Quantifying Innovation ROI: A Copula-Based Analysis of Hungarian Enterprises' Financial Performance

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Abstract

Investing in innovation is crucial for sustained growth and competitiveness in medium and large enterprises, yet quantifying its financial returns is challenging. This research examines the impact of innovation-related spending on the economic performance of Hungarian businesses from 2010 to 2020. It introduces a novel method to analyse how these investments affect Free Cash Flow to the Firm (FCFF) and proposes a unique approach to estimating the return on investment (ROI) for innovation activities. The copula methodology compares traditional assessments and models that reveal complex dependencies among financial variables. By analysing a comprehensive dataset of corporate balance sheets, this paper provides insights and strategies for effective financial management. The results suggest that strategically modelled innovation investments can enhance long-term economic success and offer better predictive capabilities than traditional methods.

Keywords*:* investment, innovation, free cash flow

JEL codes: C58, E22, G31, O32

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Introduction

Introduction and rationale

Innovation has long been recognised as a cornerstone of economic growth, competitiveness, and long-term corporate viability. In an economy that is becoming increasingly dynamic on a global scale, the capacity for innovation enables nations to adapt to rapid technological shifts, address pressing environmental challenges, and sustain economic expansion. As Angyal and Vajai (2022) have observed, innovation plays a critical role in enhancing the profitability and competitiveness of enterprises, including those in the agricultural sector. However, it is emphasised that the mere acquisition of assets is insufficient to ensure short- or medium-term profitability; instead, success requires a qualitative understanding of the factors driving financial performance.

Hungary's innovation imperative is closely tied to its transition from a centrally planned to a market-driven economy. This transformation has necessitated the development of new competencies, significant investment in modern technologies, and the establishment of a robust innovation ecosystem. (Domazet et al., 2024; Inzelt, 2002) As Lengyel and Leydesdorff (2015) observe, the transition has precipitated structural transformations in the nation's economic and institutional infrastructures, thereby impacting the scope and character of innovation endeavours.

Government policies, funding schemes, and strategic partnerships with industry and academia have been pivotal in fostering innovation in Hungary. Specifically, targeted initiatives such as the JEREMIE programme were conceived to stimulate venture capital investment, with a particular emphasis on early-stage, technology-oriented enterprises. While such schemes have supported specific high-potential projects, their overall impact has been mixed, constrained by factors such as administrative complexity, a limited pool of high-quality proposals, and relatively low risk appetite among potential recipients. (Becsky-Nagy & Fazekas, 2024)

Despite these challenges, investment in innovation remains essential to enhancing Hungary's competitiveness, especially in knowledge-intensive and high-tech sectors. Nevertheless, evaluating such investments remains challenging, as it requires capturing both tangible and intangible outcomes to facilitate effective decision-making and evaluation.

Aims and objectives of the study

The present study aims to expand the methodological framework for assessing the financial impacts of innovation investment in Hungarian enterprises. Building on prior research, the present study proposes a novel statistical approach, underpinned by a copula-based model, to elucidate the intricate, non-linear relationships governing the interplay between innovation expenditure and financial performance in medium- and large-sized firms.

The overarching objective of the research is threefold:

- The objective is to identify and evaluate the key criteria for innovation investment success in the Hungarian context, taking into consideration the institutional, sectoral and organisational dimensions.
- To understand how performance drivers differ between high-tech industries and traditional sectors, it is necessary to examine sector-specific innovation dynamics.
- It is imperative to furnish policymakers and managers with evidence-based recommendations to enhance the effectiveness of innovation investments and optimise long-term returns.

The present study seeks to offer a nuanced understanding of how Hungarian firms can align innovation strategies with financial sustainability by integrating empirical analysis with theoretical insights. This approach contributes to the broader discourse on innovation measurement and management in transitional economies.

1. Literature review

1.1. Defining innovation and its types

The concept of innovation is broad and multifaceted. According to the Oslo Manual (OECD & Eurostat, 2018), innovation is defined as the implementation of a new or significantly improved product, process, marketing method, or organisational practice within an enterprise. This definition encompasses both technological and non-technological forms of innovation, thereby highlighting the diverse pathways through which organisations can create value.

As Schumpeter (1993) and Fagerberg et al. (2009) have previously asserted, innovation is defined as the commercial application of novel concepts, representing a process that facilitates the conversion of knowledge and creativity into marketable outcomes. Within this framework, innovation is not confined to radical breakthroughs but also encompasses incremental improvements that, when aggregated, result in cumulative performance enhancements.

Innovation can be classified in various ways, most commonly by its degree of novelty and its object of change:

- **Incremental vs. Radical Innovation:** Incremental innovation is defined as the process of making gradual, continuous improvements to existing products, services, or processes, often building on existing capabilities. Conversely, radical innovation introduces fundamentally new concepts with the potential to disrupt existing markets and generate entirely new industries (Garcia & Calantone, 2002).
- **Product vs. Process Innovation:** Product innovation is defined as the introduction of new goods or services, or significant enhancements to existing ones, in terms of their attributes or intended applications. The term ‚process

innovation' is defined by the Organisation for Economic Cooperation and Development and the European Statistical Office (OECD & Eurostat, 2018) as the implementation of novel or substantially enhanced manufacturing or delivery techniques.

- **Organisational and Marketing Innovation:** These non-technological innovations encompass modifications in business practices, workplace organisation, external relations, and the adoption of novel marketing strategies.

Research conducted in Hungary (Angyal & Vajai, 2024; Török et al., 2019) has emphasised the importance of identifying innovation patterns unique to a specific sector. Whilst high-tech industries frequently focus on formal R&D and patent generation, traditional sectors such as food processing depend heavily on tacit knowledge and process optimisation. These differences influence both the metrics used to measure innovation and the strategies required to support it.

The multifaceted nature of innovation signifies that its success is contingent not solely on the novelty of the outcome, but also on the organisational context within which it is developed and implemented. This underscores the significance of integrating innovation studies with broader considerations of institutional capacity, cultural orientation, and market alignment.

1.2. Hungary's innovation landscape

The innovation environment in Hungary is shaped by a complex interplay of historical, institutional, and economic factors. The post-socialist transformation has necessitated the establishment of mechanisms to encourage technological advancement, support entrepreneurship, and integrate domestic enterprises into global value chains (Inzelt, 2002). Over the past two decades, both national and EU-level policy instruments have sought to address these needs through targeted R&D funding, infrastructure development, and incentives for collaboration between research institutions and businesses (Lengyel & Leydesdorff, 2015).

1.2.1. Institutional Support and Policy Framework

Research and development institutes, universities, and policy-driven initiatives have facilitated experimentation and technological upgrading in several sectors. Nevertheless, limitations in policy execution, bureaucratic hurdles, and funding constraints often compromise the effectiveness of these programmes. The efficacy of hybrid public–private funding models, which combine public oversight with private-sector efficiency, has been demonstrated. However, potential conflicts of interest may impede their effectiveness in fostering innovation (Inzelt, 1996).

1.2.2. Collaboration and Networking

Effective collaboration is recognised as a critical driver of innovation. Research indicates that a significant number of Hungarian firms, particularly those operating within the food and service industries, demonstrate a tendency to underutilise inter-firm partnerships and knowledge-sharing networks (Török et al., 2019; Tóth et al., 2020)using the empirical data from a 2017 survey conducted in Hungary among the largest food processing companies. Planned behavior theory (TPB. Enhancing interdisciplinary collaboration and cultivating trust-based cooperation have the potential to address existing capability gaps. The integration of disparate knowledge bases to effectively address complex problems is exemplified by high-tech sectors.

1.2.3. Financial Resources and Culture

The relationship between financial resources and culture is complex and multifaceted.

The issue of access to finance continues to present a multifaceted situation. The role of EU subsidies in supporting innovation is well-documented, yet small and medium-sized enterprises (SMEs) – a key component of the Hungarian economy – continue to face challenges in accessing these funds. The financial culture, encompassing levels of literacy and resource management skills, has been demonstrated to be significantly correlated with innovation outcomes (Győri et al., 2019; Prokop & Stejskal, 2018).

1.2.4. Sectoral Dynamics and Knowledge Integration

Hungary's sectoral innovation performance varies substantially. In the field of industry, there is a clear distinction between traditional sectors and those operating within high-tech industries. The former frequently implement improvements incrementally, relying on tacit knowledge, while the latter engage in formal R&D and benefit from globalisation. This discrepancy highlights the necessity of sector-specific strategies that capitalise on distinct strengths while addressing unique constraints (Török et al., 2019; Tóth et al., 2020)

1.3. Lean management and its role in innovation

A significant aspect of the Hungarian corporate innovation landscape is the progressive introduction of Lean Management (LM) principles. Initially developed in the manufacturing sector, LM is centred on systematically eliminating waste, optimising workflows, and maximising customer value (Womack & Jones, 2003). As time has passed, the application of the concept has evolved from the sphere of production to encompass service and administrative processes. This development reflects a more comprehensive understanding of operational excellence.

In the Hungarian context, enterprises that have adopted LM principles frequently report a reduction in lead times, a decrease in operational costs, and an enhancement in product or service quality (Losonci & Demeter, 2013). However, the implementation of LM remains inconsistent, with some organisations utilising it primarily as a cost-reduction measure rather than integrating it into a comprehensive innovation strategy. Such partial adoption can limit its potential to generate sustainable competitive advantages.

In their research, Abdallah et al. (2019) demonstrate that LM naturally aligns with incremental innovation by fostering continuous improvement and process optimisation. However, it is essential to note the potential limitations imposed by the structural rigidity frequently associated with LM, which can impede the necessary flexibility for radical innovation. It is further emphasised that the most successful outcomes in terms of innovation occur in instances where LM is coupled with a robust innovation orientation, particularly when "soft" Lean practices—with a focus on employee engagement and cultural transformation—are integrated with "hard" Lean practices, such as the utilisation of technical tools for process mapping and performance evaluation.

As demonstrated by Koloszár and Pankotay (2017), the importance of leadership commitment, a supportive organisational culture, and active employee involvement in achieving LM success is emphasised. The researchers' findings emphasise that LM is not merely a compilation of technical instruments, but rather a strategic mindset that fosters operational efficiency and the actualisation of innovation potential. The adaptability of LM across various sectors serves to reinforce its relevance. In the hospitality sector, for instance, LM practices have been shown to enhance service quality and efficiency through customer-centred process standardisation (Pankotay & Koloszár, 2019).

International insights also inform the Hungarian context. A case study by Alkhlaifat and Koloszár (2023) on the Jordanian Electricity Distribution Company (EDCO) found that while LM yielded significant operational improvements, resource–outcome misalignments persisted. This lesson is particularly relevant to Hungarian practice, where success is contingent upon the interplay of technical methodologies with cultural and leadership factors.

Beyond efficiency, LM has been demonstrated to be a driver of eco-innovation, aligning environmental objectives with operational and financial performance (Shashi et al., 2019; Leitão et al., 2019). In the context of Hungarian firms, the integration of resource efficiency and waste minimisation within innovation strategies has been demonstrated to enhance both sustainability and competitiveness.

1.4. Cultural and organisational factors

The outcomes of innovation are significantly influenced by both national and organisational culture. In the Hungarian business environment, characterised by a general aversion to risk, the adoption of disruptive technologies may be hindered, thereby constraining entrepreneurial activity (Tóth et al., 2020)using the empirical

data from a 2017 survey conducted in Hungary among the largest food processing companies. Planned behavior theory (TPB. Firms that cultivate an open, collaborative culture, coupled with market-oriented product development, tend to achieve more sustainable innovation performance (Győri et al., 2019).

The role of leadership in the shaping of such cultures is critical. It is evident that management teams which provide clear strategic direction, encourage experimentation, and reward innovative contributions create an environment in which innovation can thrive. Conversely, a paucity of managerial competence, inadequate strategic planning, and low adaptability to market changes hinder the realisation of innovation benefits.

Human capital is another decisive factor. A significant number of Hungarian companies encounter shortages in technical competencies, thereby impeding the execution of sophisticated innovation initiatives (Rideg et al., 2023). To address this challenge, targeted workforce development is required, including training, recruiting specialised talent, and stronger collaboration with educational institutions to align curricula with industry needs.

1.5. Measuring innovation performance

Measuring innovation performance is inherently challenging due to its multidimensional nature and the time lags between investment and results. The extant literature on the subject is highly varied in nature.

As Prokop and Stejskal (2018) point out, composite indicators such as R&D expenditure, patent counts and product launch numbers provide a broad overview of innovative activity. However, these indicators often fail to capture financial outcomes directly.

Process Innovation Frameworks are concerned with qualitative aspects such as leadership, organisational culture, and strategy alignment (Török et al., 2019; Piskóti et al., 2013).

Conventional financial metrics, such as return on investment (ROI) and net present value (NPV), are designed to evaluate profitability. However, they are not well-suited to account for uncertainty, extended time horizons, and intangible benefits (Silva & Pereira, 2017).

Sector-specific approaches recognise that industries such as food processing may place greater reliance on tacit knowledge and incremental improvements than on formal research and development (R&D), rendering qualitative indicators more pertinent (Tóth et al., 2020).

Despite their evident value, these methods are not without their limitations. They frequently lack financial integration, are not universally applicable across sectors, and struggle to capture long-term impacts.

To address these shortcomings, recent research (Angyal & Vajai, 2024; Angyal & Vajai, 2025) has proposed the use of Free Cash Flow to Firm (FCFF) as a comprehensive financial measure of innovation performance. The FCFF model is a cash-based accounting model that provides a comprehensive overview of a company's

financial health. It encompasses various elements, including operational costs, capital expenditures, and debt servicing. By incorporating these elements, FCFF provides a comprehensive view of a company's financial performance, accounting for both tangible and intangible outcomes. Its compatibility with discounted cash flow (DCF) models renders it particularly suitable for the valuation of innovation projects characterised by uncertainty and delayed returns (Mielcarz & Mlinarič, 2014; Gnap & Pitera, 2023)

2. Data and methodology

A review of existing literature on measuring the success of innovation investments, along with the related challenges and limitations, explicitly focused on Hungary. The literature review highlighted a lack of analysis regarding Hungarian market data and insufficient emphasis on FFCF-based evaluation methods. This finding led to the formulation of the primary research question: What is the impact of innovation expenditure on the financial performance of Hungarian medium- and large-sized companies?

As a result of the previous considerations, four hypotheses have been formulated:

- **Hypothesis One:** Investments in innovation positively affect FCFF.
- **Hypothesis Two:** A time lag exists before these investments are reflected in financial metrics.
- **Hypothesis Three:** The positive impact of innovation investments diminishes over a two-year period.
- **Hypothesis Four:** The average FCFF remains unaffected after five years.

This study utilises a dataset comprising balance sheets from Hungarian companies between 2010 and 2020. The dataset was acquired from the Ceginformacio.hu Crefoport national database, which provides financial and operational data on businesses in Hungary. It was chosen for its high granularity and breadth, offering a comprehensive timeframe of corporate financial information. The study focuses on medium- and large-sized enterprises, which are vital to the Hungarian economy. The analysis separates this segment from the larger dataset, highlighting these businesses' unique financial and operational dynamics to ensure that the insights remain relevant for policymakers and stakeholders in this sector. Key variables derived from the balance sheets include total assets, liabilities, revenue, and profitability metrics. These variables are essential for assessing medium and large enterprises' financial health and performance throughout the study period. The data underwent thorough cleaning and preprocessing to ensure consistency and reliability, which included checks for missing values, outlier detection, and standardisation to enable comparability across time and firms.

The selection criteria for the dataset required the inclusion of companies that met specific financial thresholds:

- Total assets > 0
- Total resources > 0
- Net turnover from sales > 0

Additionally, firms were filtered based on TEAOR (NACE) codes to maintain consistency in industry categorisation, aligning the dataset with international and regulatory standards. Turnover figures were standardised in EUR, as required by EU regulations, specifically Act XXXIV of 2004. (*2004. Évi XXXIV. Törvény - Nemzeti Jogszabálytár*, n.d.) The entire dataset for all Hungarian enterprises underwent rigorous examination during the research process. To enhance the clarity and comprehension of the trends, the enterprises were categorised according to their size based on the turnover figures by the EU regulation Act XXXIV of 2004. (*2004. Évi XXXIV. Törvény - Nemzeti Jogszabálytár*, n.d.) The investment amount was specified as a percentage of the total assets, which permitted the classification of the enterprises into five categories: 0-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%. The extensive dataset precludes displaying results in graphical form due to the lack of readability.

The large dataset was meticulously cleaned and pre-processed to ensure analytical accuracy and reliability:

1. **ROI-Based Filtering:**

Companies with ROI (Return on Investment) values of zero or non-calculable ROI were excluded to reduce noise in the dataset. Extreme outlier ROI values were also removed using the Interquartile Range (IQR) method (IQR * ±1.5), eliminating outliers and enhancing data reliability. The annual change in invested assets primarily shows that it fluctuates around zero, meaning businesses strive to replace depreciation. Still, the frequency of more significant investments shows a year-on-year decrease. The individual investment categories were categorised and examined separately, as described above. As shown in Table 1, the process eliminated around 15% of the original data of micro-businesses, 10% of the small businesses, 7,5% of medium enterprises, and 11% of large companies.

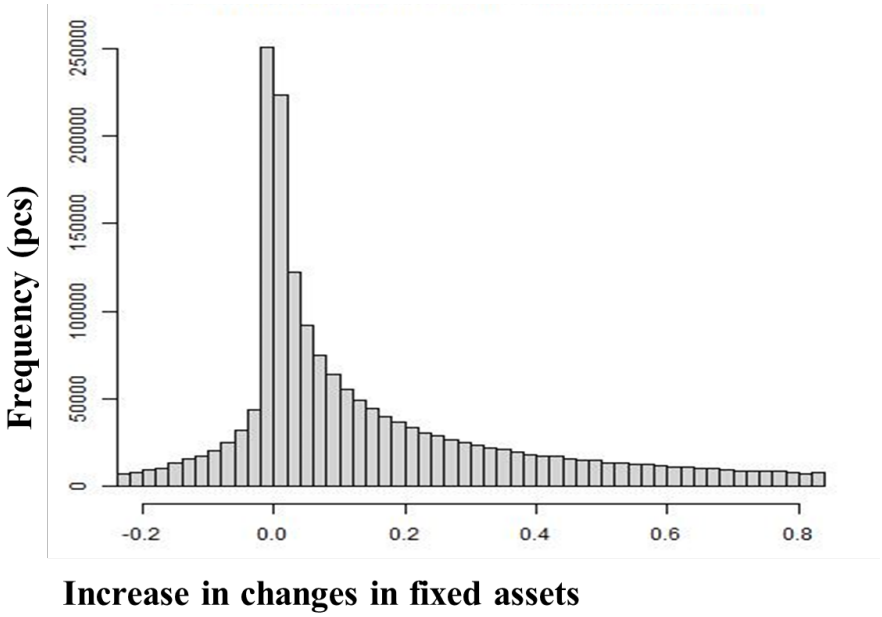
Table 1. Number of Data before and after Cleaning

Business categories based on size	Number of data before cleaning	Number of data after cleaning
Micro Businesses	2.243,098	1.903,362
Small Businesses	92,949	84,313
Medium Businesses	22,634	7,379
Large Businesses	20,943	6,549

Source: Own editing based on calculations on Crefport dataset of Ceginformacio.hu

The annual change in fixed assets fluctuates around zero, indicating that companies are attempting to offset depreciation. However, the frequency of larger investments is decreasing on an annual basis. In light of the findings presented in Figure 1, a comprehensive examination of the individual investment categories was conducted, categorising them into five distinct classes: The percentage of the population that is affected by this issue ranges from 0-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%

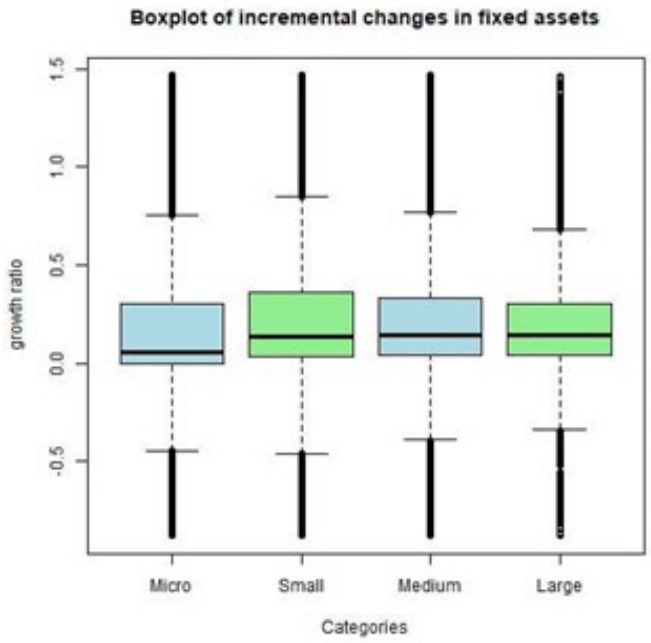
Figure 1. Annual change in fixed assets



Source: Own editing published in earlier papers (Angyal & Vajai, 2024;Angyal & Vajai, 2025)

Following the cleansing of the data, a boxplot was utilised to analyse the variation in fixed assets for innovation. The boxplot data presented in Figure 2 demonstrate significant fluctuations in both positive and negative directions, accompanied by substantial atypical investments, indicating substantial capital allocations. This finding necessitates further investigation into the concept of innovation, followed by an analysis of the variation in FCFF based on group classification and the alteration in fixed assets throughout periods of growth.

Figure 2. Boxplot of incremental changes in fixed assets by category



Source: Own editing published in earlier papers (Angyal & Vajai, 2024; Angyal & Vajai, 2025)

2. Financial Metric Transformation – see also own formulas below:

- FCFF (Free Cash Flow to the Firm) was computed for each company as follows:

$$FCFF=Earnings\ after\ Tax + Amortisation - CAPEX$$

- CAPEX (Capital Expenditures) was derived from changes in fixed assets and amortisation:

$$CAPEX=Changes\ in\ Fixed\ Assets + Amortisation$$

- Applied formulas :

$$ROI = [(Assets\ investedt + Amortisationt - Assets\ investedt\text{-}1)] / Assets\ investedt\text{-}1$$

3. FCFFdelta:

- The base year is the period when the ROI reaches or exceeds 5%. The "t" period is the current year against which the FCFF result of the base year can be examined. This allows us to examine the effectiveness of the investment over the years to a limited extent

$$FCFFdelta = (FCFFt - FCFFbase) / FCFFbase$$

4. **Currency Standardisation:**

- Turnover data was converted to EUR, facilitating consistency in size categorisation across the dataset as per EU regulations.

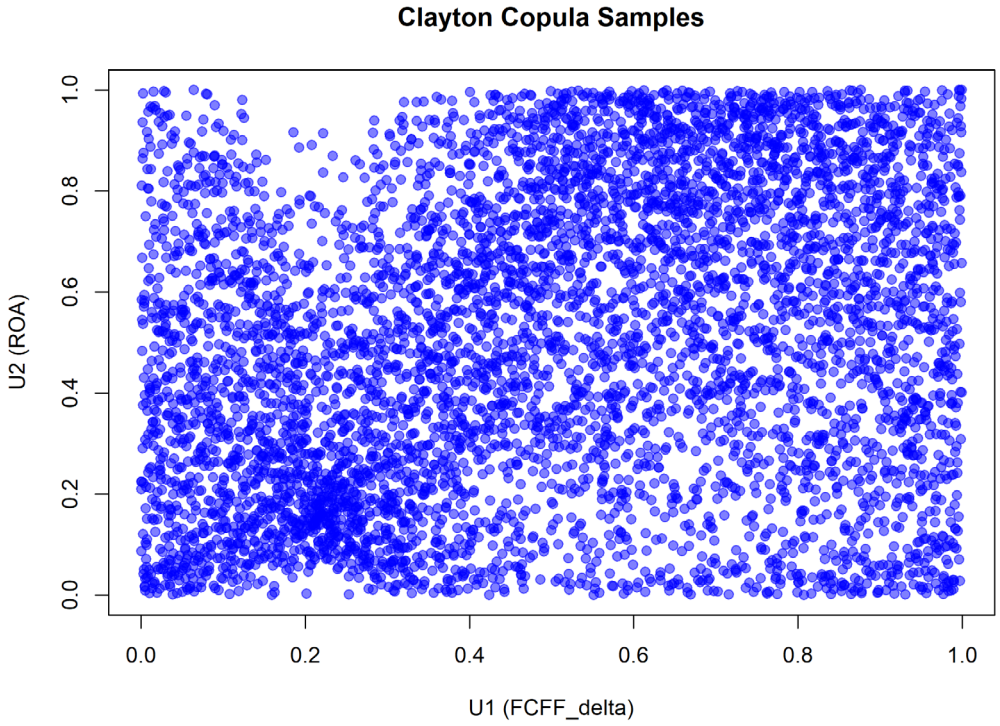
5. **Normalisation and Scaling:**

- Key variables were normalised to enable meaningful comparisons across firms and over time.

6. **Year-Over-Year Changes:**

- The year-over-year changes in FCFF were calculated to track dynamic shifts in financial performance relative to a base year. This iterative approach allowed for the identification of temporal trends and projections.
- This comprehensive research project consists of three phases. The average FCFF delta change was calculated for each base year in the first phase. In addition, income and asset categories were compared with the base year each year for the next five years to facilitate the identification of broader financial growth trends. In the second phase of the research, the FCFF delta means were compared with the year-specific means using a t-test. As a result, the averages were almost the same regardless of the relative distance between the averages for each year.
- This study represents the third phase of the research and calculates the determinants of the rate of change of FCFF in each investment category, exceeding 5%, using the Clayton Copula formula. This represents 24.298 observations with an FCFF delta greater than 5%. Other Copula calculations, such as Gauss Copula or t-Copula, did not work because the dataset typically contained extreme values. The results support the results of the previous phases (Angyal & Vajai, 2024; Angyal & Vajai, 2025) with different methods, indicating that higher investment amounts and/or sizes do not exhibit a trend-like effect on the increase in FCFF. The results shown in Figure 4 also visually demonstrate, through the Clayton Copula, that no trend-like relationship is observed in the growth of FCFF when other variables are considered. The variables tested alongside FCFF include changes in invested assets, CPI (inflation), the GDP volume index, the household consumption volume index, ROA, ROE, the efficiency index, and the indebtedness index based on the data of Központi Statisztikai Hivatal from 2024. (ÖSSZEFOGLALÓ TÁBLÁK (STADAT) – KÖZPONTI STATISZTIKAI HIVATAL, N.D.) In all instances, the alpha value of the Clayton Copula was 0.6, indicating no clear relationship.

3. Figure: Result of Clayton Copula analysis



Source: Own calculation based on Crefport dataset of ceginformacio.hu

Conclusion

This study aims to analyse the financial outcomes of innovation investments in Hungarian medium and large enterprises from 2010 to 2020. The results indicated significant trends and insights that clarified the intricate relationship between innovation expenditures and financial performance at the firm level. The lack of observable trends explains why this study could not reject the null hypothesis for all four hypotheses.

The analysis indicated that innovation projects frequently fail. The data revealed that firms often underestimated the importance of aligning their innovation efforts with market demands and long-term strategic goals. This misalignment often led to inefficient resource allocation and unachieved financial benefits. This assertion is substantiated by the elevated standard deviation of FCFF delta and the remarkably elevated outliers, as illustrated by the boxplot in Figure 2.

The findings of the Clayton Copula analyses demonstrate an absence of correlation between success or effectiveness and profitability, the capacity to generate cash flow, and the external (e.g., CPI, GDP volume index) and internal factors (e.g., ROE, ROA) examined. The study emphasised the absence of internal factors (knowledge base, network, preparedness, and other unique elements that cannot be measured) and external factors (knowledge sharing opportunities, reliability, and any external factor that is not a balance sheet item or derived from official

statistical data for which sufficient data is not available), including economic volatility and regulatory frameworks, impacting the financial outcomes of innovation investments. Firms in industries with significant regulatory constraints faced increased challenges in converting innovation expenditures into measurable financial returns.

The success of an innovation cannot be solely attributed to the level of investment. The findings indicate that managerial expertise, financial literacy, and market orientation significantly influence financial outcomes. Moreover, the importance of networking and collaboration as critical factors in innovation success warrants further investigation. The results show that companies engaged in cross-sector partnerships and knowledge-sharing networks demonstrated enhanced financial performance, particularly within complex innovation ecosystems. As the third phase of a comprehensive research project, this study suggests that soft skills, rather than hard factors, influence the success of innovation investment.

Future research directions

The findings underscore the necessity for a more sophisticated approach to assessing the effectiveness of innovation investments. Financial investment is a critical enabling factor; however, its success relies on internal capabilities and external market conditions. Policymakers and business leaders should implement tailored strategies that address specific sector challenges and capitalise on opportunities arising from digitalisation and collaboration.

Future research should broaden the analysis to include additional variables, such as firm-level debt, industry classification codes (NACE/TEAOR), the net present value (NPV) of individual investments, and soft skills such as strategic thinking and foresight. This level of detail would enhance understanding of the factors influencing innovation success.

This study contributes to the literature on innovation management by presenting empirical evidence regarding the financial dynamics of innovation investments in Hungarian medium and large enterprises. Innovation offers significant opportunities for financial growth; however, its success is not guaranteed, necessitating careful analysis of strategic intent, resource allocation, and market alignment. Addressing these challenges enables firms to effectively harness the transformative potential of innovation for sustained financial and competitive advantage.

Further research could concentrate on the identification of internal factors that can be studied at both the national and international levels and that provide quantitative data. Such factors might include, for example, companies' research relationships with universities, the nature of their scientific knowledge base (e.g. engineering, data analysis), the search for networks of contacts, and the impact of multinational companies on the innovation performance of domestic supplier companies.

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