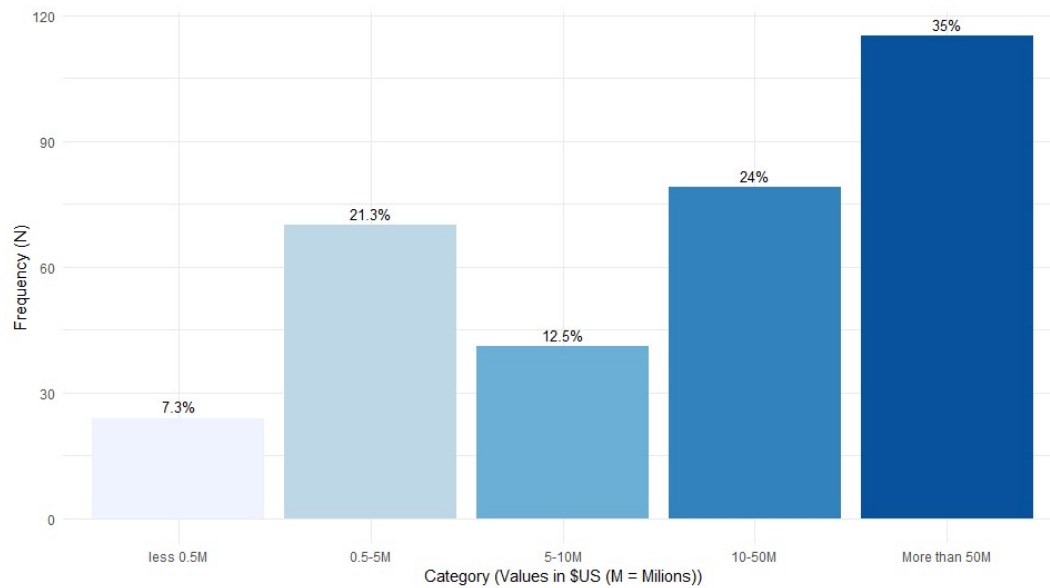


Figure 6 – Distribution by annual turnover.

Analysis of number of sites

Table 6 – Distribution of responses by number of sites.

Nr Sites	Frequency (N)	Percentage (%)
1	103	30.8
2	51	15.3
3-5	49	14.7
5-10	37	11.1
10-50	58	17.4
More than 50	36	10.8

Based on the combined analysis of Table 6 and Figure 7, regarding the number of operational sites, the sample shows a predominance of centralized organizational structures, with 30.8% (n=103) of respondents operating from a single site. This suggests that a significant proportion of the sample has centralized management processes, which may facilitate direct control and internal communication within the scope of the questionnaire.

However, a notable bimodal distribution is observed. While 46.1% of the sample is concentrated in the low-dispersion range (1 to 2 sites), a substantial segment of organizations exhibits high logistical complexity: 28.2% of participants manage more

than 10 sites, with a notable subgroup of 10.8% operating extensive networks of more than 50 locations.

This heterogeneity indicates that the questionnaire results reflect two distinct realities:

1. **Small/medium-scale organizations:** Where quality and process-related challenges are primarily focused on local execution.
2. **Large-scale organizations:** Where data interpretation must take into account challenges related to standardization, remote auditing, and the maintenance of organizational culture across multiple geographical locations.

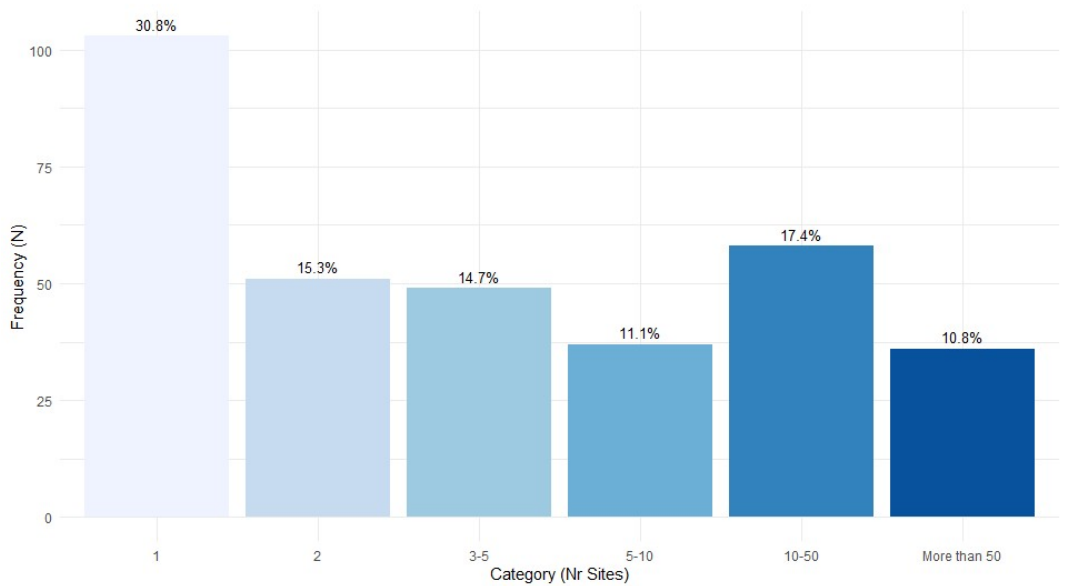


Figure 7 – Distribution by number of sites.

ISO 9001:2015 Certification

Table 7 – Distribution of responses according to ISO 9001:2015 certification.

Certification	Frequency (N)	Percentage (%)
No	65	19.4
Yes	270	80.6

Certification ISO 9001:2015

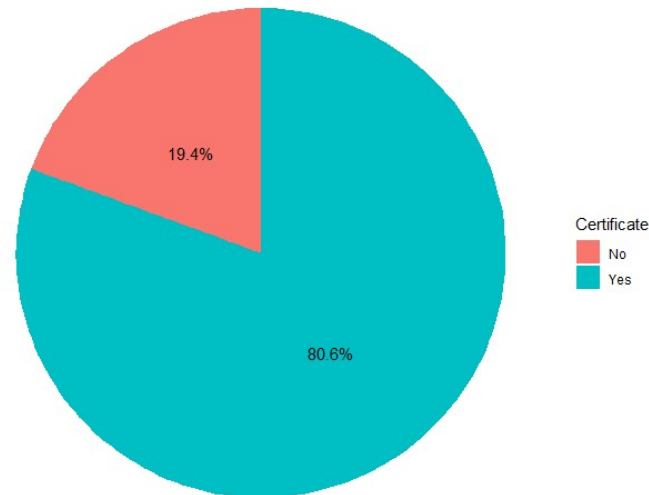


Figure 8 – Distribution according to ISO 9001:2015 certification.

Analysis of Sections 2, 3 and 4 of the questionnaires.

The analysis of the evaluation questions (Sections 2, 3 and 4) is conducted using descriptive statistics (mean and standard deviation) and divergence graphs, which are well suited to Likert scales.

Quality Culture (Section 2)

Table 8 – Summary statistics for the items in Section 2 – Quality Culture (n = 225)

vars	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
q2_1_1	4.169	1.004	4	4.348	1.483	1	5	4	-1.369	1.556	0.067
q2_1_2	4.009	1.013	4	4.144	1.483	1	5	4	-0.992	0.635	0.068
q2_1_3	4.009	1.022	4	4.160	1.483	1	5	4	-1.042	0.677	0.068
q2_1_4	3.951	1.049	4	4.105	1.483	1	5	4	-1.035	0.564	0.070
q2_1_6	3.702	1.120	4	3.829	1.483	1	5	4	-0.822	0.038	0.075
q2_1_7	3.853	1.102	4	4.000	1.483	1	5	4	-0.924	0.235	0.073
q2_2_1	3.751	1.000	4	3.845	1.483	1	5	4	-0.716	0.062	0.067
q2_2_2	3.796	0.898	4	3.867	1.483	1	5	4	-0.769	0.732	0.060
q2_2_3	3.724	0.961	4	3.812	1.483	1	5	4	-0.692	0.251	0.064
q2_2_4	3.871	0.971	4	3.983	1.483	1	5	4	-0.965	0.934	0.065
q2_2_5	3.858	0.985	4	3.972	1.483	1	5	4	-0.802	0.345	0.066
q2_2_6	3.644	1.105	4	3.746	1.483	1	5	4	-0.712	-0.176	0.074
q2_3_1	4.013	0.975	4	4.144	1.483	1	5	4	-1.033	0.876	0.065

vars	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
q2_3_2	4.058	0.926	4	4.177	1.483	1	5	4	-1.154	1.542	0.062
q2_3_3	3.751	1.057	4	3.851	1.483	1	5	4	-0.670	-0.200	0.070
q2_3_4	3.378	1.167	3	3.431	1.483	1	5	4	-0.276	-0.773	0.078
q2_3_5	3.773	1.068	4	3.895	1.483	1	5	4	-0.791	0.128	0.071
q2_3_6	3.769	1.013	4	3.878	1.483	1	5	4	-0.759	0.252	0.068
q2_4_1	4.058	1.018	4	4.221	1.483	1	5	4	-1.302	1.564	0.068
q2_4_2	4.080	0.951	4	4.199	1.483	1	5	4	-1.089	1.172	0.063
q2_4_3	4.031	0.961	4	4.149	1.483	1	5	4	-1.144	1.476	0.064
q2_4_4	4.058	0.892	4	4.166	1.483	1	5	4	-1.127	1.639	0.059
q2_4_5	4.191	0.918	4	4.343	1.483	1	5	4	-1.521	2.768	0.061
q2_4_6	4.098	0.977	4	4.238	1.483	1	5	4	-1.196	1.339	0.065
q2_5_1	3.898	1.066	4	4.050	1.483	1	5	4	-1.029	0.571	0.071
q2_5_2	3.853	1.014	4	3.978	1.483	1	5	4	-0.909	0.419	0.068
q2_5_3	3.893	1.025	4	4.039	1.483	1	5	4	-1.000	0.711	0.068
q2_5_4	3.942	0.987	4	4.066	1.483	1	5	4	-0.966	0.756	0.066
q2_5_5	3.796	1.053	4	3.917	1.483	1	5	4	-0.842	0.212	0.070
q2_5_6	3.671	1.056	4	3.773	1.483	1	5	4	-0.701	0.081	0.070

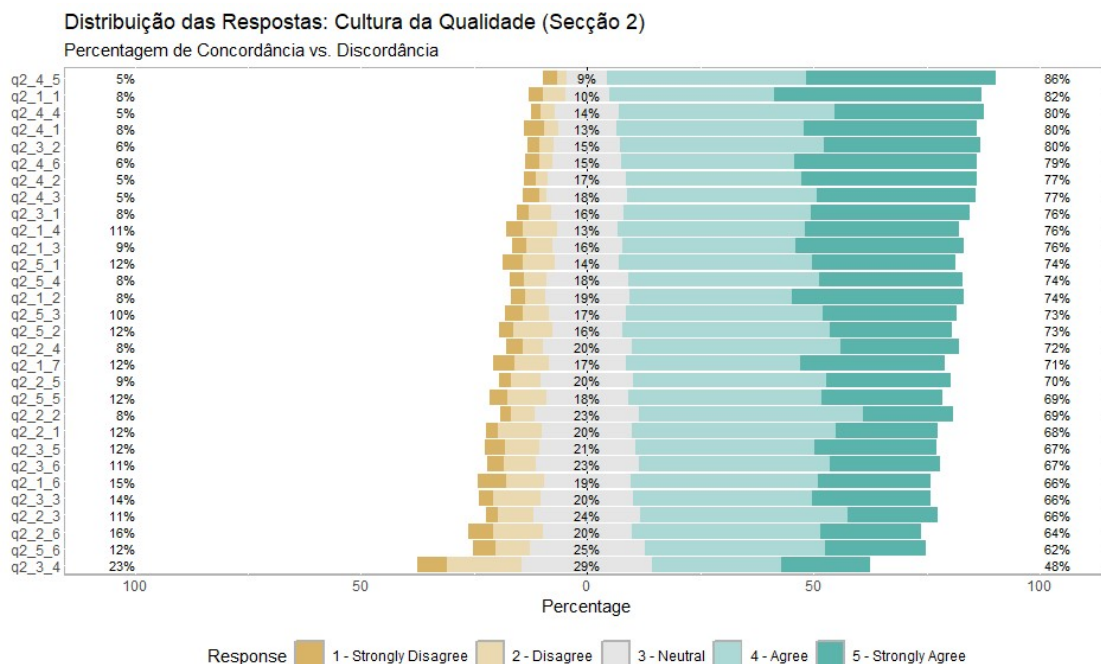


Figure 9 – Likert-scale divergence chart on perceptions of Quality Culture (n = 225).

Statistical analysis of the indicators in Section 2.

Table 8 and Figure 9 reveal an organizational profile characteristic of companies with a strong market-driven orientation, but with remaining challenges in the

institutionalization of continuous improvement methodologies and in human capital management. Accordingly, three key directions are identified:

1. External Orientation and Customer Responsiveness (Positive Benchmark)

The indicator q2_4_5 (Customer Focus) stands out as the most significant strategic asset within the sample. With a mean of 4.19 and an 86% level of consensus, organizations demonstrate a responsiveness to complaints that meets international standards of excellence. The high kurtosis (2.76) suggests that effectiveness in handling complaints is a central and cross-cutting competence, regardless of the organizations' geographic location or number of sites.

2. Gaps in the Institutionalization of Global Methodologies (Operational Risk)

In contrast to external performance, item q2_3_4 (Continuous Improvement) emerges as the most pronounced structural weakness. As the only item with a median of 3 (Neutral) and the lowest recorded mean (3.38), it indicates that globally recognised methodologies, such as Lean, Six Sigma, or Kaizen, are still not fully embedded in day-to-day operations.

- **Implication:** This “neutrality” (29%) and disagreement (23%) suggest that, although companies satisfy customer requirements, internal efficiency is often sustained through ad hoc efforts rather than robust improvement systems, which may compromise long-term competitiveness.

3. Talent Management and Recognition (Cultural Variability)

The item q2_2_6 (Employee Engagement) reveals significant fragmentation, showing one of the highest standard deviations (1.10) and one of the highest rates of disagreement (16%). Although the mean is positive (3.64), the high standard deviation indicates that recognition is not equitable. Some employees feel that their efforts to improve quality remain invisible to leadership. In international companies, recognition of contributions to quality is a key driver of talent retention.

- **Risk Analysis:** The dispersion of responses and the 16% disagreement rate suggest that reward systems are not applied consistently across all units or regions. This asymmetry in engagement may create “quality silos”, where commitment to excellence varies significantly between different departments or sites.

These results suggest that the surveyed companies possess a highly mature “customer service” layer, but lack an equally robust “process infrastructure”. For full integration, it is imperative that these organizations transition from a problem-solving culture based on reactivity to a culture of operational excellence grounded in global continuous improvement systems and the systematic recognition of human capital.

Integration of Quality and Sustainability (Section 3)

Table 9 – Summary statistics for the items in Section 3 – Integration of Quality and Sustainability (n = 225)

vars	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
q3_1_1	3.791	1.033	4	3.912	1.483	1	5	4	-0.810	0.298	0.069
q3_1_2	3.818	1.021	4	3.928	1.483	1	5	4	-0.760	0.049	0.068
q3_1_3	3.809	0.979	4	3.917	1.483	1	5	4	-0.749	0.281	0.065
q3_1_4	3.880	0.999	4	4.000	1.483	1	5	4	-0.748	0.077	0.067
q3_1_5	3.729	1.057	4	3.829	1.483	1	5	4	-0.687	-0.124	0.070
q3_1_6	3.720	1.084	4	3.823	1.483	1	5	4	-0.665	-0.216	0.072
q3_2_1	3.782	0.950	4	3.878	1.483	1	5	4	-0.738	0.306	0.063
q3_2_2	3.764	1.019	4	3.856	1.483	1	5	4	-0.629	-0.221	0.068
q3_2_3	3.609	1.072	4	3.680	1.483	1	5	4	-0.455	-0.470	0.071
q3_2_4	4.018	1.004	4	4.171	1.483	1	5	4	-1.009	0.521	0.067
q3_2_5	3.773	1.076	4	3.884	1.483	1	5	4	-0.784	-0.088	0.072
q3_2_6	3.627	1.095	4	3.718	1.483	1	5	4	-0.648	-0.253	0.073
q3_3_1	3.951	0.969	4	4.066	1.483	1	5	4	-0.928	0.699	0.065
q3_3_2	3.996	0.923	4	4.099	1.483	1	5	4	-0.838	0.425	0.062
q3_3_3	3.827	1.070	4	3.950	1.483	1	5	4	-0.721	-0.083	0.071
q3_3_4	3.787	1.064	4	3.884	1.483	1	5	4	-0.588	-0.471	0.071
q3_3_5	3.836	0.998	4	3.939	1.483	1	5	4	-0.609	-0.221	0.067
q3_3_6	3.556	1.133	4	3.641	1.483	1	5	4	-0.540	-0.465	0.076
q3_4_1	3.720	1.029	4	3.823	1.483	1	5	4	-0.647	0.088	0.069
q3_4_2	3.662	1.066	4	3.751	1.483	1	5	4	-0.513	-0.275	0.071
q3_4_3	3.569	1.084	4	3.646	1.483	1	5	4	-0.470	-0.335	0.072
q3_4_4	3.507	1.098	4	3.575	1.483	1	5	4	-0.409	-0.434	0.073
q3_4_5	3.613	1.080	4	3.713	1.483	1	5	4	-0.609	-0.048	0.072
q3_4_6	3.649	1.034	4	3.740	1.483	1	5	4	-0.569	0.117	0.069
q3_5_1	3.636	1.061	4	3.713	1.483	1	5	4	-0.512	-0.359	0.071
q3_5_2	3.822	0.947	4	3.906	1.483	1	5	4	-0.615	0.062	0.063
q3_5_3	3.907	0.938	4	4.000	1.483	1	5	4	-0.752	0.335	0.063
q3_5_4	3.702	1.007	4	3.796	1.483	1	5	4	-0.637	0.107	0.067
q3_5_5	3.693	1.017	4	3.790	1.483	1	5	4	-0.655	0.144	0.068
q3_5_6	3.840	1.014	4	3.956	1.483	1	5	4	-0.702	0.025	0.068

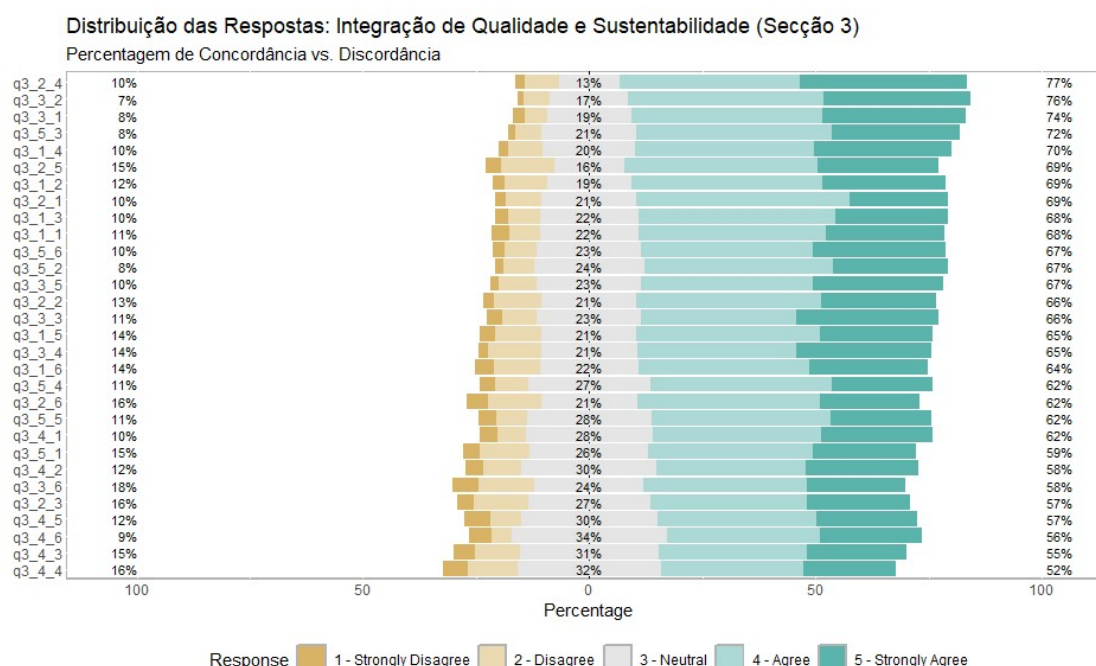


Figure 10 – Likert-scale divergence chart on perceptions of the Integration of Quality and Sustainability (n = 225).

The combined analysis of Table 9 and Figure 10 reveals how companies are addressing the challenge of integrating Quality Management with Sustainability. Unlike Section 2 (where there were clear peaks of excellence and weaknesses), this section presents more homogeneous results, but with slightly lower means, suggesting that integration remains a process still under development.

The analysis of the statistical indicators in Section 3 shows that the integration of sustainability into quality management follows a logic of “controlled internal efficiency”. Companies demonstrate maturity in areas they directly control, but show gaps in extending sustainability to their supplier ecosystems and to product design.

The key directions identified are:

1. Focus on Operations and Resource Efficiency (Strengths)

The items with the strongest statistical performance are associated with the direct optimization of costs and resources within the organization:

- **q3_2_4 (Commitment to Sustainable Practices):** With the highest mean in the section (4.02) and strong negative skewness (-1.01), commitment to reducing waste and environmental impact is a clear and widely shared priority.

- **q3_3_2 (Resource Efficiency – Operations):** The mean of 3.99 and the low standard deviation (0.92) confirm that the optimization of raw materials, energy and water is a standardized practice.
- **Interpretation:** These metrics suggest that sustainability is more readily adopted when it is directly correlated with the reduction of operational costs (Efficiency = Quality + Economy).

2. The Challenge of Sustainability in the Supply Chain

Although internal efficiency is high, the indicator q3_3_6 (Resource Efficiency – Suppliers) reveals a weakness:

- **Evidence:** This item presents the highest dispersion of responses in the section (SD = 1.13) and the lowest statistical consistency.
- **Interpretation:** In this context, prioritizing sustainable suppliers is a complex logistical and compliance challenge. The high variability indicates that not all company units are able to apply the same sustainability criteria to their external partners, creating inconsistencies across the global value network.

3. Product Design and Life Cycle (The Strategic Bottleneck)

The item q3_4_4 (Sustainable Product/Service Design) is identified as the area with the lowest level of maturity:

- Evidence: It presents the lowest mean (3.51) and the lowest skewness (-0.41) in the entire table.
- Interpretation: The assessment of social and environmental impact throughout the entire product life cycle is still not an embedded practice. This indicates that sustainability in these companies is often process-oriented (how products are made) rather than structural (what is produced), with a lack of an integrated Life Cycle Assessment (LCA) perspective in product design.

In summary, the companies in the sample demonstrate a form of “internalized sustainability”. Integration with quality is strong in aspects related to resource efficiency and the reduction of operational impact (where financial benefits are direct). However, the transition towards “holistic sustainability”, encompassing rigorous supplier selection (q3_3_6) and life-cycle-oriented design (q3_4_4), remains the principal challenge for the evolution of these organizations.

The Future of Quality (Section 4)

Section 4 of the questionnaire, *The Future of Quality*, is, among those analyzed so far, the one that presents the widest range of opinions and the most profound challenges. Whereas the previous sections focused on the “present” (culture and sustainability), this section addresses preparedness for digital and technological transformation, revealing a clear divide between theoretical optimism and practical readiness.

Table 10 – Summary statistics for the items in Section 4 – The Future of Quality (n = 225)

vars	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
q4_1_1	4.071	1.002	4	4.227	1.483	1	5	4	-1.123	0.879	0.067
q4_1_2	4.084	1.008	4	4.238	1.483	1	5	4	-1.159	1.025	0.067
q4_1_3	3.978	1.058	4	4.133	1.483	1	5	4	-0.991	0.354	0.071
q4_1_4	3.778	1.083	4	3.906	1.483	1	5	4	-0.833	0.161	0.072
q4_1_5	3.889	1.090	4	4.033	1.483	1	5	4	-0.912	0.169	0.073
q4_1_6	4.058	0.960	4	4.188	1.483	1	5	4	-1.171	1.428	0.064
q4_2_1	3.604	1.137	4	3.707	1.483	1	5	4	-0.620	-0.327	0.076
q4_2_2	3.733	1.098	4	3.851	1.483	1	5	4	-0.772	-0.037	0.073
q4_2_3	3.520	1.150	4	3.619	1.483	1	5	4	-0.557	-0.364	0.077
q4_2_4	3.507	1.134	4	3.569	1.483	1	5	4	-0.437	-0.687	0.076
q4_2_5	3.356	1.187	4	3.414	1.483	1	5	4	-0.326	-0.824	0.079
q4_2_6	3.551	1.101	4	3.630	1.483	1	5	4	-0.528	-0.370	0.073

q4_3_1	3.889	1.005	4	4.017	1.483	1	5	4	-0.881	0.463	0.067
q4_3_2	3.880	0.972	4	3.994	1.483	1	5	4	-0.863	0.536	0.065
q4_3_3	3.738	1.068	4	3.845	1.483	1	5	4	-0.715	-0.066	0.071
q4_3_4	3.471	1.150	4	3.536	1.483	1	5	4	-0.368	-0.685	0.077
q4_3_5	3.849	0.993	4	3.967	1.483	1	5	4	-0.786	0.269	0.066
q4_3_6	3.729	1.045	4	3.823	1.483	1	5	4	-0.568	-0.246	0.070
q4_4_1	3.844	1.025	4	3.967	1.483	1	5	4	-0.800	0.190	0.068
q4_4_2	3.822	1.033	4	3.939	1.483	1	5	4	-0.829	0.167	0.069
q4_4_3	3.773	1.021	4	3.873	1.483	1	5	4	-0.692	-0.061	0.068
q4_4_4	3.298	1.163	3	3.343	1.483	1	5	4	-0.236	-0.767	0.078
q4_4_5	3.707	1.006	4	3.796	1.483	1	5	4	-0.703	0.068	0.067
q4_4_6	3.702	1.067	4	3.790	1.483	1	5	4	-0.619	-0.340	0.071
q4_5_1	3.760	1.067	4	3.862	1.483	1	5	4	-0.634	-0.282	0.071
q4_5_2	3.804	1.021	4	3.912	1.483	1	5	4	-0.708	-0.021	0.068
q4_5_3	3.413	1.154	4	3.492	1.483	1	5	4	-0.465	-0.531	0.077
q4_5_4	3.698	1.030	4	3.807	1.483	1	5	4	-0.816	0.384	0.069
q4_5_5	3.556	1.125	4	3.635	1.483	1	5	4	-0.475	-0.502	0.075
q4_5_6	3.733	0.968	4	3.818	1.483	1	5	4	-0.684	0.086	0.065

The analysis of this section reveals a clear dichotomy within companies: a high level of strategic maturity, contrasted with a technological infrastructure that is still at the stage of experimentation or early implementation. The different directions identified in the exploratory analysis of the data in Table 10 were:

1. Quality as a Market Differentiator (Strategic Pillar)

The indicators relating to **strategic vision** show the strongest performance in the entire section, demonstrating that the *intention* to achieve excellence is unanimous:

Strategic Importance: q4_1_2 and q4_1_6: With mean scores of 4.08 and 4.06 respectively, the organizations confirm that quality is a fundamental pillar of the business and their principal competitive differentiator in the global market.

Interpretation: Senior management (C-Level) is aligned with modern concepts of excellence, recognizing that international survival depends on brand reputation and product quality.

2. The Challenge of Technological Integration (IoT and Connectivity)

Strategic optimism begins to decline when the organization's technical capacity for real time monitoring is assessed:

Technology Integration – IoT: q4_2_5: The mean score drops to 3.36, while the standard deviation rises to 1.19 (one of the highest in the study).

Interpretation: Although organizations aspire to be leaders in quality, many have not yet integrated IoT and intelligent sensors into their systems. The high dispersion reflects a scenario of inequality: while some multinational companies already operate with connected systems, a significant proportion of the sample (as shown by the 25–30% disagreement in the chart in Figure 11) still relies on traditional or manual monitoring methods.

3. The Bottleneck of Artificial Intelligence and Prediction (Proactive Risk)

The item *q4_4_4* (**Proactive Risk Management**) emerges as the point of lowest technological maturity in the questionnaire:

- **Statistical Evidence:** It presents the lowest mean score (3.30), and the median falls to 3. It is the indicator in which the organization feels least prepared.
- **Interpretation:** The use of Data Analytics and Artificial Intelligence to predict risks before they occur remains a distant prospect for most companies. The transition from *detective* quality (inspection) to *predictive* quality (AI-driven) is identified in this study as the greatest challenge for the future.

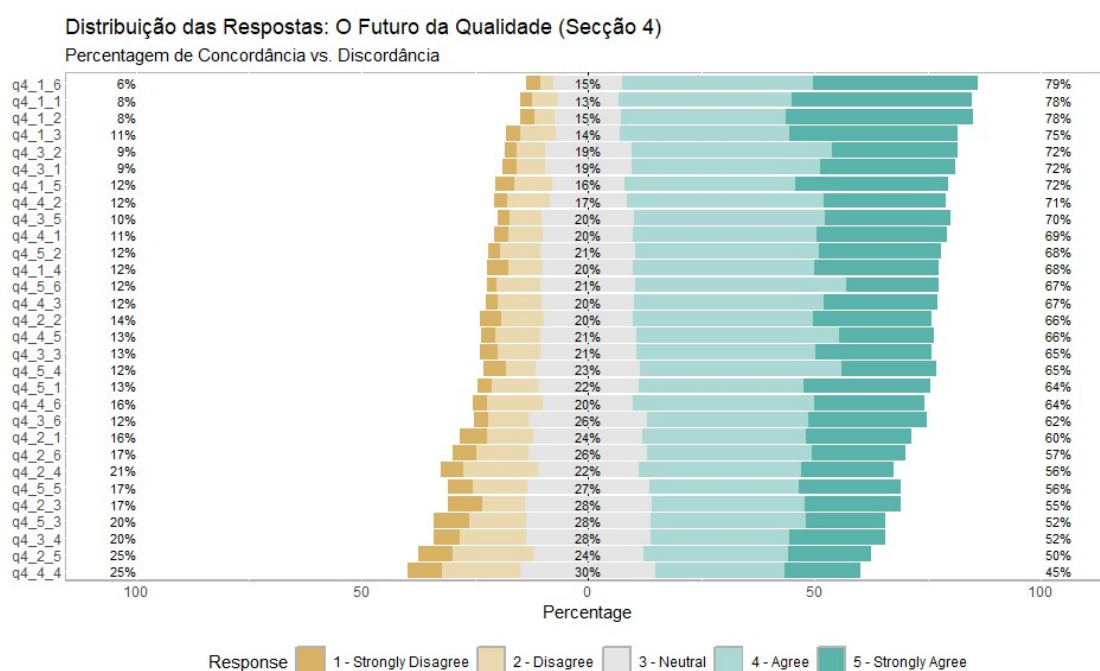


Figure 11 – Divergence chart (Likert) on the perception of the Future of Quality (n = 225).

The divergence chart in **Figure 11** clearly illustrates the technological *maturity funnel* of the companies. While the items at the top of the chart display a solid green band shifted

to the right, the lower items reveal an expansion of the grey zones (neutral responses) and brown zones (disagreement).

1. Strategic Consensus (Top of the Chart)

The items *q4_1_6* (**Market Differentiation**) and *q4_1_2* (**Quality as a Strategic Pillar**) dominates the top of the chart, with 79% and 78% agreement respectively.

- **Visual Observation:** The “Strongly Disagree” bars for these items are almost imperceptible (only 6–8%), reinforcing the notion that quality is a universal and undisputed language within the strategic agenda of multinational organizations.

2. The “Zone of Uncertainty” (Centre of the Chart)

In the middle of the distribution (items such as *q4_5_1* to *q4_2_1*), there is a significant increase in the grey zone (Neutral), which reaches 26%.

- **Interpretation:** This band represents companies that are *observing* emerging trends but have not yet taken an active position. Statistically, this reflects the flattening of the kurtosis curve observed in the table, indicating a phase of transition or uncertainty regarding the applicability of certain innovations.

3. Fragmentation and Technological Resistance (The Basis of the Chart)

The items *q4_2_5* (**IoT**) and *q4_4_4* (**AI and Prediction**) occupies the base of the chart, displaying the most heterogeneous profiles:

- **q4_4_4 (Proactive Risk Management):** Visually, it is the item with the largest accumulated disagreement bar (25%) and the highest neutrality (30%). Only 45% of respondents agree with the use of AI to predict risks.
- **q4_2_5 (IoT):** It presents a similar profile, with a disagreement bar of 25%.
- **Visual Conclusion:** The chart shows that, for these cutting edge technologies, the sample is divided into three almost equal groups: those who have already implemented them, those who remain undecided, and those who state they do not have the capacity to do so.

Assessment of Internal Consistency and Reliability of Likert Scales

To ensure the scientific validity of a questionnaire, it is not sufficient to analyse means and frequencies; it is essential to confirm that the questions within each section

measure the same construct in a coherent manner. This process is known as the **Assessment of Internal Consistency or Reliability**.

Before aggregating responses into section-level scores, it is therefore crucial to verify whether the items within each section measure the same latent concept. **Cronbach's Alpha** is the standard metric used for this purpose.

The reliability of a data-collection instrument refers to its ability to produce consistent results and to the precision with which it measures a given phenomenon. In the context of this study, the internal consistency of **Sections 2 (Culture), 3 (Sustainability) and 4 (Future)** was assessed using the **Cronbach's Alpha coefficient (α)**.

The Importance of Cronbach's Alpha

The **Cronbach's Alpha** coefficient is the statistical indicator most widely used to validate **Likert scales**. It quantifies the average correlation between the items within a subsection, ranging from 0 to 1.

A high value of α indicates that the questions are homogeneous and that respondents interpreted them in a consistent manner.

According to the established methodological literature, values of $\alpha > 0.70$ are considered acceptable for scientific research, while values **above 0.80** indicate good reliability and **above 0.90** indicate excellent reliability.

Application to the Questionnaire Sections

The analysis of internal consistency is crucial for the sections mentioned, given their multidimensional nature:

- **Section 2 Quality Culture:** This section assesses whether the items relating to leadership, customer focus and engagement converge towards a single cultural diagnosis.
- **Section 3 Integration and Sustainability:** Here, Cronbach's Alpha confirms whether perceptions of resource efficiency and sustainable design form a robust construct of "*Green Quality*".
- **Section 4 The Future of Quality:** Given the high variability observed (particularly in items such as AI and IoT), calculating α in this section is essential to determine whether *Technological Readiness* is being measured reliably despite the dispersion of opinions.

The data analysis conducted in R produced the following results:

- **Cronbach's Alpha for Quality Culture (Section 2): $\alpha = 0.982$**
- **Cronbach's Alpha for Q&S (Section 3): $\alpha = 0.985$**
- **Cronbach's Alpha for The Future of Quality (Section 4): $\alpha = 0.983$**

The assessment of internal consistency across the questionnaire scales revealed exceptional levels of reliability. According to the criteria established by **George & Mallery (2003)** and **Hair, Black, Babin & Anderson (2013)**, where values above 0.90 are classified as “*Excellent*”, the results obtained confirm the robustness of the measurement instrument.

These values indicate that the items within each section are strongly correlated. This demonstrates that the questions measure the same theoretical construct in a clear and consistent manner, leaving little room for measurement error or ambiguous interpretation among international respondents.

The results suggest that, despite the geographical dispersion of participants, there is a shared and highly coherent understanding of what constitutes **Culture, Sustainability, and the Future of Quality** within this group of companies.

The Cronbach's Alpha values obtained (all above 0.98) reflect excellent reliability. Although coefficients of this magnitude may suggest some redundancy among items (i.e., questions capturing very similar facets of the same concept), in the context of this study they validate the strength and clarity of the operational definitions adopted.

Implications for Data Analysis

A robust level of internal consistency enables the researcher to use the weighted mean of the items within a section as a single latent variable (a **global score**) in more advanced statistical analyses, such as **Pearson correlations** or **linear regressions**, thereby adding rigor and authority to the results presented. It also allows for the application of inferential analyses to test hypotheses concerning the relationship between thematic sections and sociodemographic variables.

With such a high α value, there is strong statistical assurance for creating latent variables (aggregated indices) for each section. Any subsequent analysis based on the mean values of these sections will have an almost negligible margin of error arising from insufficient internal consistency.

Correlation Between the Main Themes

We can calculate the mean score for each section (Q2, Q3 and Q4) and examine whether a significant correlation exists between them. For example, do organisations with a stronger **Quality Culture** (Q2) also tend to exhibit higher levels of **Sustainability Integration** (Q3)?

"--- Correlation Matrix (Pearson's r)---"

	score_q2	score_q3	score_q4
score_q2	1.000	0.773	0.829
score_q3	0.773	1.000	0.848
score_q4	0.829	0.848	1.000

"--- Significance Matrix (p-values) ---"

	score_q2	score_q3	score_q4
score_q2	-	<0.001	<0.001
score_q3	<0.001	-	<0.001
score_q4	<0.001	<0.001	-

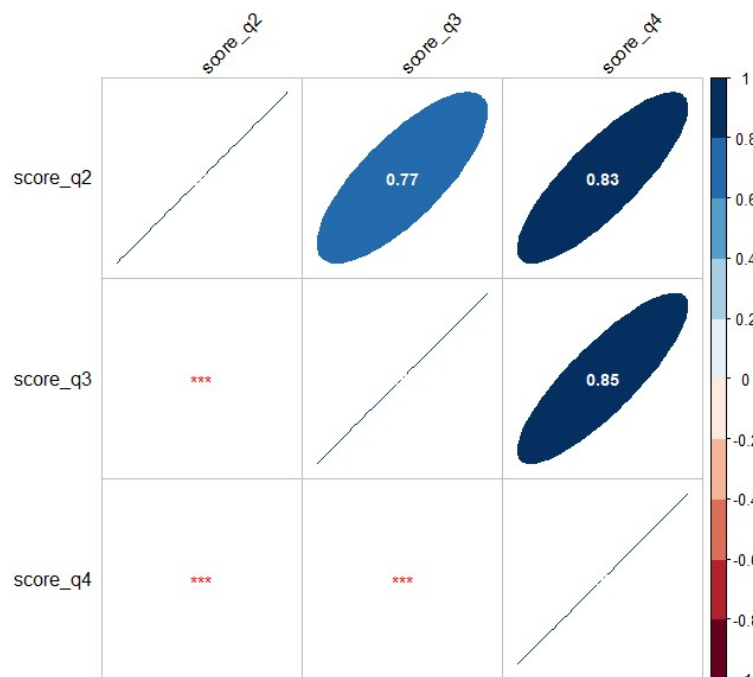


Figure 12 – Correlation Matrix Between the Dimensions

The graph in Figure 12 shows that the three dimensions (**Culture, Sustainability, and Future**) are not isolated variables but components of an interconnected system, displaying very strong and statistically significant positive correlations ($p < 0.001$, indicated by the red asterisks at the base).

Quality Culture (Q2) vs. Future of Quality (Q4)

- **Coefficient ($r = 0.83$):** This is one of the strongest correlations observed.
- **Interpretation:** It indicates that the maturity of organizational culture (leadership, customer focus, engagement) is the main driver of technological adoption. Companies with high scores in Q2 are significantly better prepared to adopt AI and IoT (Q4). The ellipse in the graph is visibly narrower, confirming this strong linear association.

Quality Culture (Q2) vs. Sustainability (Q3)

- **Coefficient ($r = 0.77$):** Although this is the “lowest” correlation in the matrix, it is still considered very strong.
- **Interpretation:** This suggests that the integration of sustainability depends on the established quality culture, although other factors (such as external regulations or costs) may influence sustainability independently of the internal culture. The ellipse is slightly “wider”, reflecting this small additional margin of variation.

Sustainability (Q3) vs. Future of Quality (Q4)

- **Coefficient ($r = 0.85$):** This is the highest correlation in the matrix.
- **Interpretation:** This result is particularly revealing. It shows that, in the view of the managers of these companies, sustainability and the technological future are inseparable. The pursuit of resource efficiency (Q3) appears to be what drives the need for digital monitoring and proactive data analysis (Q4). This study indicates that technology is not an end in itself, but a means to achieving more sustainable operations.

Comparative Analysis by Group

Comparison by Countries

The dataset was first aggregated according to the geographical distribution presented in Figure 1 (which highlights the main countries and groups the remaining ones under “Others”). Given the global nature of the data collection and the need to ensure statistical robustness in group comparisons, the responses were consolidated into broader geographical macro-regions. This approach helps mitigate sample fragmentation and allows the analysis to focus on regional patterns of quality maturity, facilitating the identification of competitive asymmetries between economic blocs (e.g., Europe vs Asia).

Since the groups “Africa” and “Latin America” still had a very small n (fewer than 10 responses), the final division adopted was: **Europe, Asia and Others**, ensuring that the statistical results remain reliable. The resulting distribution is: **Asia ($n = 40$)**, **Europe ($n = 120$)** and **Others ($n = 22$)**.

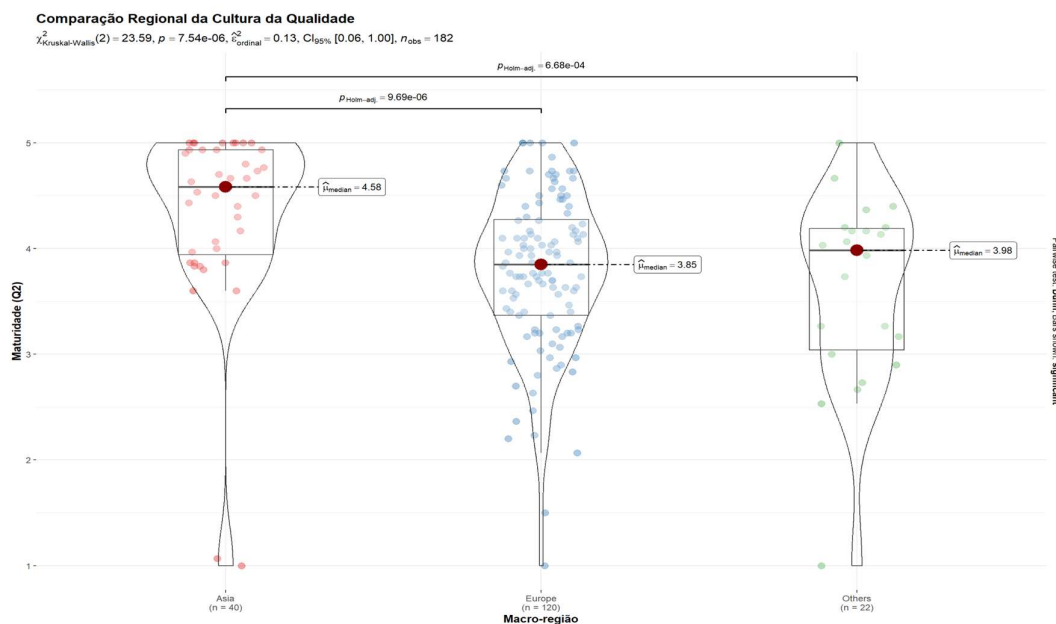


Figure 13 – Distribution of the Mean Scores for Quality Culture (Q2) by Macro-region

Based on the Kruskal–Wallis test ($\chi^2(2) = 23.59$, $p < 0.001$), there are significant differences (indicated by the comparison bars at the top) between specific groups. It can therefore be concluded that organizational culture is influenced by the regional/geographical context.

From the analysis of the graph in Figure 13, the following can also be observed:

- **Asia's Leadership:** The Asia region presents the highest median ($\tilde{\mu} = 4.200$), with a distribution highly concentrated at the upper end. This suggests that, within the Asian sample (predominantly China), the quality culture is strongly embedded and perceived very positively.
- **European Stability:** Europe shows a solid median ($\tilde{\mu} = 3.90$), but with a much wider dispersion (the “tail” of the violin). This reflects the heterogeneity of European companies, where organizations with highly mature cultures of excellence coexist with others still in earlier stages of development.

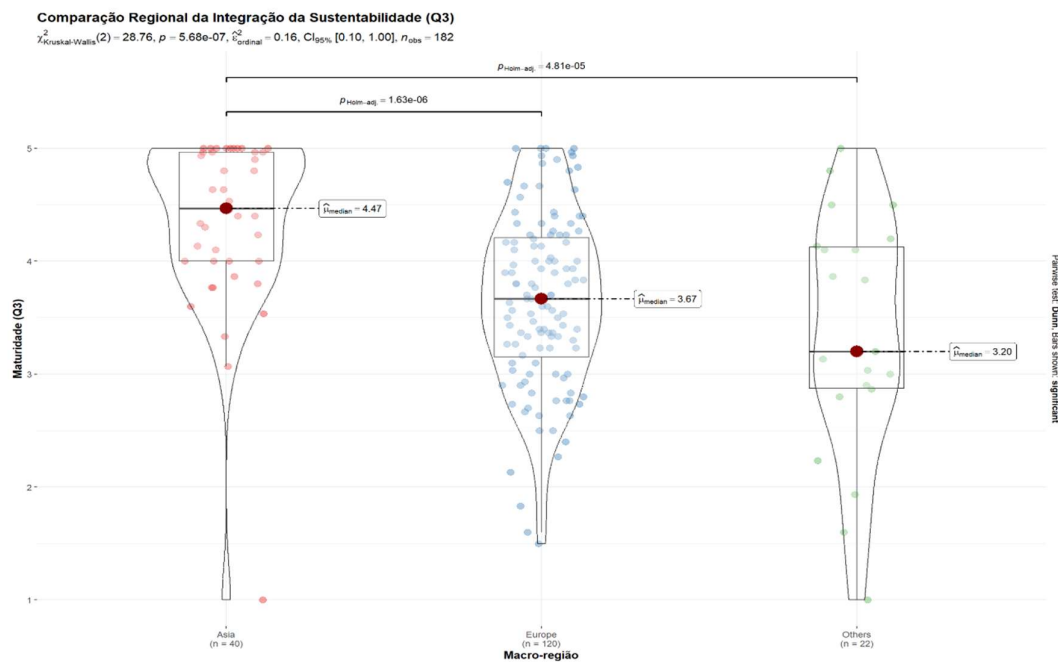


Figure 14 – Distribution of the Mean Scores for Sustainability Integration (Q3) by Macro-region

Once again, based on the Kruskal–Wallis test ($\chi^2(2) = 28.76, p < 0.001$), significant differences are observed between specific groups. It can therefore be concluded that the integration of sustainability is influenced by the regional/geographical context.

From the analysis of the graph in Figure 14, the following can be noted:

- **Asia's Positioning:** In this dimension, a median of 4.47 (Asia) indicates that most respondents fall between “Agree” and “Strongly Agree”. A median of 3.67 (Europe) shows that most respondents are closer to “Neutral/Agree”. Asia is not merely “complying” with sustainability; it is using it as a central pillar of its quality

strategy. Europe, although scoring positively, shows greater hesitation or greater dispersion (more companies with lower scores pulling the median down).

- **Variability in the ‘Others’ Group:** The group *Others* (which includes countries such as Peru or Cape Verde) often presents outliers or a wider dispersion, indicating that sustainability in these regions may depend more on individual company initiatives than on a consolidated regional norm.

Although both regions present positive mean scores in the Sustainability dimension (Q3), a significant maturity asymmetry is evident. Asia demonstrates robust leadership, placing sustainability at the top of its strategic agenda. In contrast, Europe reveals a more moderate and heterogeneous commitment, suggesting that the full integration of circular-economy and efficiency principles still faces barriers or slower implementation rhythms within the European context.

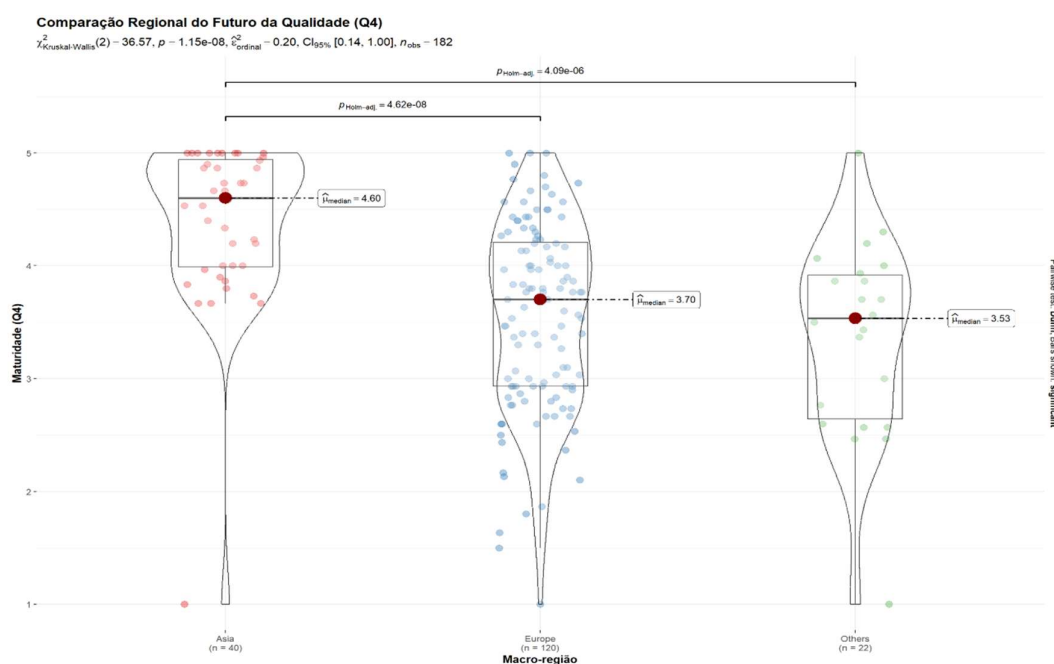


Figure 15 – Distribution of the Mean Scores for the Future of Quality (Q4) by Macro-region

Based on the analysis of the graph in Figure 15, the following observations can be made:

- **Technological Readiness:** Asia once again stands out slightly in its preparedness for the future (AI, IoT, Quality 4.0). This aligns with the literature highlighting the rapid digitalization of Eastern economies.

- **Europe in Transition:** Europe shows a competitive median, but there is a noticeable group of “lagging” companies (points at the lower end of the graph) that have not yet begun the transition towards the Future of Quality.
- **Strategic Consensus:** As in the sectoral analysis, the p -value tends to be higher here, indicating that the vision of the “Future” is a global ambition, regardless of whether a company is located in Portugal, China, or the Czech Republic.

When analysing the three figures together, the following conclusions can be drawn:

Asia as the Unquestionable Frontrunner

In the macro-regional analysis, Asia shows superior and more consistent performance across all dimensions:

- **Q2 (Culture):** Scores are high, but it is in the more “practical” dimensions (Q3 and Q4) that Asia truly distances itself.
- **Q3 (Sustainability):** Achieves the impressive value of 4.47. This indicates that, within the Asian bloc, sustainability is not merely an intention but a consolidated operational practice.
- **Q4 (Future):** Maintains its leadership, suggesting that digitalisation and innovation are embedded within the quality culture.

Europe at “Cruising Speed”

Europe, with medians around 3.7 to 3.9, demonstrates solid yet reactive maturity.

- While Asia appears to use Quality to drive Sustainability, Europe seems to be in a process of adaptation.
- The greater dispersion (longer boxes and violins) in Europe indicates a less cohesive landscape: excellent companies coexist with many others still anchored in traditional quality models that do not fully integrate the environmental pillar (Q3).

The Execution Gap (Q2 vs Q3)

- **In Europe:** There is alignment between Culture (Q2) and Sustainability (Q3) — the scores are close (3.8 and 3.7). Culture “enables” sustainability.

- **In Asia:** There is a leap. Culture (Q2) forms the foundation that enables Sustainability (Q3) to reach 4.5. This suggests that the Asian management model is more effective at transforming “mindset” into “sustainability indicators”.

Table 11 – Summary of the Analysis According to the Macro-regional Division

Dimension	Europe Diagnosis	Asia Diagnosis	Global Conclusion
Quality Culture (Q2)	Stable and diverse	Strong and cohesive	Regional culture shapes the foundation of the APQ model.
Sustainability (Q3)	3.7 (In maturation)	4.5 (Leadership)	There is a significant performance asymmetry.
Future (Q4)	Competitive	Advanced	Asia is closer to “Quality 4.0”.

The model proves to be globally applicable, but its effectiveness in integrating sustainability and future-oriented technologies is significantly higher in the Asian context compared with the European one.

Comparison by Sector of Activity

Based on Table 2, the groups that have sufficient critical mass (*N* large enough) to be analysed independently are:

1. **Industrial** (the dominant group).
2. **Services**.
3. **Health and Social**.
4. **Education**.
5. **Other Sectors** (including: *Other, Commerce, Consulting, Public Administration, Extractive, Primary, Utilities, Environment, and First Transformation*).

This aggregation is the most statistically appropriate, since groups such as *Environment* (*n* = 3) or *First Transformation* (*n* = 2), if analysed individually, would not allow statistical significance to be achieved in any test.

Table 12 – Distribution of Valid Responses by Sector of Activity

Sector	Education	Health and Social	Industrial	Services	Other Sectors
N (valid)	11	12	92	41	38

Following the application of the Kruskal–Wallis test, the results obtained for each of the dimensions considered are presented below.

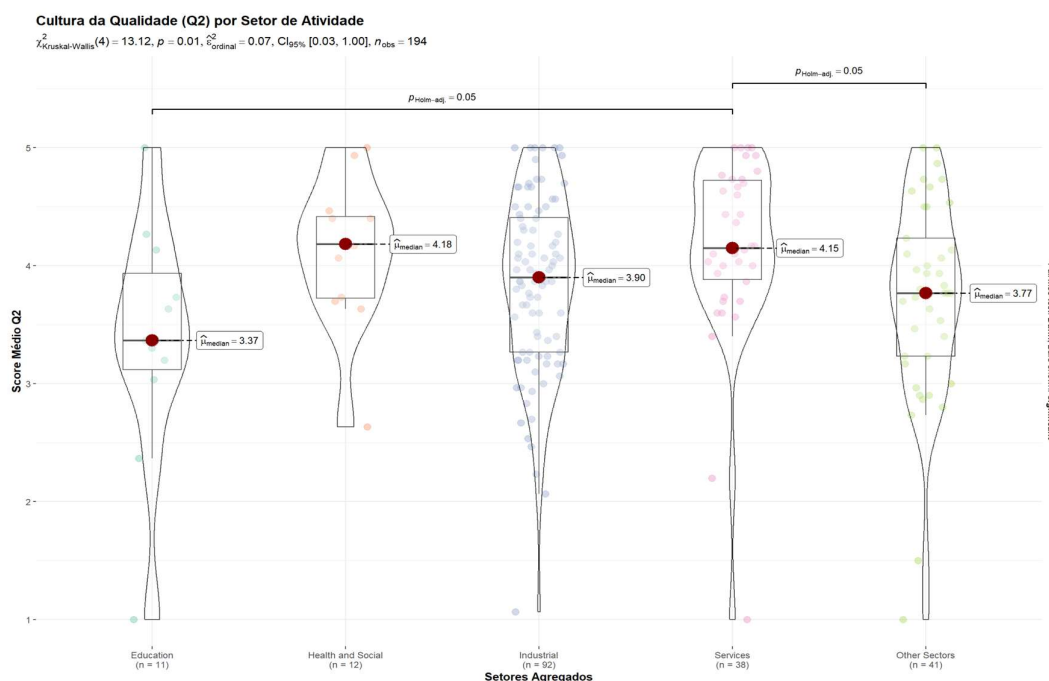


Figure 16 – Distribution of the Mean Scores for Quality Culture (Q2) by Sector of Activity

The analysis of the graph presented in Figure 16 reveals that the sector in which the organization operates has a statistically significant impact on how quality culture is experienced and perceived.

Based on the Kruskal–Wallis test presented ($\chi^2(4) = 13.12, p = 0.01$), significant differences exist between specific groups, as indicated by the comparison bars displayed at the top of the figure:

- Education vs Health and Services:** The Education sector presents the lowest median in the sample ($\tilde{\mu} = 3.37$), differing significantly from the Health and Social sector ($\tilde{\mu} = 4.18$) and the Services sector ($\tilde{\mu} = 4.15$). This suggests that educational institutions may face greater challenges in implementing a robust quality culture when compared with service-oriented or healthcare sectors;

- **Health and Social:** This sector stands out with the highest median ($\tilde{\mu} = 4.18$), indicating a stronger perception of quality culture, possibly due to the critical and highly regulated nature of its processes.

Although the **Industrial sector** is the most representative in terms of responses ($n = 92$), it presents an intermediate median ($\tilde{\mu} = 3.90$). A considerable vertical dispersion of the data is visible (as shown by the spread of the blue points). This indicates that quality culture within industry is heterogeneous, i.e., some factories demonstrate cultures of excellence, whereas others display very low levels.

The **Services and Industrial sectors** show long lower “tails” in the violin plots, indicating that some organizations within these sectors report extremely low culture scores (close to 1), despite the majority scoring above the average.

The **Other Sectors** group ($n = 41$) maintains moderate consistency ($\tilde{\mu} = 3.77$), serving as a useful baseline reference for the sample.

This analysis demonstrates that the sectoral context shapes the extent and pace at which a Quality Culture becomes established.

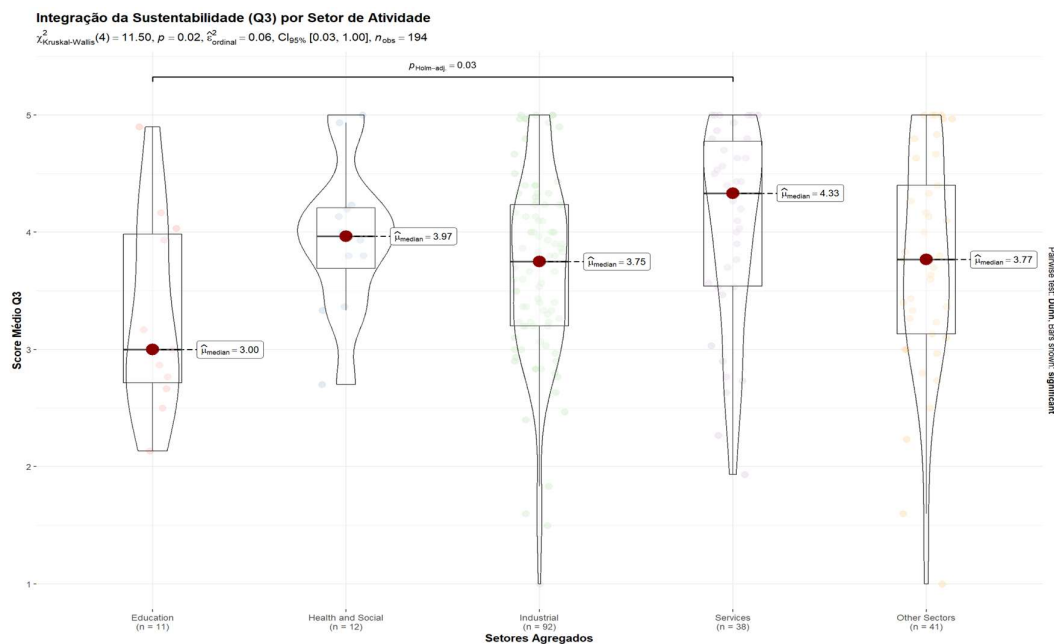


Figure 17 – Distribution of the Mean Scores for Sustainability Integration (Q3) by Sector of Activity

The analysis of the graph presented in Figure 17 reveals that, similarly to quality culture, the sector of activity significantly influences the maturity of sustainable practices ($X^2(4) = 11.50$, $p = 0.02$).

The **Services sector** presents the highest median in the sample ($\tilde{\mu} = 4.33$). A statistically significant difference exists (indicated by the upper comparison bar with $p_{\text{Holm-adj}} = 0.03$) between the **Services and Education sectors**. This suggests that service companies within the sample are more advanced in integrating resource efficiency and sustainability commitments than educational institutions.

The **Education sector** once again records the lowest score ($\tilde{\mu} = 3.00$). A median of 3.00 indicates that this sector is, on average, in a “neutral” position regarding sustainability integration, not yet demonstrating as strong an active or practical commitment as the remaining sectors.

Comparison between Industry and Health

- **Industrial ($\tilde{\mu} = 3.75$):** Although industry represents the largest proportion of the sample ($n = 92$), it scores below the Services and Health sectors in terms of sustainability. The dispersion of the data (green points) is very high, showing that environmental commitment varies substantially from one factory to another.
- **Health and Social ($\tilde{\mu} = 3.97$):** This sector maintains a solid performance above the overall average, demonstrating that quality management within these institutions is well aligned with sustainable practices.

Heterogeneity in “Other Sectors”

- The **Other Sectors** group presents a median of 3.77, but also the highest presence of lower outliers (isolated points close to a score of 1). This reinforces the idea that, within less represented sectors, there are cases where concerns regarding sustainability are almost entirely absent.

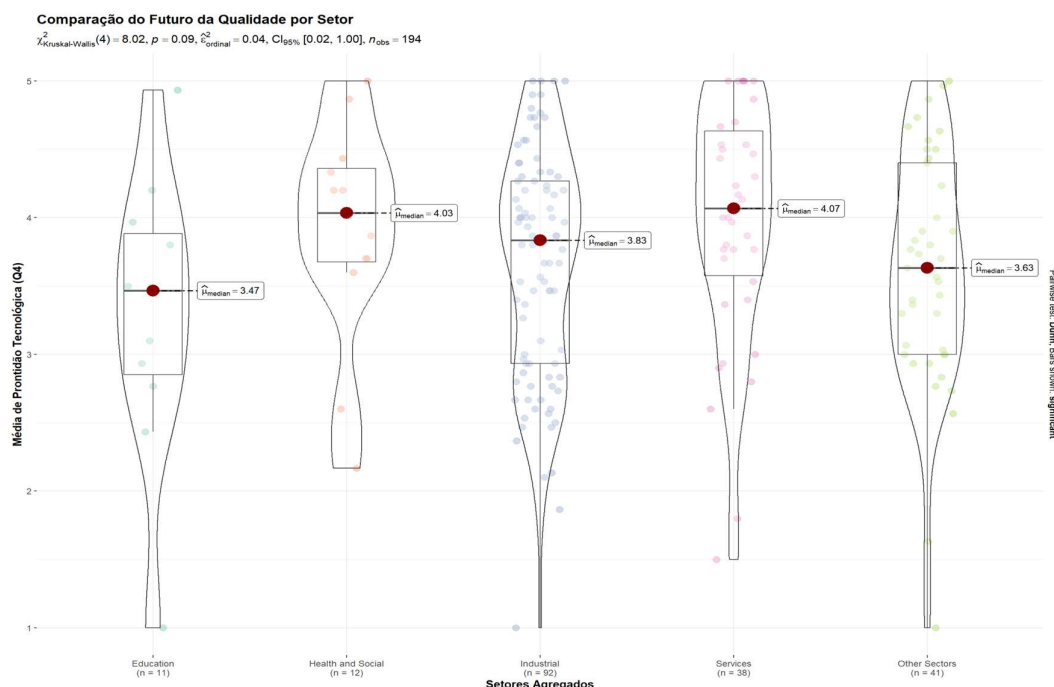


Figure 18 – Distribution of the Mean Scores for the Future of Quality (Q4) by Sector of Activity.

The comparative analysis of the graph presented in Figure 18 completes the cycle of the three dimensions, revealing a pattern of technological and strategic maturity that differs slightly from the previous dimensions.

Unlike the previous dimensions, the Future of Quality presents a p-value of 0.09 in the Kruskal–Wallis test. At the 0.05 significance level, it cannot be concluded that the sector of activity influences readiness for the future. This suggests that perceptions regarding the importance of technology and innovation are more transversal and consistent across sectors than perceptions relating to quality culture or sustainability.

The **Services** ($\tilde{\mu} = 4.07$) and **Health and Social** ($\tilde{\mu} = 4.03$) sectors continue to present the highest medians, indicating a stronger inclination towards digital and strategic transformation.

Education remains the sector with the lowest score ($\tilde{\mu} = 3.47$), although the gap between this sector and the others is statistically less pronounced in this dimension.

Table 13 – Summary of the analysis by sector of activity

Dimension	Maturity Leader	Lowest Maturity	p-value	Main Conclusion
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Culture (Q2)	Health ($\tilde{\mu} = 4,18$)	Education ($\tilde{\mu} = 3,37$)	p=0,01*	Significant. Culture is strongly influenced by the sector.
Sustainability (Q3)	Services ($\tilde{\mu} = 4,33$)	Education ($\tilde{\mu} = 3,00$)	p=0,02*	Significant. The services sector leads the green/sustainable transition.
Future (Q4)	Services ($\tilde{\mu} = 4,07$)	Education ($\tilde{\mu} = 3,47$)	p=0,09	Not significant. The future vision is the most consensual dimension.

Summary by Sector:

- **Services and Healthcare** — These are the driving forces of Quality 4.0 within the sample. They display consistently high scores (> 4.00), indicating that these organizations have already integrated quality as a cultural, sustainable, and technological value.
- **Industrial** — Although it is the largest group (n=92), it emerges as a “mid-table” sector with extreme heterogeneity. The long tails in the violin plots show that industry encompasses contrasting realities: highly advanced companies alongside others that remain very traditional.
- **Education** — This is the sector with the greatest maturity deficit across all dimensions. The results suggest that educational institutions may be more focused on bureaucratic processes than on evolving towards the new pillars of quality.

There is a clear alignment between **Culture and Sustainability** (both dependent on the sector), whereas the **future vision** appears to be a shared objective across all areas of activity, albeit with varying levels of practical implementation.

Comparison by number of employees in the organization

Unlike the country- or sector-based analyses, further aggregation is not required here, because:

- **All groups have n>50** in the total sample (Table 3). Even after removing “incomplete cases”, the groups remain sufficiently large for the Kruskal–Wallis test to retain statistical power (11–50 (n=23), 51–250 (n=59), 250–500 (n=25), and >500 (n=75)).

. **This segmentation** makes it possible to test the theory of “Economies of Scale in Quality”: does having more than 500 employees facilitate the implementation of Quality 4.0?

. **The sample is well distributed** between SMEs (the first three groups) and Large Enterprises (the final group), which provides excellent external validity for the study.

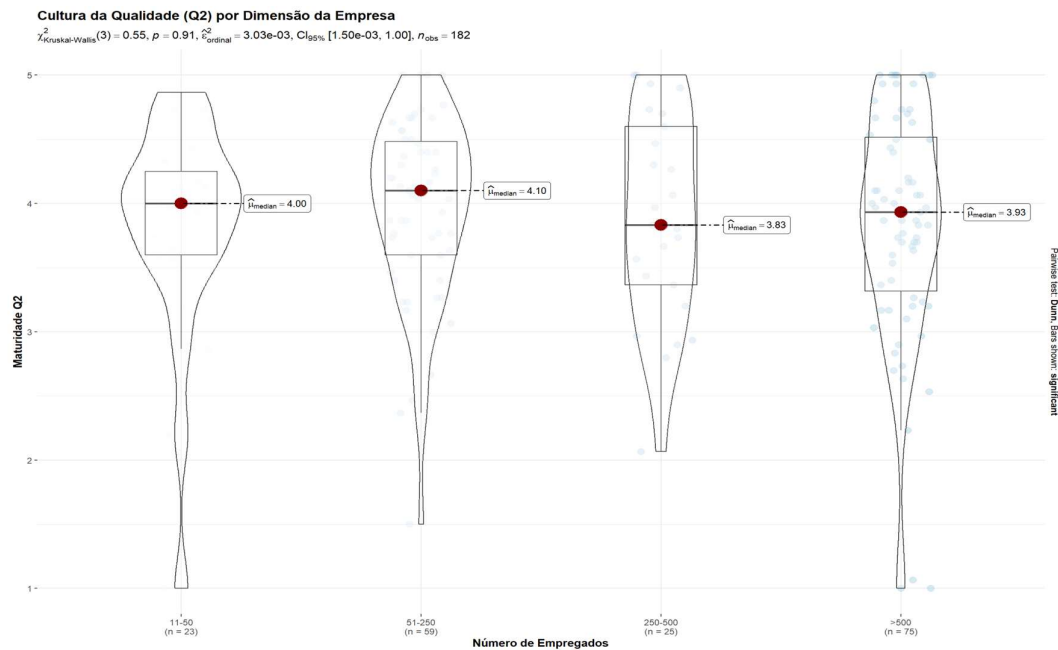


Figure 19 – Distribution of the average Quality Culture (Q2) scores by number of employees.

From the analysis of the chart in **Figure 19**, the following can be stated:

- **Inverted “U” pattern or stability** — Visually, the medians for culture tend to be high and relatively stable across groups, fluctuating slightly (e.g., between 3.8 and 4.1). It is common for small companies (11–50 employees) to show high culture scores due to leadership proximity, while large organisations (>500 employees) compensate through formalised processes.
- **Dispersion at the lower end** — The “tails” of the violin plots at the bottom of the chart show that there are outliers with very low culture scores (close to 1 or 2) in all company-size categories. This suggests that having abundant resources (>500 employees) does not guarantee a strong culture, and being small (11–50 employees) does not prevent cultural excellence.

Given that the **Kruskal–Wallis test** does not reveal statistically significant differences ($\chi^2(3)=0.55$, $p=0.91$), it can be concluded that **Quality Culture is a transversal asset that depends more on management than on organizational size.**

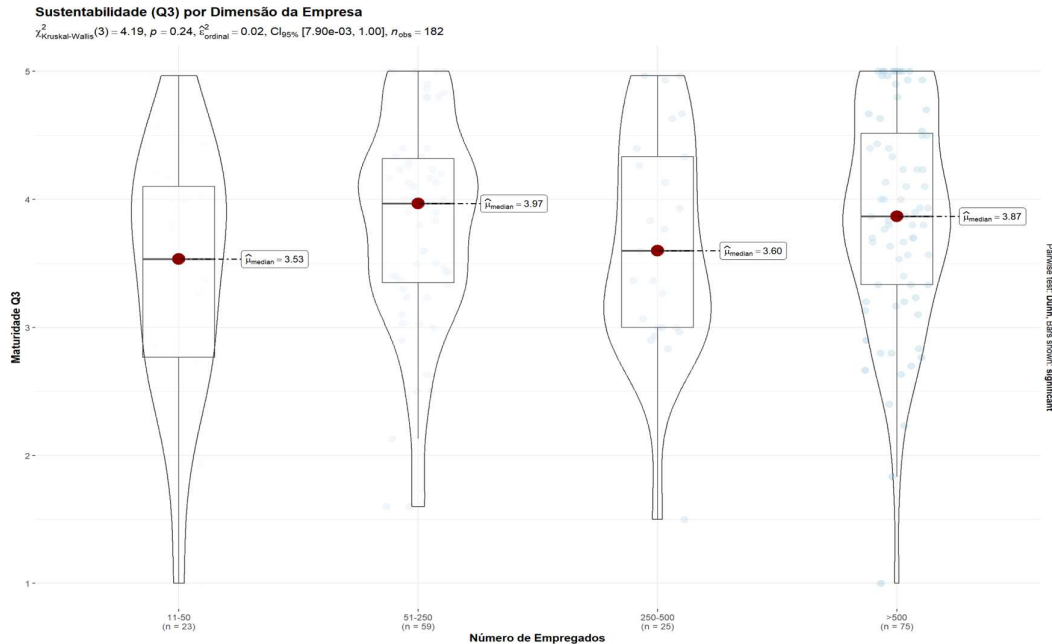


Figure 20 – Distribution of the average Sustainability Integration (Q3) scores by number of employees.

From the analysis of the chart in Figure 20, the following observations may be made: • Given that the Kruskal–Wallis test does not reveal statistically significant differences ($\chi^2(3)=4.19$, $p=0.24$), the evidence indicates that company size does not influence sustainability integration, demonstrating an absence-of-scale effect.

- The highest median belongs, interestingly, to the 51–250 employee group ($\tilde{\mu}=3.97$), slightly surpassing the >500 group ($\tilde{\mu}=3.87$). The 11–50 group shows the lowest maturity level ($\tilde{\mu}=3.53$), although the difference is not sufficient to be considered relevant by the test.
- This suggests that the **Small and Medium-Sized Enterprises (SMEs)** in the sample are just as committed to sustainability as the larger firms. This may be due to the fact that sustainability has become a market requirement for any supplier, regardless of size.
- While large companies have resources, smaller ones possess the agility to implement rapid changes that enhance resource efficiency.

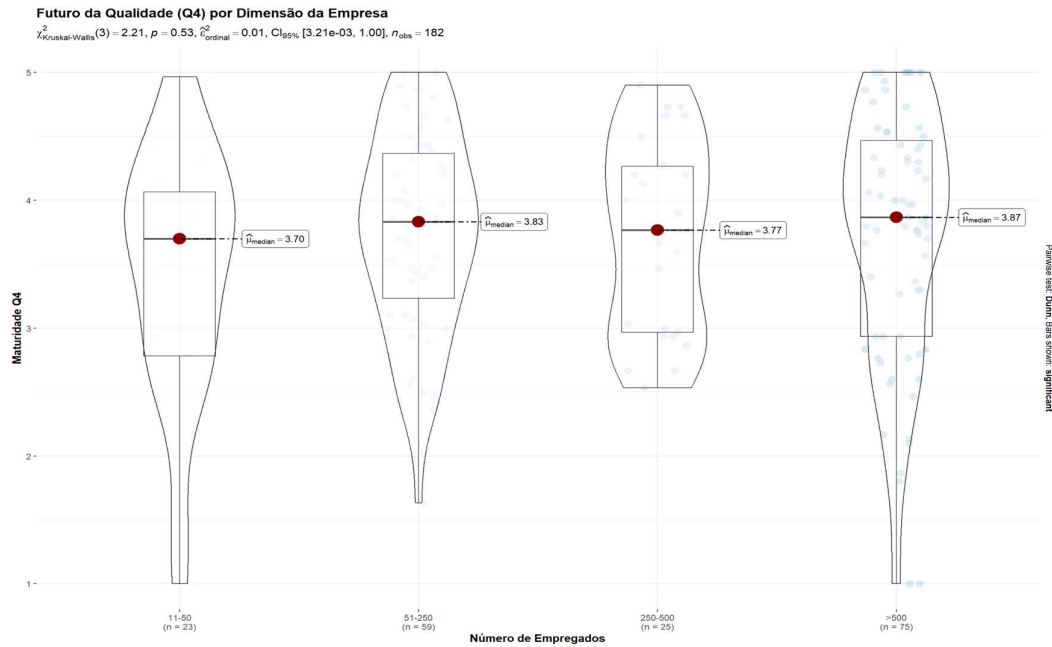


Figure 21 – Distribution of the average Future of Quality (Q4) scores by number of employees.

From the analysis of the chart in Figure 21, the following observations may be made: • Given that the Kruskal–Wallis test does not reveal statistically significant differences ($\chi^2(3)=2.21, p=0.53$), the evidence indicates that company size does not influence the Future of Quality (which encompasses AI and digitalization). The data show that SMEs are keeping pace with large companies.

Although the median of the >500 group is competitive ($\tilde{\mu}=3.87$), a greater concentration of points is observed at the top of the violin plot. This indicates that the “technological vanguard” (Quality 4.0) is slightly more frequent among large companies, even though the overall test does not consider this difference sufficiently significant to distinguish the groups.

When the three dimensions are cross-analysed by number of employees, it becomes clear that: **Size Does Not Define Maturity**. The analysis demonstrates that the APQ model (Culture, Sustainability and Future) is resilient to organizational size. This suggests that the traditional barriers faced by SMEs (lack of resources or technology) may be being overcome by a new management mindset that prioritizes agility and rapid adaptation. In this sample, **who the company is** (Sector) and **where the company is located** (Geography) weigh far more heavily on maturity than **how large the company is**.

Table 14 – Summary of the analysis by dimension in terms of number of employees.

Dimension	Behaviour in the Sample	Conclusion
Culture (Q2)	Stable and High	The human dimension of quality is universal.
Sustainability (Q3)	No scale effect	SMEs are just as “green” and efficient as large companies.
Future (Q4)	Global consensus	Digital readiness is an ambition shared across all organisational tiers.

Comparison by Percentage in the International Market

The variable representing exposure to the international market was grouped into three strategic levels: Low (<25%), Medium (25–75%), and High (>75%). The inclusion of organisations with no exports (0%) in the ‘Low Exposure’ stratum is justified by the expected behavioural homogeneity; companies with little or no international presence tend to focus their management systems on domestic requirements.

This tripartite segmentation allows for a clearer isolation of the impact of a consolidated global orientation (Medium and High groups) on the maturity of the APQ model pillars (Culture, Sustainability and Future), while simultaneously ensuring statistical balance between groups for the purpose of comparative testing.



Figure 22 – Distribution of the average Quality Culture (Q2) scores by exposure to the international market.

The Kruskal–Wallis test indicates that there are no statistically significant differences between the three levels of international exposure ($X^2(2)=2.06$, $p=0.36$).

The Quality Culture (Q2) is not an “export-driven product”. A company does not need to be highly internationalised to possess a solid culture. Cultural maturity appears to be an intrinsic characteristic of internal management, regardless of where the company sells its products. Although there is no statistical significance, a numerical progression is observed in the medians: Low (<25%) $\tilde{\mu}=3.90$, Medium (25–75%) $\tilde{\mu}=4.00$, and High (>75%) $\tilde{\mu}=4.10$.

This means there is a slight tendency for culture to become more “refined” as international exposure increases. However, the fact that the “Low” group already stands at 3.90 shows that the cultural baseline is very high even in the domestic market.

The violin plot for the High (>75%) group is shorter and more concentrated at the top. This indicates that highly exporting companies are more cohesive in their quality culture — there is less variability among them. The violin for the Low group is much longer, with several outliers at the lower end (near 1 and 2). This shows that, in the domestic/low-export market, companies with excellent cultures coexist with companies whose cultures are very weak. The international market appears to act as a “filter” that eliminates firms with low cultural maturity.

Thus, the analysis of Figure 22 demonstrates that the maturity of the Quality Culture (Q2) is resilient to the degree of organisational internationalisation ($p=0.36$). This result suggests that organisational culture is an endogenous asset, shaped primarily by internal processes and leadership rather than external competitive pressures. Nevertheless, companies with high international exposure (>75%) exhibit greater internal cohesion (lower score dispersion), suggesting that survival in global markets requires more rigorous cultural standardisation around excellence.

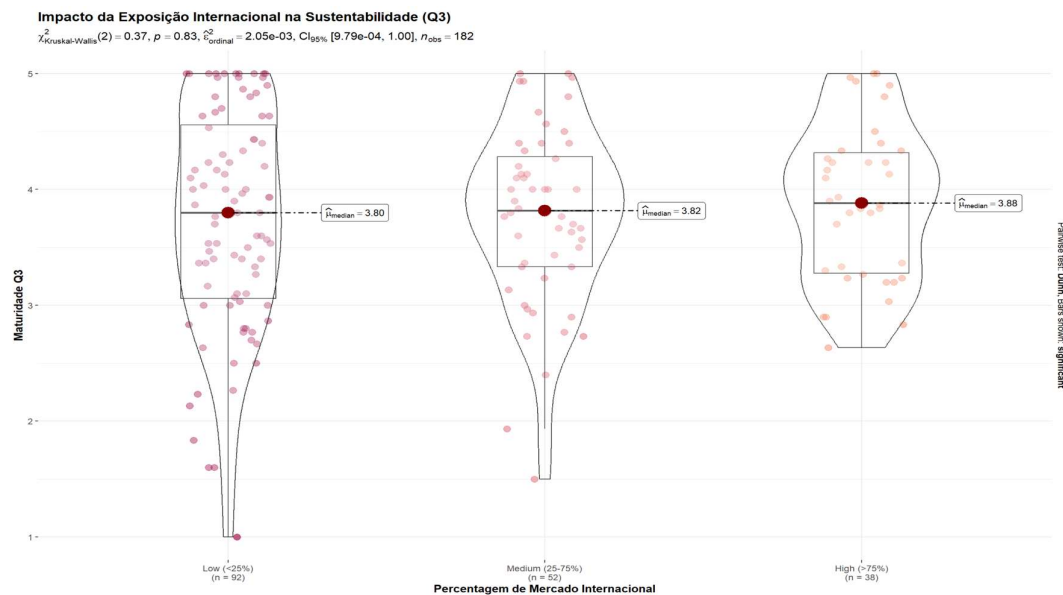


Figure 23 – Distribution of the average Sustainability Integration (Q3) scores by exposure to the international market.

The analysis of Figure 23 reinforces a surprising trend observed throughout the data: homogeneity. The variation of only 0.08 points between the lowest and highest medians across the levels of international exposure shows a complete alignment of practices.

The Kruskal–Wallis test once again indicates that there are no statistically significant differences between the three levels of international exposure ($X^2(2)=0.37, p=0.83$), revealing an absence of an “External Pressure” effect. Thus, the hypothesis that “exporting more forces companies to be more sustainable” is not confirmed in this sample. Companies operating solely in the domestic market (or with low export levels) display the same level of sustainability maturity as those exporting more than 75%.

This suggests that Sustainability (Q3) may not be a competitive differentiator in external markets, but rather a basic and transversal requirement — a *hygiene factor* — that all companies are adopting, regardless of where they sell their products.

As observed in Culture (Q2), the behaviour of the dispersion (the violin plots) shows that although exporting does not increase the average sustainability score, it appears to act as a minimum threshold. In other words: a company can be minimally sustainable and still survive in the domestic market, but it is very difficult to be minimally sustainable and maintain an international exposure above 75%.

In numerical terms:

- **Low group** — Shows very wide dispersion. There are companies at level 5 (excellent) and companies at level 1 (very weak). It is a highly heterogeneous group.
- **High group** — The violin “shrinks” at the base. Notice that there are almost no points below level 2.5.



Figure 24 – Distribution of the average Future of Quality (Q4) scores by exposure to the international market.

Once again, the Kruskal–Wallis test shows that there is no statistically significant difference ($\chi^2(2)=0.71, p=0.70$). It may therefore be stated that readiness for the Future of Quality (AI, IoT, Digitalisation) is not reserved for global companies. Firms with low or no international exposure are investing in technology at the same level as major exporters. This suggests that digitalisation is viewed as a requirement for internal operational survival (efficiency), rather than merely a tool for external competitiveness. Although not statistically significant, the median of the High group ($\tilde{\mu}=3.97$) is numerically higher than those of the Low ($\tilde{\mu}=3.80$) and Medium ($\tilde{\mu}=3.78$) groups.

A visual concentration of points at the top of the plot is observed for the High group. This indicates that, although the group as a whole is not statistically different, the “elite” of exporting companies reaches the upper limit of the scale (level 5.0) more frequently.

In terms of dispersion, a pattern similar to that of Q2 and Q3 is observed:

- **Low group (<25%)** — The violin extends down to level 1.0. There are companies that remain entirely “analogue” or lack a forward-looking vision.

- **High group (>75%)** — The “tail” of the violin cuts off much earlier (around level 2.5).

It may therefore be affirmed that international exposure does not necessarily “pull” the average upwards, but it does eliminate poor performance. To compete globally, the market imposes a “technological floor” below which a company ceases to be viable.

Table 15 – Summary of the analysis by dimension in terms of international exposure.

Dimension	Global Diagnosis	Strategic Conclusion
Culture (Q2)	p=0.36 (Not significant)	Culture is a stable internal asset.
Sustainability (Q3)	p=0.83 (Not significant)	Sustainability is a universal basic requirement.
Future (Q4)	p=0.70 (Not significant)	Technology is democratised across all levels.

The combined analysis of **Figures 22, 23 and 24** reveals an unexpected finding: organisational maturity, as measured by the APQ model, is **independent of the company’s degree of internationalisation**. Contrary to the literature, which often identifies external markets as the main drivers of innovation and rigour, the data show that companies focused on the domestic market achieve levels of excellence comparable to those of major exporters.

The only visible effect of internationalisation is the **reduction of negative variance**: the greater the exposure to the global market, the lower the tolerance for poor performance, resulting in the elimination of organisations with insufficient maturity in the pillars of **culture, sustainability** and **technology**.

Comparison by Annual Turnover

For the analysis of the impact of financial size on organisational maturity, the original annual-turnover categories were consolidated into three representative strata: **Small (<5M€)**, **Medium (5–50M€)** and **Large (>50M€)**.

The original segmentation contained groups with low representativeness (e.g., <0.5M with only 24 responses), which could inflate the standard error. The new grouping ensured robust sample sizes (**nSmall=44; nMedium=69; nLarge=69**), providing the Kruskal–Wallis non-parametric tests and the post-hoc comparisons with greater statistical power to detect real differences between medians.

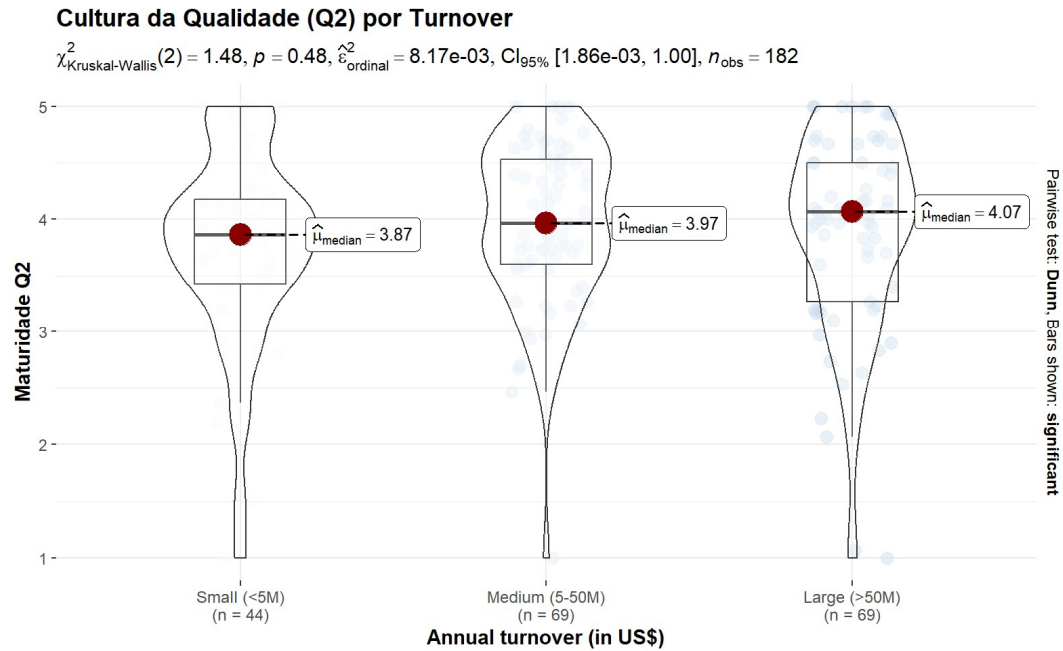


Figure 25 – Distribution of the average Quality Culture (Q2) scores by Annual Turnover.

The analysis of **Figure 25** shows that the Kruskal–Wallis test does not detect statistically significant differences between the three levels of financial health ($\chi^2(2)=1.48, p=0.48$). The observed medians were $\tilde{\mu}=3.87$ for **Small (<5M€)**, $\tilde{\mu}=3.97$ for **Medium (5–50M€)** and $\tilde{\mu}=4.07$ for **Large (>50M€)**.

The Quality Culture emerges as the most democratic pillar of the APQ model. The absence of significant differences indicates that excellence in leadership and employee commitment is not something “purchased” through large budgets; rather, it is a transversal characteristic found in both small and large organisations.

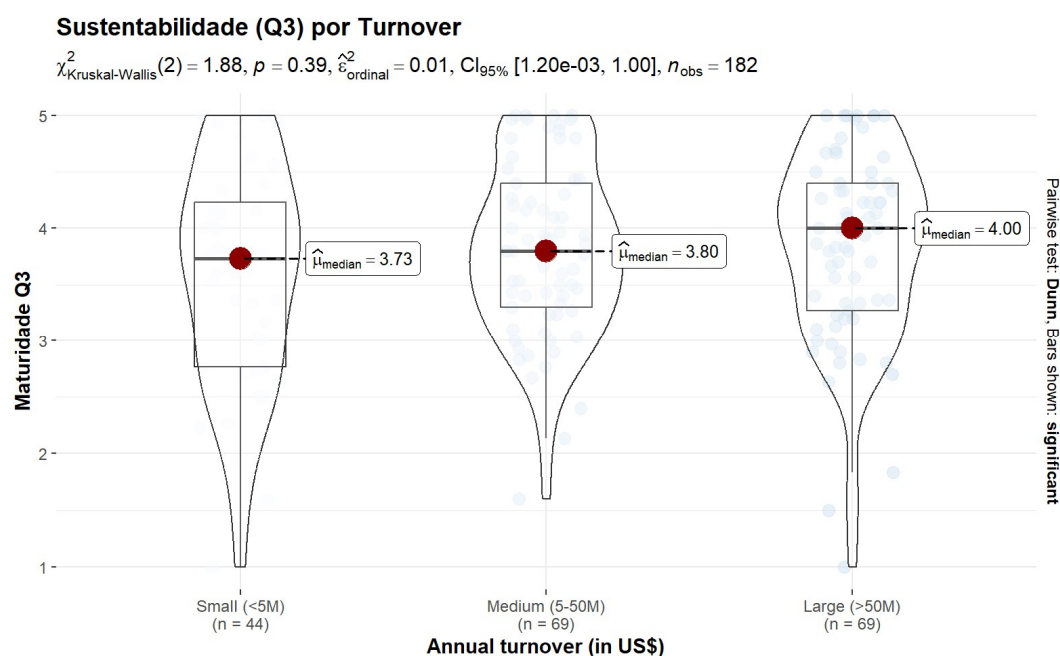


Figure 26 – Distribution of the average Sustainability Integration (Q3) scores by Annual Turnover.

This analysis makes it possible to assess whether the integration of sustainability practices and ESG commitments (Environmental, Social and Governance) is influenced by the organisation’s financial scale.

The analysis of **Figure 26** shows that the Kruskal–Wallis test does not detect statistically significant differences between the three levels of financial health ($X^2(2)=1.88, p=0.39$). The observed medians were $\tilde{\mu}=3.73$ for **Small (<5M€)**, $\tilde{\mu}=3.80$ for **Medium (5–50M€)** and $\tilde{\mu}=4.00$ for **Large (>50M€)**.

The data suggest that sustainability has become a transversal and “democratised” requirement across the business landscape, not strictly dependent on the availability of large budgets for its implementation.

Although a slight numerical increase in medians is observed as turnover rises, the absence of statistical significance reinforces that small companies can be just as mature in ESG practices as large corporations.

A greater consistency (lower dispersion) is observed in the **Large** group, indicating that companies with higher turnover tend to have more standardised sustainability processes, whereas **Small** companies show greater performance volatility.

Within the APQ Model, this pillar demonstrates that socio-environmental responsibility is now a **management capability**, not merely a consequence of financial scale.

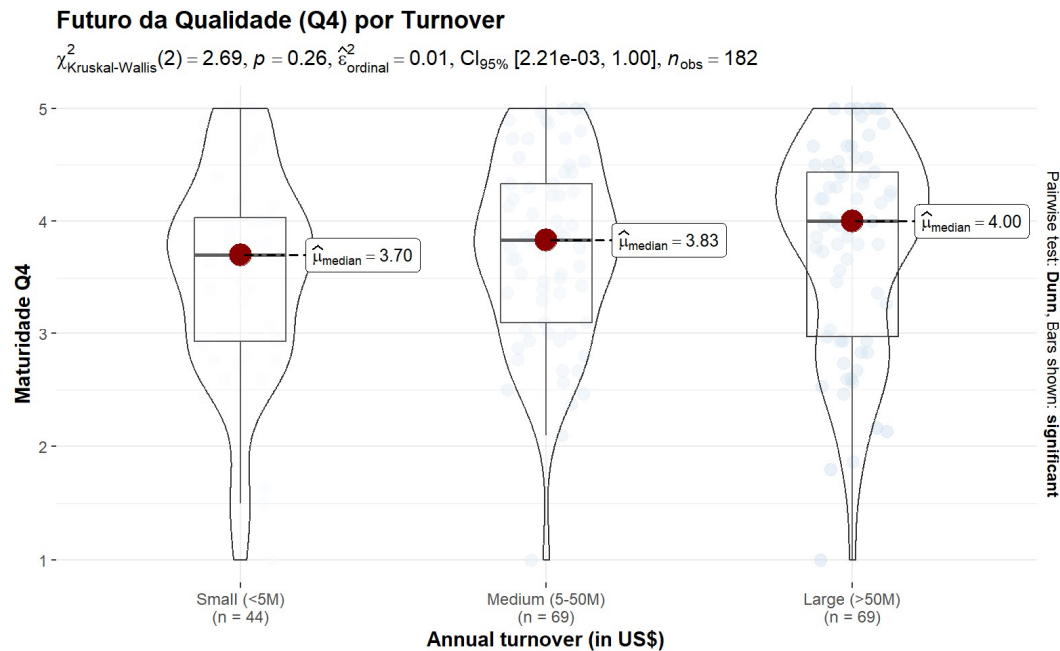


Figure 27 – Distribution of the average Future of Quality (Q4) scores by Annual Turnover.

This analysis assesses how the financial capacity of organisations (measured by annual turnover) influences their readiness for **Quality 4.0** and the adoption of emerging technologies.

The analysis of **Figure 27** shows that the Kruskal–Wallis test ($X^2(2)=2.69, p=0.26$) does not identify statistically significant differences between turnover groups regarding technological maturity. The observed medians were $\tilde{\mu}=3.70$ for **Small (<5M€)**, $\tilde{\mu}=3.83$ for **Medium (5–50M€)** and $\tilde{\mu}=4.00$ for **Large (>50M€)**.

Although the overall result is not statistically significant, a clear numerical progression in the medians is visible. The **Large (>50M€)** group is the only one to reach the 4.00 mark, suggesting that higher turnover may facilitate investment in digitalisation and AI tools.

The fact that the **Small (<5M€)** group presents a median of 3.70 indicates that micro and small enterprises are not excluded from the digital transition, managing to maintain competitive levels of technological readiness even with theoretically more limited financial resources.

Examining the violin plots, the **Large** group shows a greater concentration of responses at the top of the scale (level 5), while the **Small** group displays a longer tail extending down to level 1.0. This reinforces the idea that higher turnover acts as a “**technological floor**”, reducing the likelihood of poor digitalisation performance.

Within the APQ Model, this dimension highlights that technological maturity is increasingly a **management capability**, not merely a reflection of financial scale.

It can be argued that, with regard to the Future pillar (Q4), financial scale appears to facilitate consistency but does not constitute a barrier to excellence for smaller firms, thereby supporting the premise that Quality 4.0 is accessible to organisations with different levels of investment capacity.

Table 16 – Summary of the analysis by dimension in terms of turnover.

Dimension	Global Diagnosis	Median Trend	Strategic Conclusion
Culture (Q2)	p = 0.48 (Not significant)	Stable (3.87 → 4.07)	Culture is a resilient asset; excellence in leadership does not depend on budget size.
Sustainability (Q3)	p = 0.39 (Not significant)	Increasing (3.73 → 4.00)	ESG practices are transversal, but financial scale brings greater standardisation.
Future (Q4)	p = 0.26 (Not significant)	Ascending (3.70 → 4.00)	Capital acts as a facilitator for digitalisation and technological readiness.

In summary, annual turnover acts as a stabilising and standardising element, although it is not a statistical determinant of absolute superiority in organisational maturity. In **Culture (Q2)**, the indicator proves irrelevant, showing that excellence-driven values are transversal and independent of budget size.

In **Sustainability (Q3)** and **Future (Q4)**, despite the absence of statistical significance (p=0.39 and p=0.26, respectively), a numerical progression of medians and a drastic reduction in dispersion are observed in higher-turnover groups. This indicates that, although small companies can achieve high levels of technological readiness and ESG commitment, the financial scale of large organisations functions as a “**safety floor**”, eliminating mediocre performances and ensuring more consistent processes.

Comparison by Number of Sites

According to the distribution presented in **Table 6**, the variable referring to the number of operational units (sites) was aggregated into three categories: **Single Site (1)**, **Reduced Multi-Site (2–5)** and **High Complexity (>5)**. This methodological decision is

justified by the need to ensure the robustness of statistical tests, creating groups with balanced frequencies ($n \geq 100$).

Theoretically, this division makes it possible to analyse whether geographical dispersion imposes additional challenges on the cohesion of the **Quality Culture (Q2)** or whether, on the contrary, the need to manage multiple locations drives digitalisation and the **Future of Quality (Q4)** through remote-monitoring systems and digital standardisation.

Table 17 – Distribution of valid responses by number of sites.

Nr Sites	Single Site (1)	Multi-Site (2-5)	High Complexity (>5)
n (valid)	61	50	71

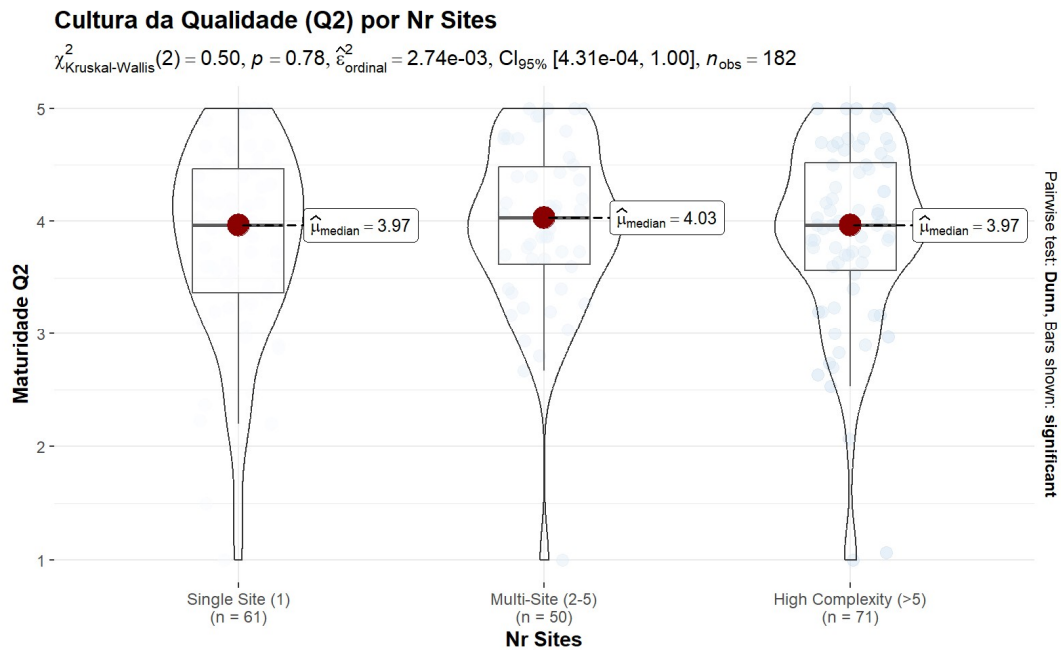


Figure 28 – Distribution of the average Quality Culture (Q2) scores by Number of Sites.

The Kruskal–Wallis test ($X^2(2)=0.50, p=0.78$) indicates that there are no statistically significant differences between organisations operating from a single site and those with high geographical dispersion (>5 sites).

It can therefore be stated that **Quality Culture is not diluted by physical expansion**. An organisation does not lose its identity or cultural cohesion when opening new units. This suggests that companies are successful in transferring their values and leadership

practices across multiple geographical contexts, maintaining a uniform standard of excellence.

The plot in **Figure 28** shows that the medians are practically identical across groups, displaying a rare level of consistency in management data: **Single Site (1): $\tilde{\mu}=3.97$** , **Multi-Site (2–5): $\tilde{\mu}=4.03$** , and **High Complexity (>5): $\tilde{\mu}=3.97$** . The variation is only **0.06 points**, reinforcing the idea that cultural maturity is a solid foundation that does not fluctuate with structural complexity.

Observing the violin plots and point density, heterogeneity is visible at the extremes: both single-site organisations and highly complex ones (>5 sites) show a long lower tail, with outliers near level 1.0. This indicates that **poor culture can exist at any scale**.

The central violin appears “shorter” at the base, revealing greater consistency in the **Multi-Site (2–5)** group. This suggests that organisations in an intermediate expansion phase tend to be more rigorous in maintaining cultural alignment to ensure that growth does not lead to loss of control.

In summary, the analysis of **Figure 28** demonstrates that **Quality Culture Maturity (Q2) is independent of operational complexity**, as measured by the number of sites ($p=0.78$). The results show that organisations maintain a high median maturity level (approximately 4.00) whether they operate in a centralised or dispersed manner. This uniformity suggests that organisational culture functions as a **resilient guiding thread**, capable of crossing physical boundaries without losing strength, supporting the premise that excellence in leadership and values is a **strategic management capability**, not a by-product of physical proximity among employees.

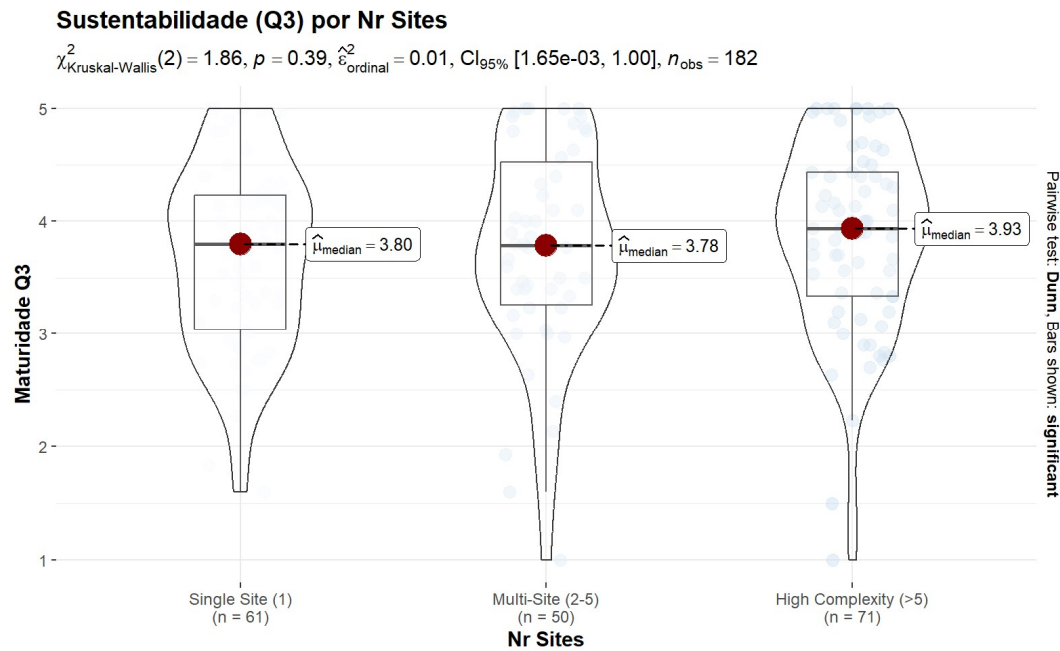


Figure 29 – Distribution of the average Sustainability Integration (Q3) scores by Number of Sites.

The Kruskal–Wallis test ($\chi^2(2)=1.86, p=0.39$) shows, as observed for **Quality Culture (Q2)**, that there are no statistically significant differences between centralised and geographically dispersed organisations.

The plot in **Figure 29** shows that the medians are very similar across groups: **Single Site (1)**: $\hat{\mu}=3.80$, **Multi-Site (2–5)**: $\hat{\mu}=3.78$, and **High Complexity (>5)**: $\hat{\mu}=3.93$. The proximity of these medians suggests that the commitment to sustainability is a centralised corporate guideline that is successfully replicated across all sites, regardless of their number. Although not statistically significant, the high-complexity group (>5 sites) presents the highest median (3.93). This may indicate that organisations operating across multiple locations face greater regulatory and social scrutiny, motivating them to strengthen their sustainability processes to ensure compliance across all fronts.

Regarding dispersion, the **High Complexity** group shows a greater density of responses at the top of the scale (levels 4 and 5), whereas **Single Site** organisations display greater variability at the lower end of the distribution. This reinforces the idea that operational complexity requires a higher minimum level of ESG maturity to manage sustainability risks effectively.

Thus, the number of operational sites is not an inhibitor of quality or sustainability. On the contrary, the data indicate that organisations with high operational complexity (>5 sites) tend to exhibit more consistent processes and slightly higher medians, suggesting that geographical dispersion acts as a driver for the implementation of more robust and standardised management systems.

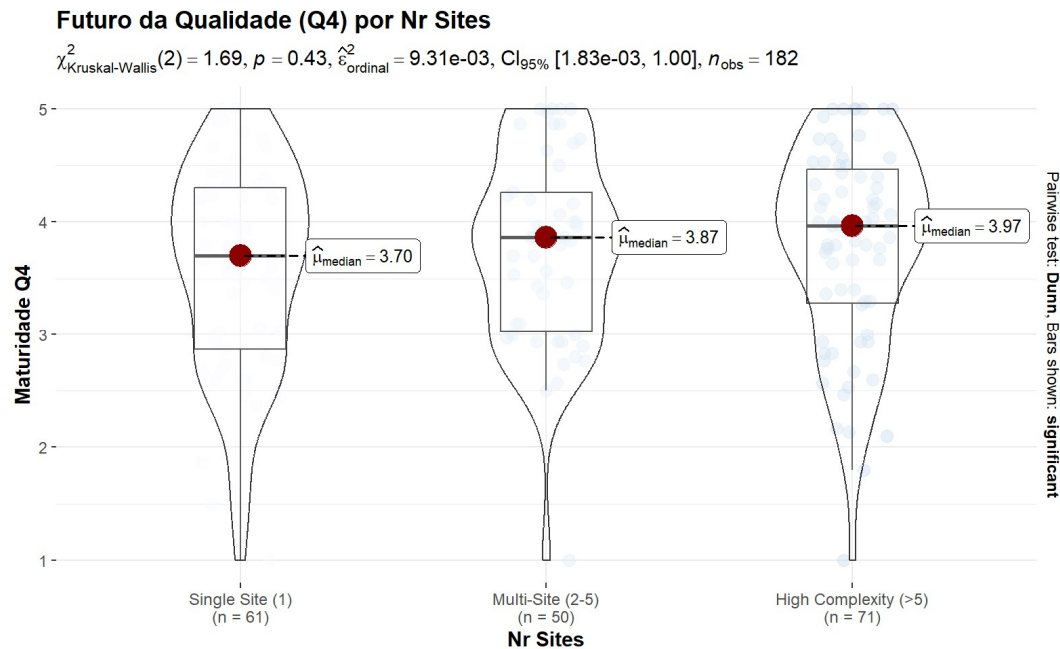


Figure 30 – Distribution of the average Future of Quality (Q4) scores by Number of Sites.

The Kruskal–Wallis test ($\chi^2(2)=1.69, p=0.43$) shows that there is no statistically significant difference between the groups. Geographical dispersion, on its own, does not guarantee a technological leap that deviates from the overall average of the sample.

The plot in **Figure 30** shows that the medians are close across the groups: **Single Site (1): $\hat{\mu}=3.70$, Multi-Site (2–5): $\hat{\mu}=3.87$, and High Complexity (>5): $\hat{\mu}=3.97$.**

Unlike **Quality Culture (Q2)** or **Sustainability (Q3)**, where values were almost flat, here the medians show a clear upward staircase. There is an increase of **0.27 points** between Single Site and High Complexity. Although the Kruskal–Wallis test indicates that this is not “statistically different” (due to internal variance within groups), the practical trend suggests that the more geographically dispersed an organisation is, the more it invests in technologies that support quality.

The group with more than five sites is the one that comes closest to the **level 4.00 (Excellence)** threshold. This reinforces the theory that **Quality 4.0**—remote monitoring, cloud-based data, systemic integration—ceases to be a “luxury” and becomes a necessary management tool for coordinating multiple geographical units.

Observing the plot, it is noticeable that in the **High Complexity (>5)** group, the base of the violin is higher. This means that, while single-site organisations may still have very low levels of digitalisation (near 1.0 or 2.0), organisations with many sites are effectively “forced” to maintain a minimum technological level in order to operate efficiently.

Overall, the analysis of **Figure 30** suggests that although the number of sites does not produce statistically significant differences ($p=0.43$), operational complexity acts as a **practical driver** of digitalisation. Organisations with multiple sites tend to adopt more advanced technological systems to ensure coordination, visibility and standardisation across their network.

Table 18 – Summary of the analysis by dimension in terms of number of sites.

Dimension	Significance Level (p-value)	Median Trend	Strategic Diagnosis
Culture (Q2)	$p = 0.78$	Stable (3.97 → 3.97)	Cultural cohesion and leadership are resilient and do not fragment with geographical dispersion.
Sustainability (Q3)	$p = 0.39$	Stable/Increasing (3.80 → 3.93)	ESG policies are transversal, with slight consolidation in high-complexity structures.
Future (Q4)	$p = 0.43$	Ascending (3.70 → 3.97)	Physical dispersion acts as a practical driver for digitalisation and the adoption of Quality 4.0.

From **Table 18**, the following conclusions can be drawn:

- **Independence from Geographical Scale:** The high p-values across all dimensions ($p>0.05$) confirm that the APQ Model is robust and applicable to different structural configurations, with dispersion not acting as a limiting factor for maturity.
- **Cultural Cohesion (Q2):** With $p=0.78$, Quality Culture emerges as the most stable pillar, indicating that leadership and values permeate the organisation even without the physical proximity associated with a single-site structure.
- **Technological Acceleration (Q4):** Although not statistically significant ($p=0.43$), the increase in the median to 3.97 in the high-complexity group suggests that technology (Quality 4.0) becomes the management tool of choice to ensure control and efficiency in decentralised operations.

Overall, this analysis shows that, in this sample, operational complexity is not a barrier but rather a context that **favours standardisation and technological modernisation**.

Comparison by ISO 9001 Certification

To assess whether holding **ISO 9001 certification** significantly influences the perception of organisational culture, leadership and commitment to quality, a **Mann–Whitney test** was conducted for two independent groups. The result, **$W = 2179.5$ with $p = 0.93$** , shows that there is no statistically significant difference between certified and non-certified companies.

This indicates that certification, in itself, is **not a predictor of a more mature quality culture** within this sample.

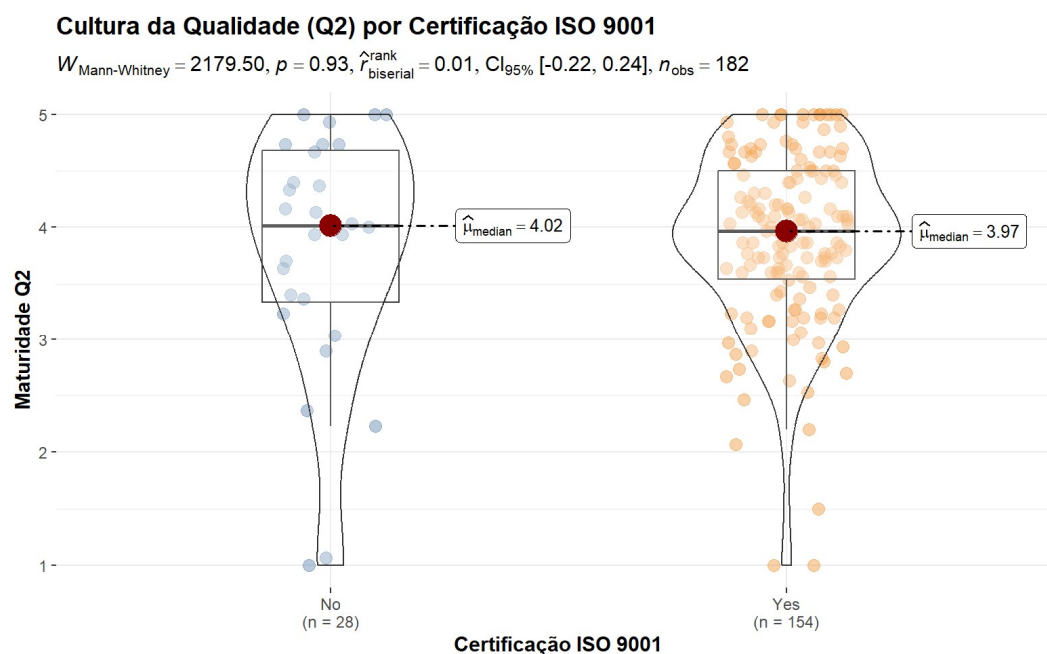


Figure 31 – Distribution of the average Quality Culture (Q2) scores by ISO 9001 Certification.

The plot in **Figure 31** shows that the medians for the two groups are: **Non-Certified (No): $\hat{\mu} = 4.02$ (n=28)** and **Certified (Yes): $\hat{\mu} = 3.97$ (n=154)**. Surprisingly, non-certified companies present a slightly higher median (although without statistical relevance due to the small comparative sample size).

The very high p-value (0.93) suggests that **Quality Culture is an intrinsic managerial asset**, independent of whether organisations are formally certified under **ISO 9001**. This may indicate that the non-certified companies in the sample already operate with high levels of rigour, possibly to meet direct customer or market requirements.

It is important to note that the vast majority of companies are certified (154 vs. 28). The high cultural maturity observed in the “No” group may reflect a **selection bias**: the few companies without ISO 9001 that chose to respond to a survey on “Excellence” are likely already highly engaged with the topic.

Additionally, the certified group (Yes) shows a **much longer tail of negative outliers** (reaching level 1.0), whereas the “No” group is more cohesive at the top. This suggests that certification does not prevent the existence of severe cultural gaps in some organisations; ISO 9001 ensures the system, but does not necessarily guarantee the lived culture across all employees.

The results indicate that ISO 9001 certification is **not a differentiating factor** in the maturity of **Quality Culture (Q2)** ($p=0.93$). Both types of organisations show high medians (around 4.00), reinforcing the idea that cultural excellence stems from consolidated leadership practices rather than formal normative compliance.

The **Mann–Whitney test**, $W = 2126.5$ with $p = 0.91$, further confirms that there is no statistically significant difference between certified and non-certified companies. Although ISO 9001 focuses on quality management, it does not automatically translate into higher sustainability maturity within this sample.

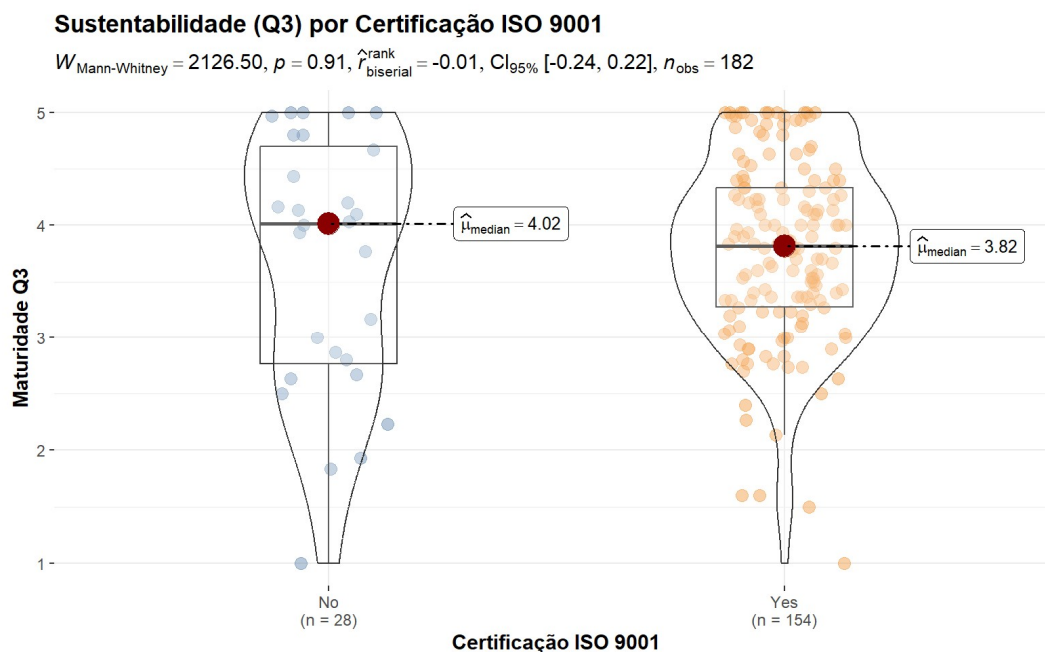


Figure 32 – Distribution of the average Sustainability Integration (Q3) scores by ISO 9001 Certification.

The plot in **Figure 32** shows that the medians for the two groups are: **Non-Certified (No):** $\tilde{\mu} = 4.02$ ($n=28$) and **Certified (Yes):** $\tilde{\mu} = 3.82$ ($n=154$). As observed for **Quality Culture**

(Q2), the small group of non-certified companies again presents a slightly higher median, reinforcing the idea that excellence in these pillars can be achieved independently of formal certification.

Once more, the extremely high p-value (0.91) demonstrates that the integration of sustainability practices is **transversal across the sample**. This suggests that the drivers of sustainability—ethical pressures, market expectations or regulatory requirements—operate independently of the formalised quality management system.

The violin plot for certified companies (Yes) in **Figure 32** shows considerable dispersion, with responses ranging from level 1.0 to 5.0. This indicates that holding ISO 9001 certification does not, by itself, guarantee a minimum sustainability standard; some certified organisations display very low maturity in this pillar.

The analysis of **Sustainability (Q3)** confirms the trend observed in organisational culture: ISO 9001 certification does **not** induce significant differences in sustainability maturity ($p=0.91$). The presence of high medians in both groups suggests that organisations are adopting ESG practices as a **core strategic capability**, regardless of the formalisation of quality management systems.

The **Mann–Whitney test**, $W = 2185.0$ with $p = 0.91$, further confirms that there is no statistically significant difference between certified and non-certified companies. Although ISO 9001 focuses on quality management, it does not automatically translate into higher sustainability maturity within this sample.

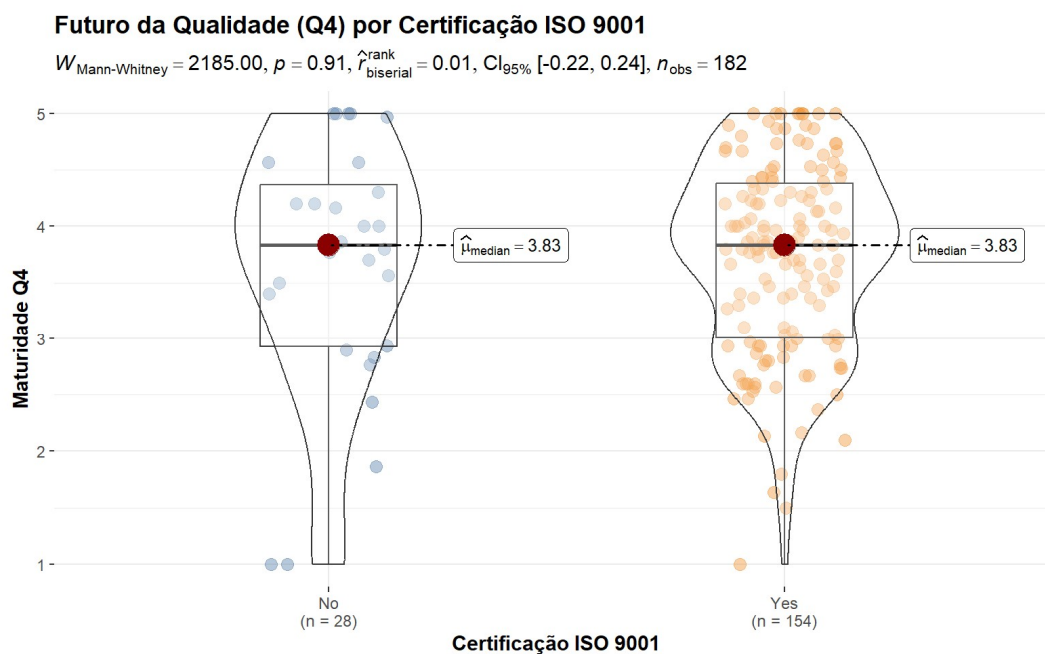


Figure 33 – Distribution of the average Future of Quality (Q4) scores by ISO 9001 Certification.

The plot in **Figure 33** shows that the medians for the two groups are: **Non-Certified (No): $\tilde{\mu} = 3.83$ (n=28)** and **Certified (Yes): $\tilde{\mu} = 3.83$ (n=154)**. The medians are *exactly identical*, indicating complete homogeneity in the central level of technological maturity across both groups.

The identical medians (3.83) suggest that **ISO 9001 certification does not act as either a catalyst or an inhibitor** for digital transition. The adoption of **Quality 4.0** technologies appears to be driven by other strategic or sector-specific factors rather than by formal compliance with the standard.

The fact that both groups show a relatively high median (close to 4.00) indicates that the overall sample already possesses a considerable level of technological maturity.

Although the medians coincide, the certified group displays **lower dispersion at the base of the violin** compared with what was observed for **Quality Culture (Q2)**, although it still includes isolated cases with very low maturity (level 1.0). This suggests that certification may contribute to reducing extreme underperformance, but it does not eliminate it entirely.

Table 19 – Summary of the analysis by dimension in terms of ISO 9001 certification.

Dimension	Certified (Yes)	Non-Certified (No)	p-value
Culture (Q2)	$\tilde{\mu} = 3.97$	$\tilde{\mu} = 4.02$	p = 0.93
Sustainability (Q3)	$\tilde{\mu} = 3.82$	$\tilde{\mu} = 4.02$	p = 0.91
Future (Q4)	$\tilde{\mu} = 3.83$	$\tilde{\mu} = 3.83$	p = 0.91

ISO 9001 certification proves to be statistically irrelevant for distinguishing the level of maturity across the pillars of the **APQ Model** ($p > 0.90$ in all cases). These results suggest that the organisations in the sample have already integrated the principles of **excellence, sustainability, and digitalisation** into their managerial core, making formal certification more of a recognition of existing practices than a competitive differentiator in terms of organisational maturity.

Final Summary and Key Conclusions

The results of the study reveal an international landscape characterised by high organisational maturity, although marked by relevant asymmetries between dimensions and groups. In the domain of **Quality Culture**, a particularly strong performance is observed in customer focus and leadership commitment, with item *q2_4_5* standing out as the most robust indicator in the entire section. The report highlights that “indicator *q2_4_5* emerges as the greatest strategic asset of the sample”, demonstrating consolidated practices in complaint handling and customer orientation. However, continuous improvement appears as the weakest area, especially in item *q2_3_4*, which presents the lowest mean and the only median equal to 3. This suggests that, despite well-established quality practices, the institutionalisation of structured methodologies such as Lean, Kaizen or Six Sigma remains limited in many organisations.

Regarding the integration between **Quality and Sustainability**, the results point to solid operational maturity, with strong performance in resource efficiency and internal sustainable practices. Nevertheless, weaknesses persist in integrating sustainability across the value chain, particularly in sustainable design and engagement with external stakeholders. These findings indicate that sustainability is often treated as a set of internal practices rather than fully incorporated as a transversal strategic axis.

In relation to the **Future of Quality**, organisations demonstrate a clear strategic vision and widespread recognition of the importance of innovation and digital transformation. However, the effective adoption of advanced technologies—such as IoT, smart connectivity and data-driven risk management systems—remains uneven. Item *q4_4_4*, associated with predictive risk management, shows the weakest performance in the section, revealing that the transition to Quality 4.0 is still at an early stage in many contexts.

The internal consistency analysis confirms the robustness of the scales used, with Cronbach’s Alpha values above 0.98 in all dimensions. Correlations between Quality Culture, Sustainability and the Future of Quality are high, ranging from 0.77 to 0.85, demonstrating that these dimensions do not operate in isolation but form an interdependent system of organisational practices and perceptions.

Comparative analyses reveal interesting patterns. Regionally, Asia presents the highest mean values across all three dimensions, while Europe shows greater heterogeneity. In terms of sector, services and healthcare emerge as the most mature, whereas education shows the lowest values. Company size, measured by number of employees, is not a determining factor, as small and large organisations display similar maturity levels. The degree of internationalisation also does not produce significant differences, although highly exporting companies show less negative variability. Turnover does not stand out

as a differentiating factor, and **ISO 9001 certification**, surprisingly, does not correlate with higher maturity levels, with the report noting that “ISO 9001 certification proves statistically irrelevant for discriminating maturity level”.

In summary, the study shows that organisations exhibit a consolidated quality culture and a reasonable integration of sustainable practices, but face challenges in institutionalising continuous improvement and adopting advanced technologies. Organisational maturity appears high and relatively homogeneous, regardless of size, sector or certification, suggesting that internal cultural and strategic factors carry more weight than structural characteristics. These results open avenues for future research focused on identifying organisational profiles, maturity models and causal relationships between the dimensions analysed.

Perspectives for Future Work

The present study has established a solid foundation regarding organisational maturity across the pillars of **Culture (Q2)**, **Sustainability (Q3)** and **Future (Q4)**. However, the absence of statistical significance in some contextual variables suggests that organisational reality is more heterogeneous than traditional categorizations (such as number of sites or turnover) are able to capture. The following lines of inquiry are therefore proposed for future exploration:

Identification of Organisational Archetypes (Cluster Analysis)

Although isolated variables do not fully discriminate maturity levels, there is potential for the existence of latent organisational profiles.

- **Objective:** Apply unsupervised learning algorithms (such as K-means or Hierarchical Clustering) to group organisations based on the combination of their scores in Q2, Q3 and Q4.
- **Added Value:** This would make it possible to identify, for example, whether a group of “*Traditional Resisters*” (low maturity across all pillars) exists in contrast to “*Digital Visionaries*” (high maturity in Q4 but potential gaps in Q2). Such segmentation would enable the creation of tailored transition roadmaps for each profile, rather than generic recommendations for the entire industrial sector.

Validation of the Causal Model (Path Analysis / SEM)

One of the theoretical questions that remains open concerns the directionality of the relationships between the pillars of the **APQ Model**.

- **Objective:** Apply Structural Equation Modelling (SEM) or Path Analysis to test whether Quality Culture (Q2) acts as a critical antecedent (mediating factor) for Sustainability (Q3) and the Future of Quality (Q4).
- **Key Question:** Can an organisation achieve excellence in **Quality 4.0 (Q4)** without first consolidating a strong culture of leadership and commitment (Q2)?
- **Added Value:** This analysis would transform the APQ Model from a diagnostic tool into a predictive strategic tool, helping managers prioritise investments (e.g., investing first in people/culture to ensure the success of subsequent technological investments).

References

- Hair, J., Black, W. C., Babin, B. J., & Anderson, R. E. (2013). *Multivariate data analysis* (PDF eBook. ed.). (P. Higher, Ed.) Pearson new international edition Ed.
- George, D., & Mallery, P. (2003). *SPSS for Windows Step by Step: A Simple Guide and Reference, 11.0 Update*. Allyn and Bacon.
- R Core Team. (2025). R: A Language and Environment for Statistical Computing. *R Foundation for Statistical Computing*. Vienna, Austria. Obtido de <https://www.R-project.org/>
- Wickham, H., & Wickham, M. (2019). Package tidyverse. Easily install and load the 'Tidyverse.
- Xie, Y. (2017). Dynamic Documents with R and knitr. Chapman and Hall/CRC.

