

Digitalisation and Innovation in the Largest Czech Family Businesses: Innovative Behaviour and Generational Decision-Making

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Abstract: Digital technologies open up new possibilities and opportunities for family businesses to innovate and grow. They change the way companies think and implement innovation. Digital innovation supports new products, processes, and business models, and changes innovation processes. Family businesses in the Czech Republic are managed by the founding generation or the first generation of successors and are active in traditional industries. Research on Czech family businesses in the field of innovation is minimal. The innovation activities of companies operating in the Czech Republic are monitored by the statistical office according to the Oslo Manual methodology, without a focus on family businesses, including findings related to digital technologies and innovation. The aim of this paper is to determine how digital technologies are changing innovative behaviour and generational decision-making in the field of innovation in family businesses. To this end, a questionnaire survey was conducted on a research sample of 200 of the largest Czech family businesses. This ranking of family businesses is determined by Forbes based on selected financial indicators and specific characteristics related to family ownership. The results of the questionnaire survey made it possible to answer the following research questions: What digital tools are used in the innovation process? How does the introduction of digital technologies influence the implementation of certain types of innovation? How do the attitudes of the founding generation and the successor generation towards digital transformation differ? What are the main barriers to the introduction of digital technologies in family businesses operating in traditional industries? The questionnaire is evaluated using descriptive statistics. At the same time, cluster analysis, Ward's technique with Euclidean distance, is applied, which allows the research sample of the largest family businesses to be divided into groups based on criteria related to innovation behaviour and generational decision-making. Family businesses must transform to survive and grow, because the skills and approaches needed to implement innovation and thus grow the business today are very different from those needed by previous generations.

Keywords: Digital Transformation, Digital Innovation, Family Business, Innovative Behaviour, Generational Decision-making, Cluster Analysis

1. Introduction

Modern technologies open up new possibilities and opportunities for family businesses to innovate and grow. However, innovation is not just about implementing new technologies, but also about changing the ways in which a company thinks about and implements innovation (Hinings et al., 2018). In the digital age, innovation refers to new products, processes, or business models enabled by digital technologies or embedded in data and software (OECD, 2019). According to Bornhausen and Wulf (2024), digital innovations are riskier than conventional innovations due to their complexity, rapid pace, and generational perception.

Digital capabilities and investments in innovation, research, and development are among the key priorities for family businesses in Central and Eastern Europe (PwC CEE, 2024). At the same time, Filep et al. (2023) point out the existing differences between the characteristics of family businesses in Western Europe and those in Central and Eastern Europe due to differing economic and historical developments, while also noting that research on family businesses in Central and Eastern Europe is minimal.

There is no official database of family-owned businesses in the Czech Republic. Innovation activities carried out by companies in the Czech Republic are tracked by the Czech Statistical Office using the methodology of the Oslo Manual (2018), without a specific focus on family-owned businesses. The latest report by the Czech Statistical Office on innovation activities in the Czech Republic for 2020–2022 also lacks findings related to technology use and digitalisation.

According to the concept of socio-emotional wealth (SEW), decision-making regarding innovation is based not only on financial indicators but also on the desire to maintain control, family identity, and continuity across

generations (Berrone et al., 2012). In this context, digitalisation can be perceived as a threat, as it requires openness to external knowledge and disrupts the established hierarchy in decision-making (López-Muñoz et al., 2025).

This paper aims to address gaps in research on family businesses, particularly in the areas of innovation behaviour and digitalisation, using a sample of the 200 largest Czech family businesses according to the Forbes ranking. It seeks to analyse innovation behaviour and the impact of digital tools on innovation behaviour in large family businesses, including an examination of the attitudes of founders and their successors. To this end, a questionnaire survey was conducted, and the results were evaluated using descriptive statistics. At the same time, cluster analysis was applied to define a typology of companies based on their approach to innovation, digitalisation, and financing.

2. Literature Review

Filep et al. (2023) highlighted the existing differences between the characteristics of family businesses in Western Europe and those in Central and Eastern Europe. A defining characteristic of these businesses is their age, which is around 30 years. For the most part, they are managed by the founding generation or the first generation of successors. They focus primarily on long-term goals and sustainability. They predominantly represent the small and medium-sized enterprise sector. A significant portion of family businesses are active in traditional industries. However, the level of innovation is lower than in Western Europe.

According to a PwC CEE study (2024), 64% of family businesses in Central and Eastern Europe—including the Czech Republic—are owned by the first generation, while 36% have been passed on to the second or subsequent generations. This is also confirmed by a survey by AMSP ČR (2024), which found that the largest share of family businesses is owned by their founders, though this applies primarily to the smallest firms. A survey by MSP ČR (2024) indicates that the largest proportion of family businesses are established as limited liability companies (68%), with a quarter operating as self-employed individuals. Kljucnikov et al. (2021) report that limited liability companies perform better in terms of local innovation than other firms structured under different legal forms. In two-thirds of firms with multiple owners, direct ownership by family members predominates, while just under one-fifth are structured as family funds.

Large family businesses are less innovative than non-family businesses because they seek to keep ownership and control in the hands of family members, which leads to a reluctance to take risks and invest in the uncertain outcomes of science and research. A company's innovativeness is examined from various perspectives. According to Steinerowska-Streb and Wziątek-Stasko (2020), the innovative capacity of family firms is determined by the continuous development of knowledge among owner-managers. Family firms whose owner-managers continuously expand their knowledge introduce significantly more product and marketing innovations. According to Urbaníková et al. (2020), there is a statistically significant relationship between company size, the generation managing the company, and the number of types of innovations introduced. They point out that second-generation family businesses can therefore be considered more innovative than first-generation family businesses. Uhlaner et al. (2026) highlight the link between social capital and product innovation as applied to small and medium-sized enterprises. Skrbková and Rydvalová (2026) examine how size, age/generation, and family ownership—both individually and in combination—influence the innovativeness of family businesses. It was found that medium and large family businesses are perceived by potential successors as more innovative than small businesses. Folvarcná et al. (2020) concluded that there is a relationship between succession in family firms and the selection of various sources of invention and financing for innovation activities. The greatest effects in implementing innovations are achieved through intergenerational collaboration.

According to a PwC CEE study (2024), family businesses in Central and Eastern Europe intend to focus over the next two years on innovation and digital transformation, new sources of revenue, and adapting to changing customer preferences. An OECD study (2019) defines digital innovation as new products, processes, or business models enabled by digital technologies or embedded in data and software. At the same time, innovation processes are changing thanks to the use of AI-based analytics and other digital technologies. Tutar et al. (2024) highlight the importance of digital innovations in managing uncertainty in family businesses through new organisational structures and business models based on digital innovations.

According to a PwC CEE study (2024), NextGen sees its role primarily in modernizing management structures and driving digital transformation. They aim to shift companies from intuitive management to more professional processes. While founders often focus on survival and continuity, NextGen views the transformation of the company through technology as essential for remaining competitive in the digital era. Similarly, the authors

Worek et al. (2025) examined the challenges family businesses face in adopting and implementing technology. They point out that family businesses often adopt technology slowly due to concentrated ownership, risk aversion, and a focus on non-financial goals.

Mikušová and Stanovská (2025) found that the approach to digitalisation among historically young family businesses does not differ significantly from the attitudes of owners in countries with a long history of family businesses. They also identified several groups of barriers to digitalisation: resources, change, data security, and employees.

3. Methodology

The methodological framework describes the research process and the methods used to analyse the data.

3.1 Methodology for Selecting the Research Sample and Conducting the Survey

The research sample was set by a purposive selection from the list of the 200 largest Czech family-owned companies featured in Forbes magazine (2025). The ranking has been published since 2021 and is compiled based on average values over the last three years for key indicators, namely revenue, EBITDA, and the number of employees. The original database of 200 companies was verified through an analysis of the public registry, focusing on the consistency of the surnames of statutory representatives and owners. After excluding 19 entities (failure to meet the definition, mergers), the initial sample consisted of 181 companies.

Data collection was conducted electronically using Google Forms via a structured questionnaire divided into an identification section, innovation behaviour and decision-making across generations, and the status of digitalisation and digital transformation. The questionnaire contained 26 questions (dichotomous and polytomous questions with single or multiple-choice options). A total of 181 companies were contacted, and 90 completed questionnaires were received, resulting in a response rate of approximately 50%. Structure of the research sample (n = 90) highlighting the most significant weights only:

- Organisational structure: single business entity (72.2%), holding company (27.8%).
- Management: joint founder and successor (43.3%), exclusively second generation (32.2%), formal transfer of authority from the first to the second generation while maintaining the founder's influence (11.11%), founder-led management (7.78%), third-generation management (3.33%), transition from second to third generation (2.22%).
- Size by No. of employees: 250–499 employees (30.0%), 100–199 employees (21.1%), companies with 200 to 249 employees (13.33%) and those of 500 to 999 employees (13.33%).
- Revenue: over CZK 1 billion (56.7%), CZK 0,5–1 billion (28.9%), and CZK 0,1–0,5 billion (14.44%).
- Economic activity (CZ-NACE): manufacturing (48.9%), wholesale and retail trade, including repair of motor vehicles (16.7%), construction (14.4%), professional, scientific, and technical activities (4.44%), and others.
- Legal form: joint-stock company (48.89%), limited liability company (47.78%), other (3.33%).

Research questions: Q1: What digital tools are used in the innovation process? Q2: How does the adoption of digital technologies affect the implementation of certain types of innovations? Q3: How do the attitudes of the founding generation and the succeeding generation toward digital transformation differ? Q4: What are the main barriers to the adoption of digital technologies in family-owned businesses operating in traditional industries?

3.2 Cluster Analysis Method

Cluster analysis was performed using the Jamovi software program v2.7, which is designed for statistical data analysis. The cluster analysis was conducted in the following steps:

- **Data preparation and standardisation:** The Likert scale items were transformed into 8 composite variables (arithmetic means in seven cases and a sum in one case) covering innovation barriers (average barriers: overall intensity of perceived innovation barriers, abbreviated as **BARR** in the tables), financing dimensions (1. internal: own resources and family contributions, **INT**; 2. market: banking/loan products, external investors, and customer financing, **MKT**; 3. subsidies, **SUB**), digital technologies (operational and production technologies: automation, ERP/CRM, IoT, **TECH**; digital business and data infrastructure: artificial intelligence, cloud solutions, e-commerce, **DBI**; security

and sustainability: cybersecurity and energy-efficient technologies, **SUST**) and the digitalisation index (the sum of areas in which the company implements digital innovations, **DIX**). Due to differing scales, the data was standardized to z-scores, using the formula $z = \frac{x-\mu}{\sigma}$, where x = raw score, μ = mean and σ = standard deviation.

- **Hierarchical cluster analysis:** Ward's method (Ward, 1963; Henning et al., 2015) was used to determine the optimal number of clusters, including interpretation of the dendrogram and analysis of the increase in the linkage distance.
- **Non-hierarchical cluster analysis:** Application of the K-means method using the Hartigan–Wong algorithm. To eliminate sensitivity to initial conditions and find the global optimum, 50 random iterations were performed.
- **Validation:** The quality of the clustering was verified using an analysis of variance (the ratio of between-cluster to within-cluster sums of squares, ANOVA), testing the significance of differences between clusters.
- **Characteristics of typological groups:** Calculation of centroids for individual clusters and subsequent description of typological groups based on attitudes toward innovation, digitalisation, and financing.

4. Results

The results of the questionnaire survey are presented using descriptive statistics, and the results of the cluster analysis performed using Jamovi software are supported by calculations and accompanied by commentary.

4.1 Innovation and Digitalisation in Family Businesses – Interpretation of Questionnaire Survey Results

The survey revealed that innovation is an integral part of the philosophy and values of family businesses. As many as 63.33% of respondents agreed with this statement. The primary strategic benefit of implemented innovations is most often seen in expansion and the development of new opportunities (26.67%). The primary responsibility for initiating and implementing innovations most often lies with the successor generation (30.00%), followed by family management (25.56%) and the founder or owner (17.78%). The level of agreement between the founding and successor generations regarding the need to innovate is high, at 58.89%.

In terms of the type of innovation activities, innovations in internal business processes are implemented most frequently (46.67%), followed by product innovations (43.33%). Marketing and organisational innovations are implemented the least. The nature of the innovations implemented is predominantly incremental, accounting for 76.67% of family businesses, while radical innovations are implemented by only 23.33% of family businesses. The share of turnover invested in innovation most often ranges from 4% to 10% of turnover (46.67%).

A significant barrier (rating scale 3) to implementing innovative activities is considered to be the shortage of qualified personnel (42.2%) and the administrative complexity and lack of clarity surrounding grant programs (30.00%). Financial constraints (37.78%) and a conservative approach and the desire to maintain best practices (38.89%), prioritizing long-term survival and family values over risky innovations (37.78%), and a lack of knowledge of the market or technologies (40.00%) are considered moderately strong barriers (rating scale 2). The weakest barriers (value scale 1) are the fear of losing family influence due to the entry of external partners or investors (41.11%) and differing views among family members regarding risk and the direction of innovation (48.89%). The data are presented in Figure 1 as follows.

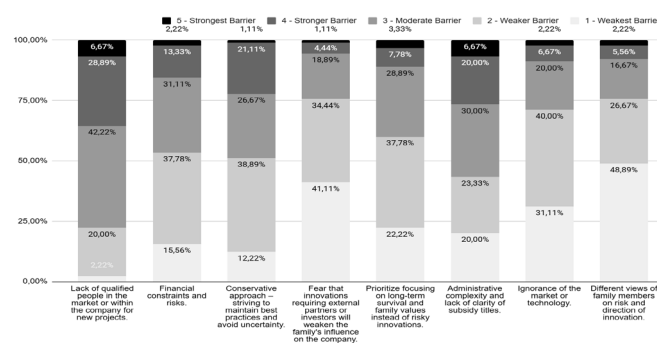


Figure 1: Distribution of Barrier Weights

Innovations are primarily financed from internal sources. The most common responses are on the rating scale of 4 (33.33%) and 3 (30.00%). Financing innovations through banking products is rated at levels 3 and 4 on the scale, each accounting for 30.00%. The use of grants as a source of innovation financing is relatively limited. The highest share was recorded at level 2 (36.67%). Deposits or loans from family members play a minor role in financing innovation, and assistance from external investors or external non-family creditors is also used minimally. Deposits or payments from customers also represent a marginal source of innovation financing.

The primary significance of digitalisation for family businesses is most often seen in operational efficiency and the automation of existing activities (58.89%). This is followed by strategic development and changes to the business model (16.67%) and changes to the company's innovative DNA as a means of ensuring the long-term survival of the family legacy (11.11%). The current level of digitalisation among companies is relatively high. The most common response is a situation where most key processes are digitally managed and data is shared (51.11%). Another 20.00% report the use of advanced technologies to manage the entire company, and 16.67% report the presence of standard digital tools without full system integration. The sample is thus characterized by a relatively high, yet varying, degree of digital maturity.

For the next three years, the most strongly emphasized digital priorities (rating scale 5) include ERP/CRM enterprise information systems (52.22%) and cybersecurity (45.56%), automation and robotics (34.44%), cloud solutions (34.44%), e-commerce and digital sales channels (27.78%), artificial intelligence and machine learning (38.89%), and sustainable and energy-efficient technologies (35.56%). The Internet of Things is most frequently rated with a medium score of 3 (33.33%).

In the area of digital innovation, companies most frequently digitize internal processes (83.3%), making this area the clear dominant domain of digital transformation. Digital communication and collaboration were cited by 55.6% of respondents, digital manufacturing and operations by 50.0%, digital security also by 50.0%, and digital commerce and marketing by 43.3%. The highly specialized area of business forecasting or failure prediction appeared only once (1.1%).

The founding generation's attitude toward the adoption of new digital technologies is predominantly positive, with the most common responses falling on a rating of 4, accounting for 37.78%. The successor generation's attitude is significantly more open. The most common responses fall on a rating of 5, accounting for 60.00%. The primary source of digital know-how is most often the successor generation (54.44%), followed by younger non-family employees (13.33%) and founders who are actively educating themselves in the digital field (13.33%).

The most common impact of digitalisation on a company's ability to innovate is an increase in efficiency and capacity for implementing innovations (37.78%), followed by improved data-driven decision-making (25.56%). A smaller group of respondents (15.56%) views digitalisation primarily as a tool for maintaining operations, without any significant direct impact on the company's ability to innovate.

4.2 Hierarchical Cluster Analysis

A hierarchical cluster analysis was conducted to identify typological groups of family businesses. The analysis was based on eight aggregated variables (z-scores) representing key areas of digitalisation, financing, and perceived barriers to innovation. A total of 90 family businesses were analysed. The Euclidean metric was used to calculate distances, and Ward's method (Ward.D2) was selected as the clustering method. Based on the dendrogram analysis (Figure 2) and the analysis of the increase in linkage distance (breakpoint at level 10), a solution with four clusters was selected.

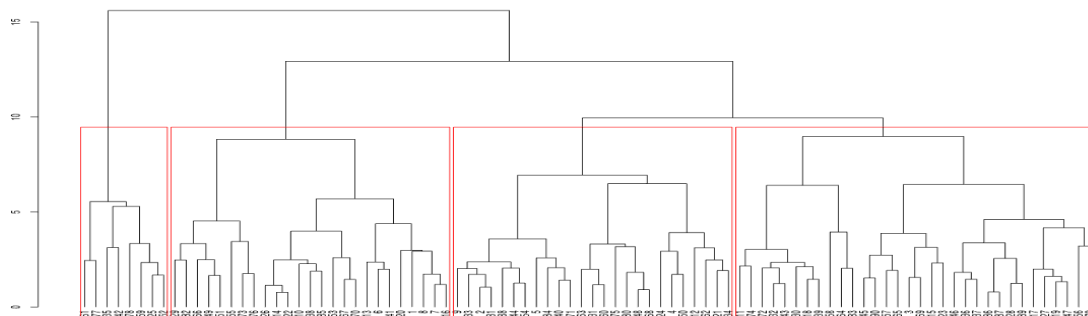


Figure 2: Dendrogram

This classification exhibits optimal internal homogeneity and a balanced structure ($n = 25, 25, 32$, and 8), which better reflects the heterogeneity of the sample than a model with higher aggregation. This result confirms that family businesses in the sample under study do not form a homogeneous group but can be classified into several systematically distinct types. Alternative models incorporating additional variables (attitudes, management, and innovative behaviour) exhibited lower stability and poorer interpretability (dominance of a single cluster). The original specification was therefore retained for the final segmentation, while the additional variables are used for subsequent cluster profiling.

4.3 Non-hierarchical Cluster Analysis (K-means)

The results of the hierarchical procedure were followed by a non-hierarchical K-means analysis (the Hartigan–Wong algorithm) with the aim of refining the classification of 90 companies. Eight standardized variables (z-scores) covering the dimensions of digitalisation, financing, and barriers were included in the model. Based on prior testing, the solution was fixed for $k = 4$. To eliminate the influence of the initial configuration of the centroids, 50 random initialisations were used, from which the solution with the lowest intra-cluster variability was selected. The resulting model explains 41% of the total variability (292.4 out of a total of 712.1 in between-cluster variability); see Table 1.

Table 1: Sum of squares

Clusters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Between Clusters	Total
Value	124.4	53.7	112.4	129.2	292.4	712.1

The companies were divided into four relatively balanced groups ($n=23, 29, 27, 31$). Three clusters are of comparable size, while one cluster is significantly smaller.

Cluster 2 ($n = 9$) identifies a minority segment with unique characteristics. The interpretation and profiling of individual types of family businesses were conducted based on centroid analysis (Table 2) and a profile graph (Figure 3), which confirm qualitative differences in the companies' approaches to innovation and digitalisation.

Table 2: Centroids of clusters

Cluster #	DIX	SUST	DBI	TECH	SUB	MKT	INT	BARR
1	0.128	-0.089	0.882	-0.103	-0.405	-0.144	0.733	-0.773
2	-0.552	1.401	1.383	1.551	0.547	2.130	0.860	0.613
3	-0.580	-0.344	-0.601	-0.853	-0.781	-0.437	-0.209	0.590
4	0.572	-0.048	-0.525	0.370	0.823	-0.131	-0.613	-0.118

The Cluster Profiles plot provides a visual representation of centroid values across individual variables. The graph shows that individual clusters have specific combinations of high and low values across the various dimensions. The identified clusters are not only quantitatively distinct but also differ qualitatively in their approach to innovation, digitalisation, and financing.

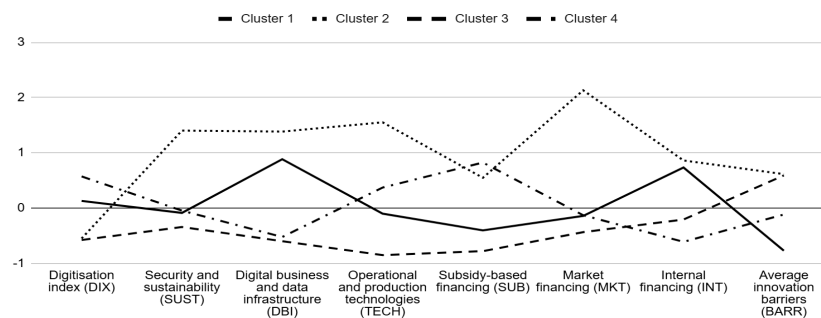


Figure 3: Cluster Profiles plot

Based on a centroid analysis, four distinct types of family businesses were identified, differing in their combination of digitalisation levels, methods of financing innovation, and perceived barriers.

Cluster 1 (n=23): The group of family-owned companies exhibits a high level of digital infrastructure (0.88) and a strong reliance on internal financing (0.73). Minimal perceived barriers (−0.77), combined with slightly above-average overall digitalisation, indicate the ability to implement innovation processes smoothly and autonomously without the need for external resources.

Cluster 2 (n=9): This smallest segment comprises the most technologically advanced companies, with the highest scores in both infrastructure (1.38) and operational technologies (1.55). A key feature is the intensive combination of market-based (2.13), grant-based, and internal financing. Higher perceived barriers (0.61) likely reflect the high complexity and risks of cutting-edge technology projects.

Cluster 3 (n=27): A typical characteristic is overall below-average digital and technological performance across all dimensions (index −0.58), accompanied by low utilisation of all forms of financing. Above-average perceived barriers (0.59), combined with investment passivity, indicate a defensive strategy and the existence of significant structural constraints.

Cluster 4 (n=31): Companies with the highest overall level of digitalisation (0.57), which is, however, closely linked to the use of grant programs (0.82) amid a shortage of internal resources (−0.61). The digitalisation strategy is selective—focused more on operational technologies (0.37) than on comprehensive data infrastructure (−0.52).

4.4 Testing the Statistical Significance of Differences Between Identified Clusters

The statistical significance of the differences between clusters was verified using one-way analysis of variance. The results (see Table 3) confirmed highly significant differences ($p < 0.001$) for all eight variables. The key differentiating factors are, in particular, digital infrastructure ($F = 43.02$), market financing ($F = 32.22$), and operational technology ($F = 30.44$).

Table 3: One-Way ANOVA (Fisher's)

	DIX	SUST	DBI	TECH	SUB	MKT	INT	BARR
F	9.58	8.88	43.02	30.44	28.08	32.22	15.88	12.49
df1	3	3	3	3	3	3	3	3
df2	86	86	86	86	86	86	86	86
p	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001

Despite local violations of homogeneity of variances in some dimensions—such as digital business and data infrastructure, internal financing, and protection and sustainability (Levene's test, $p < 0.05$)—the ANOVA results can be considered robust given the balance of the sample and the high level of significance; see Table 4.

Table 4: Homogeneity of variances test (Levene's)

	DIX	SUST	DBI	TECH	SUB	MKT	INT	BARR
F	0.784	2.994	3.486	1.148	0.752	1.673	3.509	2.713
df1	3	3	3	3	3	3	3	3
df2	86	86	86	86	86	86	86	86
p	0.506	0.035	0.019	0.334	0.524	0.179	0.019	0.050

Descriptive statistics (see Table 5) confirm the cluster profiles: Cluster 4 exhibits the highest level of digitalisation ($M = 0.57$), while Clusters 2 and 3 are well below average ($M = -0.55$; -0.58). The relatively low standard deviation within the groups demonstrates their internal homogeneity and confirms the practical usefulness of the identified typology for distinguishing between companies' technological and financial strategies.

Table 5: Group descriptives

	Cluster	N	Mean	SD	SE
Digitalisation index (DIX)	1	23	0.1278	0.893	0.1862
	2	9	-0.5522	0.598	0.1995
	3	27	-0.5796	0.846	0.1629
	4	31	0.5719	0.963	0.1729
Security and sustainability (SUST)	1	23	-0.0887	1.054	0.2198
	2	9	1.4011	1.135	0.3784
	3	27	-0.3437	0.692	0.1332
	4	31	-0.0477	0.835	0.1499
Digital business and data infrastructure (DBI)	1	23	0.8822	0.839	0.1749
	2	9	1.3833	0.760	0.2533
	3	27	-0.6011	0.559	0.1075
	4	31	-0.5248	0.496	0.0891
Operational and production technologies (TECH)	1	23	-0.1026	0.732	0.1526
	2	9	1.5511	0.958	0.3194
	3	27	-0.8526	0.668	0.1286
	4	31	0.3703	0.642	0.1153
Subsidy-based financing (SUB)	1	23	-0.4052	0.633	0.1321
	2	9	0.5467	0.892	0.2973
	3	27	-0.7815	0.644	0.1239
	4	31	0.8232	0.794	0.1426
Market financing (MKT)	1	23	-0.1439	0.764	0.1594
	2	9	2.1300	0.958	0.3192
	3	27	-0.4367	0.619	0.1191

	Cluster	N	Mean	SD	SE
	4	31	-0.1313	0.623	0.1119
Internal financing (INT)	1	23	0.7326	0.909	0.1896
	2	9	0.8600	1.302	0.4339
	3	27	-0.2085	0.704	0.1354
	4	31	-0.6126	0.654	0.1174
Average innovation barriers (BARR)	1	23	-0.7735	0.833	0.1737
	2	9	0.6133	0.400	0.1332
	3	27	0.5900	1.038	0.1998
	4	31	-0.1181	0.761	0.1366

5. Conclusion

The results of the questionnaire survey showed that internal management and operational tools, particularly ERP and CRM systems, play a significant role in the innovation processes of the companies studied (research question Q1). The implementation of technologies primarily supports process-based and incremental innovation (research question Q2). At the same time, it was found that the founding and successor generations view digital transformation positively, but with varying degrees of enthusiasm (research question Q3). The main barriers to the adoption of digital technologies include a shortage of qualified personnel, a lack of best practices, long-term survival concerns, and financial constraints (research question Q4).

The results of the cluster analysis revealed the existence of four distinct groups of family businesses, which differ primarily in terms of their level of digitalisation, technological maturity, and access to innovation financing. These differences were further statistically confirmed using analysis of variance (ANOVA).

Ethics Declaration

Ethical approval was not required for this study since the study relied solely on anonymised data.

AI Declaration

In preparing this manuscript, the authors used artificial intelligence (AI) tools to support selected research and writing tasks. Relay.app was used during data collection for automated web scraping (to construct the sample of Czech family firms based on Forbes rankings) and for generating survey invitations via Google Forms. ChatGPT (5.X Plus) supported language editing, proofreading, and methodological descriptions. AI was used only for operational and editorial support and did not generate data or perform analysis or interpretation. All AI outputs were reviewed and verified by the authors, who retain full responsibility for the study design, data collection, analysis, interpretation, and final content of the manuscript.

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