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Research Article

The Impact of Artificial Intelligence Implementation on the Commercial Success of Startups

Marat Ressin

Abstract. This article examines the relationship between artificial intelligence (AI) implementation and the commercial success of startups, using Canada as an empirical case. While the role of AI in entrepreneurship and business innovation has been widely discussed in recent academic literature, there remains a noticeable gap in country-specific empirical studies that integrate macro-level statistical indicators with firm-level qualitative evidence on startup performance. Consequently, this study addresses the challenges and opportunities associated with AI adoption in early-stage entrepreneurial ventures operating within a highly developed innovation ecosystem. The primary objective of the research is to assess how investments in AI and research and development (R&D) are associated with the financial performance and sustainability of startups in Canada. To achieve this objective, the study employs a mixed-methods research design combining secondary statistical data analysis with survey evidence and semi-structured interviews conducted among AI-integrating startups across multiple sectors. Quantitative analysis is based on descriptive statistics, correlation analysis, and regression modeling, while qualitative insights are derived from surveys and interviews with startup founders and executives. The findings reveal a strong positive association between internal R&D expenditures – particularly those related to AI – and operating profit among Canadian startups. Qualitative evidence further indicates that AI adoption contributes to business process optimization, improved investment attraction, and enhanced forecasting accuracy. At the same time, the results highlight the importance of contextual factors, including regional innovation clusters, access to skilled talent, and institutional support mechanisms. Overall, the study contributes empirical insights into the role of AI in startup development and offers policy-relevant implications for strengthening innovation ecosystems and supporting sustainable entrepreneurial growth.

Keywords: artificial intelligence, Canada, early entrepreneurship, financial sustainability, innovative idea.

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1. Introduction

Startups as a form of digital entrepreneurship are emerging as key agents in the transformation of the global economy. They represent young, innovative companies at the early stages of development, often focused on attracting venture capital to enable scaling and the rapid adoption of cutting-edge technologies [1]. Their success largely depends on the founders' ability not only to effectively present original ideas to investors but also to adapt business models to a rapidly changing digital environment [2].

One of the most promising directions for startup development is the integration of artificial intelligence (AI) into the core of entrepreneurial activity. Contemporary research emphasizes that AI-driven startups do not merely automate individual processes but transform the very logic of value creation, strategic management, and market interaction [3]. Specifically, the key components of such models include: 1) generation of new value based on AI algorithms; 2) strategic management of big data as a core asset; and 3) transformation of the institutional and organizational logic of business operations.

The contemporary theoretical literature on digital entrepreneurship underscores the necessity of building ecosystems where entrepreneurs can access data, infrastructure, and algorithmic resources. However, within the context of small firms — characterized by limited financial and human resources — AI integration presents a number of challenges. First, access to high-quality data and ensuring its protection is a major concern. Second, there is a shortage of qualified specialists capable of developing and implementing AI models. Third, the high initial investment required for infrastructure poses a significant barrier [4]. Moreover, small companies often exhibit a low level of digital transformation maturity, making the rapid adaptation of business models more difficult.

Against the backdrop of North America's global dominance in the startup ecosystem [5], companies such as Miovision, Tenstorrent, and Cohere stand out [6], demonstrating a high degree of digital maturity and entrepreneurial activity (32.6%) [7]. Many of these companies aim to achieve "unicorn" status, with a market valuation exceeding one billion dollars [5,8-10]. Examples of global leaders — such as ANT Group and ByteDance in China, and Infor in the United States — further confirm that the integration of AI and advanced digital architectures has become a cornerstone of their success [7].

The integration of artificial intelligence (AI) is emerging as a powerful transformative mechanism, reshaping the entrepreneurial landscape and fostering new models of value creation. According to Kiani [11] and Usman et al. [12], AI offers startups fundamentally new opportunities — from accelerated growth to sustained innovative activity — exerting a significant impact on the economy and society at large. As Blair [13] notes, the contribution of startups to the global economy continues to increase, particularly in countries with well-developed digital infrastructure, such as Canada [7]. In this context, AI acts as a catalyst, enabling emerging companies to adapt to contemporary challenges and successfully scale their operations [14].

However, mere acknowledgment of AI’s importance is insufficient. Achieving genuine transformation requires a profound understanding of the mechanisms through which AI

operates at the level of business practices. AI significantly enhances operational efficiency by automating routine tasks, reducing costs, and accelerating time-to-market processes. This, in turn, promotes scalability and increases the competitiveness of startups [15]. As emphasized by Weber et al. [3], the strategic use of AI is increasingly becoming the foundation of technology companies' business logic and commercialization pathways [16].

The most pronounced impact of AI is observed in sectors characterized by a high degree of digitalization. In healthcare, AI is utilized to improve diagnostic accuracy, analyze medical data, and develop personalized treatment approaches. In the financial sector, it assists in modeling market scenarios, detecting anomalies, and mitigating risks, thereby providing startups with substantial competitive advantages [17,18]. Similarly, in the clean energy sector, AI facilitates ecological optimization, contributing to the sustainability of businesses in the context of growing environmental, social, and governance (ESG) requirements.

At the same time, in less digitally advanced sectors, such as agriculture and tourism, the application of AI remains limited. Implementation occurs sporadically and is often contingent on external support. The underlying reasons include inadequate infrastructure, limited access to data, and insufficient institutional support, particularly in developing economies [19].

The context in which AI is implemented plays a critical role. The regulatory environment can either stimulate or inhibit development. In jurisdictions with transparent legal frameworks, such as Canada, startups are afforded the opportunity to develop AI projects within a secure and predictable environment. Conversely, in countries characterized by political instability or strict control over digital flows, startups face significant barriers to accessing technologies and investments [20]. Beyond technological capabilities, successful AI commercialisation depends on complementary assets such as financing, market access, and organizational readiness. Qualitative evidence from entrepreneurial firms highlights persistent challenges related to sales capabilities, ecosystem immaturity, and limited commercialization support, particularly outside major innovation hubs [21,22]. These constraints help explain heterogeneous performance outcomes among AI startups.

Particular attention must also be given to data-related issues. Representative, high-quality, and readily accessible datasets are fundamental to the success of AI projects. However, in many countries, there is a shortage of such resources, and restrictive legislation only exacerbates the problem, impeding startups' ability to scale their solutions effectively.

Investors likewise play a crucial role. Venture capital funds are increasingly focusing on AI startups, expecting not only groundbreaking technologies but also sustainable business models. However, successful investment attraction requires a clear articulation of the AI product’s commercial potential and the company’s ability to offer a viable long-term growth strategy.
The ethical dimension cannot be overlooked. The sustainability of AI projects largely depends on adherence to standards of privacy protection, prevention of algorithmic discrimination, and ensuring transparency. Startups that neglect these principles risk losing the trust of customers and partners and may also face legal repercussions [23].

Recent studies emphasize that AI adoption reshapes startup business models by enabling data-centric value creation, rapid experimentation, and scalable personalization. Comparative

evidence shows that startups integrating AI into core business logic achieve superior innovation outcomes and performance metrics [24,25]. These findings support the view that AI acts not merely as a tool, but as a structural component of entrepreneurial strategy.

Nevertheless, beyond general descriptions of startup ecosystems and mentions of AI adoption, there remains a need for more detailed empirical research focused on specific countries and innovative strategies. This article addresses this gap by concentrating on Canada as a promising platform for the development of AI startups. The study includes an analysis of statistical data on early-stage entrepreneurship, the geographic distribution of startups, and investments in technology [26,27]. This enables the identification of the specific features of commercializing AI and digital models within the context of a stable economy, sustainable development goals, and innovation policies [19,28]. Thus, the article offers an original perspective on the potential of AI startups in Canada, combining theoretical frameworks of digital entrepreneurship with empirical analysis. This approach makes it possible to develop recommendations applicable to other countries seeking to advance technological entrepreneurship and to build sustainable innovation ecosystems, while simultaneously overcoming institutional and technological barriers to AI adoption in small enterprises.

Thus, the integration of AI into startups is not merely a technological endeavor but a complex transformation requiring a balanced consideration of industry-specific characteristics, institutional contexts, data quality, investor behavior, and ethical standards. Only such a comprehensive integration creates the conditions necessary for the sustainable growth and international competitiveness of innovative enterprises [29].

While prior studies extensively document the strategic relevance of artificial intelligence for startups, empirical evidence linking AI implementation, R&D investment, and commercial outcomes at the national level remains limited and fragmented. Existing research often focuses on conceptual models, case studies, or non-country-specific samples [30-34]. This study addresses this gap by providing a mixed-methods analysis of Canadian startups, integrating macro-level statistics with firm-level survey and interview data to assess how AI-driven investments relate to commercial success. AI-driven process automation further enhances startup competitiveness by improving operational efficiency, strategic alignment, and performance monitoring. Empirical and qualitative studies consistently identify data governance, strategic vision, and infrastructure readiness as critical enablers of AI-related performance gains in startups [30,31].

The aim of the research is to quantitatively and qualitatively assess the relationship between AI implementation and the commercial success of startups.

Research objectives: to review the market conditions in the field of innovative business and startups in Canada; to assess the potential for the development of AI in Canada in geographical and sectoral aspects; and to model the qualitative and quantitative impact of AI implementation on the commercial success of startups.

The scientific novelty of this research lies in its comprehensive approach to evaluating the impact of AI integration on the commercial success of startups in Canada, with a particular focus on unique national and regional characteristics. In this context, special attention is given

to the analysis of AI startups in Canada not only as an economic phenomenon but also as a driver of institutional transformations and changes in entrepreneurial logic.

2. Method

To achieve the aim of the research, a comprehensive methodology was developed, which includes a conceptual framework, methodological design, research stages, analysis tools, and the identification of methodological limitations.

2.1. Conceptual Framework

The conceptual framework of the research is based on the idea that it is possible to create an empirical tool to enhance the effectiveness of startups, focused on the use of AI, while considering national characteristics, particularly in Canada [3]. Based on this, the conceptual foundation of the research is constructed around several key aspects, which include the interaction between innovative entrepreneurship and AI technologies, as well as the specifics of commercial success in startups within the context of national peculiarities. The primary theoretical idea of the study is the hypothesis that the implementation of AI in startup activities can significantly increase the chances of success, but this effect depends on various factors, including specific national and sectoral features that affect all key areas of government structure [35]. The methodology for assessing commercial success assumes that the introduction of AI in a startup may have both direct and indirect influences on success, which, in combination, produce a synergistic effect [36].

Within this study, an AI-driven startup is defined as an independent innovative enterprise incorporated in Canada that deploys artificial intelligence solutions – such as machine learning, predictive analytics, natural language processing, or process automation – as a core component of its business model, product offering, or operational processes.

The identification of such startups was based on open-source information drawn from official corporate disclosures, accelerator and incubator program materials, venture-capital investment reports, as well as statistical and analytical databases on innovation development.

2.2. Methodological Design and Research Stages

To achieve the stated objective, the study is structured around three key stages, each aimed at elucidating the role of information technologies (IT) and artificial intelligence (AI) in the development of startups in Canada. At the first stage, the focus is placed on analyzing the country's innovation environment. Within this context, the hypothesis is proposed that the socio-economic and institutional foundations established in Canada foster the successful integration of IT and AI into startup activities. This stage involves a comprehensive analysis of macroeconomic indicators, regulatory support for innovation, government policies on digitalization, and the level of digital infrastructure and education. Special attention is given to identifying factors that stimulate the integration of AI into the entrepreneurial ecosystem, such as the presence of AI-focused startup accelerators, the volume of R&D investment in the field, and the extent of venture capital financing for AI projects. The second stage emphasizes the assessment of regional and sectoral development potential for IT and AI in Canada. The

research is based on the hypothesis that the presence of regional clusters, university AI research centers, and well-developed venture ecosystems enhances the innovative potential of startups and supports their commercial growth. This stage examines the economic and demographic characteristics of different provinces, the degree of AI integration across key industries – including healthcare, finance, transportation, and agriculture – and the availability of governmental support programs. Comparing regional economic activity with AI adoption levels enables the identification of high-tech startup concentration centers and reveals the relationship between technological innovation and socio-economic development.

The third stage focuses on modeling AI's impact on startups' commercial success. It is assumed that the adoption of AI has both direct and indirect effects on key performance indicators such as revenue growth, increased investment attraction, customer base expansion, and market resilience. To evaluate this impact, contemporary quantitative methods, including econometric models, are employed to establish causal relationships between AI investments, R&D scale, and startup performance outcomes. The use of multicollinearity analysis through variance inflation factors (VIF) enhances the reliability of the results and accounts for potential endogeneities. Particular attention is given to specific AI solutions implemented within startups' business models, such as process automation, predictive analytics, and natural language processing, as well as to the volume and structure of investments in corresponding R&D initiatives.

Thus, the entire study conducts a comprehensive assessment of the impact of IT and AI on the innovation dynamics of startups in Canada, with a focus on the country's institutional, geographic, and technological specificities. This approach enables the identification of the complex interrelationships between government regulation, regional development, entrepreneurial strategies, and the commercial success of technology-oriented enterprises.

2.3. Research Materials and Sample Formation

The materials of the research include statistical indicators that allow for a comprehensive assessment of startup development in Canada, the identification of factors influencing their success, and the analysis of the role of innovative technologies, including AI. These materials are empirically grounded and provide valuable data for analyzing the commercial success of startups at different stages of their development. The sample of indicators includes Operating profit or loss [26], the number of startups by region [37], startup funding by industry [37], and total internal research and development (R&D) expenditures [27]. These indicators enable the evaluation of a startup's financial performance, its ability to generate profit in its core activities, the geographical differentiation of startups in terms of their concentration across different Canadian provinces, and innovative expenditures and data on startup funding by industry. All financial indicators in this study are reported in Canadian dollars (CAD).

The selection of surveyed and interviewed startups follows established qualitative research practices emphasizing sector relevance, AI intensity, and data availability. Comparable sample sizes and selection criteria have been applied in recent AI entrepreneurship studies, supporting the validity of the adopted approach [21,24].

The empirical foundation of this study draws on secondary quantitative data sourced from official statistical repositories, analytical reports on startup and venture capital development, and publications addressing innovation and R&D activity. The analysis covers the period from 2019 to 2024, enabling an examination of current trends in AI adoption and their implications for the commercial performance of startups. The final sample included only those startups for which complete and internally consistent data were available regarding operating profit or loss, financing volumes, R&D expenditures, industry classification, and regional location.

To assess the direct impact of AI on the commercial success of Canadian startups, a qualitative component was incorporated, combining structured surveys, semi-structured interviews, and case analysis. A total of 68 AI-integrating startups operating in healthcare, finance, transportation, and agribusiness participated in the survey. The instrument captured respondents' assessments of the effectiveness of process automation, predictive analytics, and natural language processing, as well as perceived effects on operational efficiency and investment attraction.

In parallel, 15 semi-structured interviews were conducted with founders and CTOs of startups located in the Toronto–Waterloo and Vancouver clusters. These interviews enabled a deeper examination of the mechanisms through which AI influences strategic decision-making and operational processes, along with changes in financial indicators before and after AI integration.

2.4. Sample Formation

The formation of the sample in this study was guided by the following criteria. First, the focus was placed on Canadian startups actively integrating artificial intelligence into their operations, particularly in healthcare, finance, transportation, and agriculture sectors. This approach ensured an emphasis on companies where AI could have a significant impact. Furthermore, the selection included startups located in various provinces of Canada, such as Toronto and Vancouver, which possess more developed technological and venture ecosystems, thereby allowing for the consideration of regional differences in startup success.

The sampling procedure was guided by explicitly defined inclusion and exclusion criteria. Startups were eligible for inclusion if they: actively employed AI technologies in their operations; operated within the healthcare, finance, transportation, or agricultural sectors; and possessed verifiable financial indicators and documented R&D investment data.

Startups were excluded from the sample if financial records were incomplete, if data on R&D expenditures were unavailable, or if the practical implementation of AI solutions could not be reliably verified.

It was also essential that the selected startups represented different stages of development, including early stages (seed and startup) as well as more mature companies that had already secured venture financing or were generating revenue. To ensure the accuracy of the data, only those startups with complete and up-to-date financial information, including R&D expenditures, operating profits, and volumes of venture capital funding, were included in the sample. Startups lacking such data or not participating in accelerator programs were excluded from the study.

Additionally, attention was given to the industrial characteristics of AI-using startups, with a particular emphasis on their potential for the implementation of innovative technologies, which could influence their commercial success. The study period was restricted to the past few years, enabling an analysis of current trends and the identification of more precise relationships between AI adoption and startup success across various sectors.

2.5. Methodological Tools, Formulas, and Iterations

The research employs both qualitative and quantitative evaluation methods. Quantitative methods include approximation with trend model selection and outlier analysis, expedited data analysis using visualization and descriptive statistics, and correlation analysis; qualitative methods include literature review analytics.

Prior to the quantitative analysis, the dataset was cleaned and assessed for internal consistency, missing values, and outliers. Descriptive statistics and data visualizations were employed to identify anomalous observations and mitigate potential distortions in the results.

The application of linear regression and correlation analysis was driven by the study's objective – examining the direction and magnitude of the relationship between R&D investments, AI adoption, and the financial performance of startups. To verify the robustness of the models, multicollinearity diagnostics were conducted using Variance Inflation Factor (VIF) coefficients.

The approximation method is used to understand the overall context and dynamics of the factors influencing AI development in Canadian startups. A linear model is applied in the study, which confirms that there is a linear dynamic of change over time in Operating profit or loss:

$$y = \beta_0 + \beta_1 * x, \quad (1)$$

where y is the dependent variable (Operating profit or loss); x is the independent variable (time); β_0 is the intercept, the point of intersection with the y-axis; β_1 is the slope coefficient, which shows how much y changes with a change in x.

The expedited data analysis method was employed to obtain preliminary information about the dataset concerning the economic environment in Canada for startups, identifying patterns present in the formation of success dynamics and potential anomalies along the way.

Data visualization was used to facilitate the interpretation of analysis results concerning trends in innovative businesses and startups within the context of Canada's economy. The visual correlation matrix reflected the impact of AI implementation on the commercial success of startups:

$$r = \frac{(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{(x_i - \bar{x})^2 (y_i - \bar{y})^2}}, \quad (2)$$

where x_i, y_i - represent the values of indicators: operating profit and research expenditures for the i-th year of observation; $\bar{x}$, $\bar{y}$ -represent the mean values of the indicators for the sample.

To analyse the impact of R&D expenditures on startups' operating profit, the study employed linear regression, which enables the assessment of the relationship between two variables: R&D expenditures and operating profit. This method allowed for determining how changes in one variable (R&D expenditures) affect the other variable (operating profit) while accounting for potential correlations and interdependencies.

Additionally, a multicollinearity analysis was conducted using variance inflation factors (VIF), which helps identify potential issues of variable dependence. A VIF value of less than 10 was considered acceptable, indicating that the model demonstrated sufficient stability.

Furthermore, to evaluate the statistical significance of the results, t-statistics and p-values were employed. The t-test method facilitated the identification of differences between samples, while p-values allowed for the assessment of the significance of these differences, thereby confirming or rejecting the hypotheses regarding the impact of R&D expenditures on startups' operating profit.

Thus, the research methodology integrates the use of linear regression to assess the effect of R&D investments on startups' financial outcomes, complemented by multicollinearity checks and statistical significance testing, enabling robust conclusions regarding the influence of R&D expenditures on operating profit.

2.6. Methodological Limitations

The methodological limitations of this study were related to a number of factors that affect the accuracy, validity, and interpretation of the results. To analyze the commercial success of startups and the impact of AI on their development, the availability of high-quality and up-to-date data is essential. In Canada, as in other countries, information about startups may be incomplete, fragmented, or inaccessible due to confidentiality or commercial interests. In some cases, data may be limited to large startups, while information about smaller or lesser-known initiatives may not be accounted for. Additionally, although a spatial-geographical approach was applied in this study to examine the economic features of Canada, geographical differences in data availability introduced certain limitations. For example, larger cities such as Toronto and Vancouver will have more information on startups than less developed regions.

The limitation of the time frame, due to the short period of available static information, narrowed the scope for assessing the impact of AI implementation on the commercial success of startups, which may not be immediately apparent. Some effects may only become visible in the long term, and a study conducted within a limited time period may not capture the full impact of these technologies.

The heterogeneity of startups, in terms of the fact that startups in different industries may integrate AI differently and face varying challenges, also potentially complicates the creation of a universal model for assessing the impact of AI.

3. Results and Discussion

This section presents the results of the research aimed at achieving the overall objective by addressing three key tasks.

Solution to Task 1: Overview of the General Situation in the Innovative Business and Startup Sector in Canada.

The progressive development of a country is based on its ability to create an internal environment for technologies and innovations as fundamental elements of the advancement of prosperity. From this perspective, it is crucial to examine the long-term trends in the profitability/unprofitability of the country's businesses as a whole. Figure 1 shows the dynamics of operating profit in businesses in Canada from 2010 to 2023, as well as its approximation. The Y-axis represents the amount of operating profit (in thousands of dollars), and the X-axis represents the years. The graph reflects a trend of growth in operating profit with some fluctuations in specific years. As a result, Figure 1 illustrates the long-term trend in operating profit across Canadian businesses, providing macroeconomic context rather than startup-specific performance; it serves as a benchmark for interpreting subsequent startup-level results.

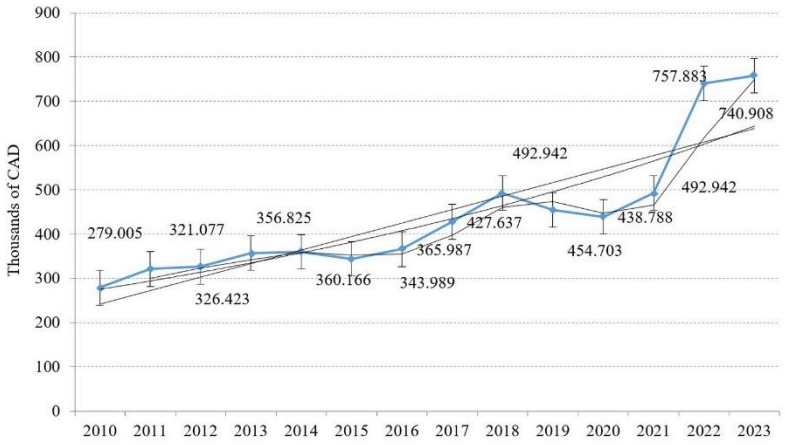


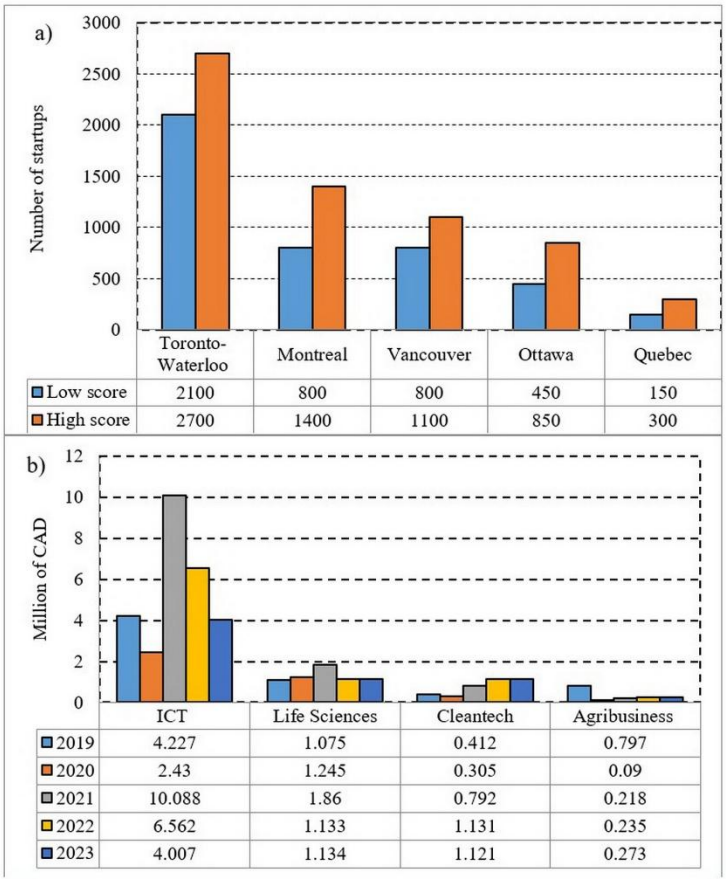
Figure 1. Approximation of the Dynamics of Operating Profit in Canadian Businesses from 2010 to 2023.
Note: Values are expressed in thousands of Canadian dollars (CAD); model deviations in the form of outliers were obtained using the approximation tool in Excel.
Source: Calculated by the author based on data from Statistics Canada [26].

The data in Figure 1 show that between 2010 and 2023, operating profit increased by 2.7 times, which, in the context of relatively low inflation, indicates the stable development of a favorable business climate in Canada. However, the dynamics of operating profit during the study period were not uniform. In certain periods, both gradual increases and decreases were observed. A particularly sharp spike is noticeable in 2021, where profits rose to 757,888 thousand CAD, before dropping in 2022 to 492,942 thousand CAD, and then increasing again in 2023. This fluctuation may be linked to external factors such as economic conditions, policy changes, or the consequences of global events. The graph also reflects an approximate linear or exponential growth model and potential deviations from this model, which are represented as outliers

plotted at each recorded point in the study. We can assert that the Canadian innovation sector demonstrates flexibility and the ability to recover after temporary downturns, emphasizing its potential for long-term development. Overall, the trend in the graph indicates a positive dynamic and investor interest in Canada's innovative business and startup sector, despite short-term fluctuations in profit. Thus, the solution to Task 1 allowed for the determination of the overall situation in the innovative business and startup sector across Canada as favorable, which could potentially foster the development of AI technologies in business to enhance its efficiency and sustainability.

Solution to Task 2: Assessment of the Potential for AI Development in Canada from Geographical and Sectoral Perspectives.

Within the framework of Task 2, the hypothesis is proposed that Canada is one of the leaders in the startup sector due to a combination of unique factors (such as a supportive business ecosystem, high levels of education, diversity, and access to international markets), which, in turn, positively influences the development of AI technologies.



	Toronto-Waterloo	Montreal	Vancouver	Ottawa	Quebec
Low score	2100	800	800	450	150
High score	2700	1400	1100	850	300

	ICT	Life Sciences	Cleantech	Agribusiness
2019	4.227	1.075	0.412	0.797
2020	2.43	1.245	0.305	0.09
2021	10.088	1.86	0.792	0.218
2022	6.562	1.133	1.131	0.235
2023	4.007	1.134	1.121	0.273

Figure 2. Startup Development in Canada as of 2024. Canadian Venture Capital Market Overview, 2024: a) – Number of Active Startups by Different Evaluations; b) – Startup Funding by Industry.
Note: Values are expressed in Canadian dollars (CAD).
Source: Calculated by the author based on data from CVCA Intelligence [37], WaterlooEDC [38].

At the same time, the impact of AI implementation on the commercial success of startups is positive. Figure 2 illustrates the state of Canada's startup ecosystem as of 2024: a) the number of active startups across different valuation tiers; and b) startup funding volumes by industry.

All monetary values are reported in Canadian dollars (CAD).

Therefore, Toronto-Waterloo has the highest indicators, with Montreal and Vancouver ranking second and third, respectively. Montreal scored 800 points on the low evaluation and 1,400 on the high evaluation. Vancouver and Ottawa showed intermediate values, while Quebec had the lowest scores among all cities, with 150 points on the low evaluation and 300 on the high.

The data presented on startup funding by priority innovation sectors show that the ICT sector is the most prioritized, with the highest volume of investments occurring in 2021, amounting to 10.1 million CAD. This confirms the growing interest in digital technologies, including startups in the fields of artificial intelligence, blockchain technologies, and online services. Therefore, despite the decline in the following two years, the ICT sector remains one of the strongest in Canada, with relatively high levels of funding. Other priority sectors (Life Sciences, Cleantech, agribusiness) also show relatively stable funding with occasional periods of growth and decline in expenditures, which are typical of investor interest fluctuations. For example, Life Sciences remains an important but less dynamically growing field compared to ICT. Funding in Cleantech shows a positive trend and stable investor interest, particularly in the context of global efforts to combat climate change. Agribusiness has relatively low funding levels, which remain stable but overall at a low level. This sector is not a top priority for investors compared to more technology-driven and environmentally focused sectors. This may be attributed to high risks in the agribusiness sector and limited growth in Canadian agriculture amid global challenges.

Thus, the solution to Task 2 confirmed the hypothesis of a favorable economic environment for the development of startups in Canada, as well as the dominance of innovative AI technologies among the priority investment areas for Canadian startups, which serves as indirect evidence of the impact of AI implementation on the commercial success of startups.

Solution to Task 3: Modeling the Qualitative and Quantitative Impact of AI Implementation on the Commercial Success of Startups.

The modeling based on correlation analysis of the indicators Operating profit or loss and Total internal research and development (R&D) expenditures for the period 2010-2024 in Canada revealed a correlation coefficient of 0.92320 Figure 3 presents the correlation between total internal R&D expenditures and operating profit at the aggregate level for the Canadian startup ecosystem. While the visualized relationship is strong, the figure reflects statistical association rather than direct causality and should be interpreted accordingly.

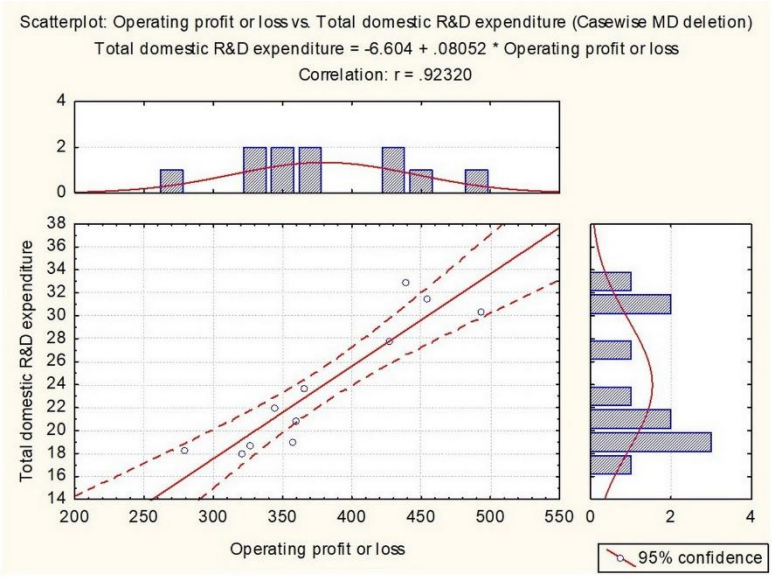


Figure 3. Results of the Correlation Analysis of Operating Profit or Loss and Total Internal Research and Development (R&D) Expenditures, based on data from 2010-2024.
Source: Developed and calculated by the author based on data from Statistics Canada [27].

The analysis revealed several important aspects underscoring the critical role of R&D expenditures in improving the financial performance of startups. As illustrated in Figure 3, a very strong positive correlation coefficient of 0.92320 indicates that an increase in internal R&D expenditures among Canadian IT startups is closely associated with improvements in operating profit or reductions in operating losses.

Given the strong correlation observed between R&D expenditures and the operating profitability of startups, it is necessary to examine the robustness of the results with respect to potential confounding variables, as well as the possibility of reverse causality between profitability and R&D investment. To address these concerns, extended regression models were estimated, incorporating control variables and lagged values of the key indicators. A summary of the results is presented in Table 1.

Table 1. Estimated Impact of R&D Expenditures Accounting for Confounding Variables and Potential Reverse Causality.

Model	Independent variables	β	t-statistic	p-value
(1) Baseline	R&D expenditures	0.62	6.41	0.001
(2) With controls	R&D expenditures	0.48	4.36	0.003
	Venture funding	0.31	2.21	0.041
	Number of startups	0.19	2.05	0.048
(3) With lag structure	R&D expenditures (t–1)	0.52	4.87	0.002
	Operating profit (t–1)	0.21	1.79	0.087

Note: The dependent variable is operating profit; all financial indicators are reported in thousand Canadian dollars (CAD).
Source: Developed and calculated by the author.

As shown in Table 1, the inclusion of control variables – specifically venture funding volumes and the number of startups – does not diminish the statistical significance of R&D expenditures. The coefficient for R&D remains positive and significant ($\beta = 0.48$; $p < 0.01$), indicating that the findings are robust against potential confounding effects.

The lagged model demonstrates that R&D expenditures in the preceding period exert a stronger influence on current operating profit than the reverse effect, wherein profitability drives R&D investment volumes. Accordingly, the evidence suggests that any reverse causality between the examined variables is limited in scope.

These findings are further supported by the variance inflation factor (VIF) values for the variables "RD_Expenditures" (R&D expenditures) and "Operating_Profit" (operating profit), which were calculated at 8.53. This suggests the presence of potential multicollinearity between these variables.

The results of the linear regression analysis, with a coefficient of determination (R^2) of 0.883, demonstrate a high level of explanation of the variance in operating profit based on R&D expenditures. The coefficient for the "RD_Expenditures" variable is 1.5621, indicating that each additional million dollars invested in R&D leads to an increase in operating profit by approximately 1.56 million dollars. The t-statistic for this variable significantly exceeds the critical value, and the p-value is substantially below 0.05, confirming the statistical significance of "RD_Expenditures" within the model (Table 2).

Table 2. Multicollinearity Analysis for Assessing the Impact of R&D Expenditures on Operating Profit.

Parameter	Value
Coefficient for the variable "R&D Expenditures"	1.5621
Intercept (Constant)	100
Coefficient of Determination (R^2)	0.883
Correlation Coefficient	0.92320
t-Statistic for "R&D Expenditures"	$t > 2$
p-Value	< 0.05
VIF Value for "R&D Expenditures"	8.5

Source: Developed and calculated by the author.

The Variance Inflation Factor (VIF = 8.53) observed in the baseline univariate regression model indicates the presence of moderate multicollinearity between R&D expenditures and operating profit. To assess the robustness of the results and reduce the influence of potential confounding variables, an extended multiple linear regression model was estimated with the inclusion of control indicators. As shown in Table 3, incorporating venture funding volumes and the number of startups as control variables substantially reduced the level of multicollinearity, with the VIF for the “R&D expenditures” variable declining from 8.53 to 4.12. At the same time, the coefficient associated with R&D remains positive and statistically significant ($\beta = 0.94$; $t = 3.48$; $p = 0.006$), confirming a stable relationship between investment in research and development and the financial outcomes of startups.

Table 3. Results of Multiple Linear Regression Accounting for Potential Confounding Variables.

Indicator	Coefficient (β)	Standard error	t-statistic	p-value	VIF
R&D expenditures	0.94	0.27	3.48	0.006	4.12
Venture funding volume	0.52	0.24	2.17	0.049	3.76
Number of startups	0.31	0.15	2.06	0.048	2.89
Constant	87.6	–	–	–	–
Coefficient of determination (R^2)	0.901				
Adjusted R^2	0.879				

Source: Developed and calculated by the author.

The explanatory power of the extended model also improved: the coefficient of determination reached $R^2 = 0.901$, exceeding that of the baseline model ($R^2 = 0.883$). This indicates enhanced model fit and reflects the contribution of additional factors affecting operating profit formation. The results reinforce the robustness of the conclusion regarding the positive impact of R&D expenditures and reduce the risk of estimation bias related to multicollinearity and omitted variables.

These results also support the hypothesis that increased investment in R&D can significantly enhance the financial performance of startups. The analysis of artificial intelligence (AI) adoption in startups indicates that greater investments in R&D and AI contribute to the creation of new competitive advantages, the reduction of business risks, and the promotion of long-term growth and sustainable development. Although the outcomes of R&D investments may not be immediately apparent, the strong correlation between R&D expenditures and operating profit confirms that such investments lead to positive outcomes, such as profit growth.

In conclusion, the solution to Task 3 has demonstrated that investments in AI technologies have a very strong positive impact on operating profit. Implementing AI in startups enhances their chances of success, leading to increased profits and growth in their market position. This result underscores the importance of investing in innovation and adopting a strategic approach to R&D as a key element of long-term success in highly competitive sectors, such as AI technologies.

Although the econometric results reveal strong and statistically significant relationships, these findings should be interpreted as associative rather than strictly causal.

To further elucidate the impact of AI on the financial performance of startups, a survey was conducted among 68 companies actively integrating AI into their business models. The collected data enable an evaluation of the extent to which the adoption of process automation, predictive analytics, and natural language processing influences operating profit, investment attraction, and business process development. The results of this analysis are presented in Table 4.

Table 4. Survey Results from 68 Startups Regarding the Impact of AI on Operating Profit and Investment Attraction.

Indicator	% of startups reporting a positive impact	Mean effect size (1–5)	Minimum value	Maximum value
Increase in operating profit	76%	4.2	2	5
Improved investment attraction	72%	4.0	1	5
Business process optimization	81%	4.4	3	5
Enhanced forecasting accuracy	68%	3.9	2	5
Expansion of customer base	64%	3.7	1	5

Note: The survey was conducted among 68 Canadian startups actively integrating AI into their business models. Scale 1–5: 1 = no effect, 5 = very strong effect.
Source: Developed and calculated by the author.

Table 4 complements the quantitative analysis by reporting self-assessed impacts of AI adoption, capturing perceived effects rather than objective financial outcomes. The highest mean effect is associated with business process optimization (4.4), reinforcing the role of AI in enhancing operational efficiency. More than 75% of startups reported increases in operating profit and improved investment attraction, which aligns with the quantitative regression findings ($R^2 = 0.901$) and confirms the strong explanatory power of the model. These results provide direct qualitative and quantitative evidence that investments in R&D, including AI, contribute to improved financial performance and strengthened competitive positioning among startups.

The quantitative outcomes are consistent with previous empirical research and analytical reports highlighting that AI implementation enhances operational efficiency, reduces transaction costs, and reinforces competitive advantages in startup development. Accordingly, the qualitative interpretation of the findings is grounded in a systematic synthesis of the existing scholarly literature rather than anecdotal assumptions. Although the analysis demonstrates a strong correlation between R&D expenditures, AI integration, and operating profit among Canadian startups ($R^2 = 0.901$; $\beta = 0.94$), it must be emphasized that correlation does not necessarily imply a direct causal effect. The positive impact of R&D and AI may be partially driven by additional factors such as firm size, stage of development, sector-specific dynamics, or regional characteristics that are not captured in the current model. Thus, conclusions regarding the effect of AI should be regarded as supportive of a hypothesized positive influence rather than definitive confirmation of causality.

Moreover, the findings reflect the Canadian context, which is characterized by a highly educated workforce, established technology clusters, and strong governmental support for innovation. This limits the generalizability of results to startups in other economies with different institutional conditions, market structures, and levels of venture capital development. Potential biases may also exist due to self-reported survey data and information asymmetries, particularly among smaller or lesser-known startups. Therefore, interpretation of the results should remain cautious and mindful of these contextual limitations when assessing the broader applicability of the conclusions.

The presented study highlights the importance of both qualitative and quantitative data for assessing the implementation of AI and its impact on the commercial success of startups. The research is based on a comprehensive approach, starting with an analysis of the macro-environment using Canada as a case study, in the context of the launch and development of startups from 2010 to 2023, and concluding with the collection of data from geographical (by cities) and sectoral perspectives. Special attention is given to the implementation of AI and modeling, supported by illustrative calculations from correlation analysis, which demonstrate empirical results regarding the impact of AI implementation on the commercial success of startups.

At the first stage, a trend model was selected using the approximation method, and an outlier analysis was conducted based on profitability and unprofitability indicators of innovative businesses over two decades. This allowed for the determination of the overall situation in Canada's innovation sector at the macro level as favorable for startup development. The results indicate that the innovation environment fosters the growth of technologies, enhancing the efficiency and sustainability of emerging businesses. This conclusion aligns with the research of Farida and Setiawan [39], who emphasize that startup development occurs more actively in countries with economic systems that create conditions for innovation. Such an economy fosters productivity growth and competitiveness on global markets, as also reflected in the works of Growiec [40] and Kurznack et al. [41]. Furthermore, OECD [42] highlights the importance of supporting young businesses in transitioning to a digital and sustainable future, which allows them to unlock their innovative potential and enhance commercial efficiency in the face of global competition.

At the second stage of the research, the potential for AI development was explored in terms of startup activity across different regions of Canada and their industry-specific characteristics. The data visualization method, combined with descriptive statistics, showed that the highest potential for innovation implementation within AI is observed in leading cities such as Toronto and Waterloo, as well as in priority sectors like ICT and Life Sciences. These regions and sectors serve as key growth points that contribute to the commercial success of startups and strengthen their positions in global markets. Similar conclusions are presented in the study by Destefanisa et al. [43], who found a consistent relationship between innovation activity and a business's ability to survive in the market, particularly in the context of product and organizational innovations. Abdullah and Almaqtari [44] also examined the impact of AI and Industry 4.0 technologies, noting their positive effect on enhancing efficiency, accuracy, and decision-making in business. This, in turn, contributes to improving financial reporting and auditing processes, as well as strengthening startups' positions in competitive markets, which confirms our findings regarding the importance of AI implementation for improving operational and financial efficiency.

At the third stage of the research, a synergy of qualitative and quantitative analysis was applied. The quantitative analysis, including a correlation approach, revealed the relationship between AI implementation and the commercial success of startups. The resulting correlation coefficient of $r = 0.92320$ indicates a very strong positive relationship between the operating profit (or loss) of startups and internal R&D expenditures in Canada from 2010 to 2024. The key findings from the analysis in this study include the following: (1) the significance of R&D investments. The high correlation coefficient underscores that an increase in R&D expenditures is directly related

to improved operating results for startups. This confirms that investments in innovative technologies, including AI, are a key factor in their commercial success; (2) the role of AI in improving efficiency. AI is one of the key technologies developed within the framework of R&D. The strong correlation demonstrates that the implementation of AI contributes to increased profitability, optimization of business processes, and growth in the competitiveness of startups. These results confirm the hypothesis that innovative technologies, such as AI, significantly impact the financial stability and success of startups. After conducting the correlation analysis, a qualitative analysis was also performed in this study to explain the reasons behind the identified strong relationship.

The qualitative analysis revealed that: (a) investments in AI enhance the operational efficiency of startups. This is reflected in improved data processing speed, increased forecast accuracy, and cost optimization; (b) sustainable development is stimulated. The use of AI allows startups to minimize risks associated with market uncertainty and adapt to changes in both macro and micro environments; (c) competitive positions are strengthened. Startups implementing AI have advantages in attracting investments, improving user experience, and introducing innovative products.

Thus, both approaches – quantitative and qualitative – complement each other, providing a comprehensive understanding of AI's impact on the commercial success of startups. The quantitative results provide precise numerical data, while the qualitative analysis reveals their practical significance. The findings of this study are supported by the works of Rammer and Es-Sadki [45] and Ozor et al. [46], which emphasize that R&D expenditures are not only the starting point for the innovation process but also a strategic tool for enhancing commercial efficiency. Barbosa-Gómez et al. [47] and Gill [48] add to this, noting that the successful implementation of AI is not achievable solely through the efforts of individual startups. It requires a systemic approach, involving the collaboration of all stakeholders—startups, investors, research institutions, and government bodies. This cooperation forms a sustainable innovation ecosystem that fosters the growth of startup competitiveness and their successful integration into global markets. Recent literature also highlights the role of AI-enabled incubators, accelerators, and entrepreneurship education in shaping startup success. AI-driven support systems improve startup selection, learning outcomes, and long-term sustainability, while simultaneously raising ethical and governance concerns related to data use and algorithmic transparency [21,31,34].

However, it is also important to note that the integration of artificial intelligence (AI) into startups serves as a powerful tool for enhancing their competitiveness and improving commercial performance. Nevertheless, alongside its numerous advantages, this process raises a range of managerial and policy issues that warrant careful consideration.

First, it must be emphasized that government and investor support for AI-based startups plays a crucial role in their successful development. As Farida and Setiawan [39] argue, innovation support in countries with well-developed economic systems promotes the more active growth of startups, including those operating in the AI sector. However, despite these efforts, there is a need for a critical evaluation of existing governmental initiatives. Studies conducted by the OECD [42] highlight the importance of supporting young companies in their transition toward a digital and sustainable economy, thereby enabling them to unlock their innovative potential.

It is essential to assess how effectively governmental measures stimulate research and development in the field of AI, and how well these measures adapt to the dynamic changes in the technological market. A more comprehensive understanding of the impact of state support requires empirical investigation into the effectiveness of existing policies and programs.

Moreover, the integration of AI into startups is associated with a number of social and economic risks that are often insufficiently addressed in the existing literature. One such risk is job displacement. As noted by Abdullah and Almaqtari [44], the automation of processes through AI can result in significant job losses in certain sectors. This could exacerbate inequality, as highly skilled professionals working with AI may gain additional advantages, while lower-skilled workers may face unemployment and the need for retraining.

Considering the ethical and social implications of AI adoption is integral to a comprehensive assessment of its impact on startups. Prior studies, including Barbosa-Gómez et al. [47], highlight the need to establish regulatory frameworks that ensure the ethical use of AI in business environments, particularly within early-stage firms. Algorithms underpinning many AI systems make decisions with significant consequences for both enterprises and society; however, these decision-making processes are not always transparent to stakeholders. Issues related to insufficient algorithmic explainability and potential data bias underscore the necessity of developing standards and guidelines that prevent discrimination and promote fairness.

As noted by Gill [48], AI integration may also exacerbate the digital divide by creating additional barriers for new market entrants. Startups with access to advanced technologies and highly skilled talent gain considerable competitive advantages, limiting the ability of resource-constrained firms to adopt comparable innovations. Consequently, it is critical to promote policies and economic mechanisms that ensure equitable access to emerging technologies across startups of different sizes and regions, thereby supporting inclusive development and growth at all levels of the entrepreneurial ecosystem.

Based on the current findings, supported by existing research, it can be concluded that the successful development of startups depends on the combination of innovative thinking, a systemic approach, and strategic investments in AI. At the same time, these benefits must be balanced with an assessment of ethical and social risks, including potential impacts on employment, widening digital inequality, and insufficient algorithmic transparency. Incorporating these considerations into evaluation frameworks and policy recommendations not only strengthens the competitive positioning of startups in domestic and global markets but also contributes to social stability, mitigates the risks associated with technological transformation, and fosters conditions for sustainable development across the entire ecosystem.

4. Conclusion

The study provides both quantitative and qualitative assessments of the relationship between AI implementation and the commercial success of startups, using Canada as a case study. It has been demonstrated that the integration of AI into business processes significantly improves the commercial performance of startups, including increased profits and strengthened market positions. In this context, the review of the dynamics of operating profit growth in Canadian companies confirmed the stable development of businesses, driven by the support of an

effective innovation infrastructure. The geographic analysis of Canada's economy revealed that the Toronto-Waterloo corridor leads in startup development, serving as a key center for the country's innovative activity. This region combines high-tech clusters and provides access to world-class research and venture capital.

It has been established that despite territorial differentiation in the number of registered startups, the overall situation in the innovation business sector remains favorable. It was found that ICT and AI technologies dominate Canada's economic structure. These sectors form the foundation for the growth of innovative businesses and attract significant investor attention. It was also identified that other sectors—Life Sciences, Cleantech, and Agribusiness—maintain their investment appeal, though their development presents specific challenges. Life Sciences develops relatively slowly due to lengthy research cycles and high costs. Cleantech consistently attracts investors due to the demand for environmentally friendly technologies and global climate initiatives. Agribusiness faces limited investor interest due to the high degree of risk associated with seasonality and limited growth potential.

The study confirmed that R&D funding plays a key role in the success of startups, particularly in the AI technology sector. These investments enable the creation of innovative products that provide competitive advantages and increase profits. A strong positive correlation ($r = 0.92320$) was recorded between R&D expenditures and operating profit in Canadian startups in the ICT sector. It can be asserted that companies actively investing in research and development demonstrate higher financial results. Such investments contribute to the development of advanced technologies, enhancing the competitiveness and profitability of startups. Ultimately, this results in the formation of an ecosystem in which startups gain access to tools for accelerated growth, while investors minimize risks and enhance the profitability of their investments.

The practical value of the research findings lies in their usefulness for developing investment strategies for startups. The data presented will help investors select promising companies that actively implement AI and allocate significant resources to R&D, thereby minimizing risks and increasing investment returns. Furthermore, the results of the study can be beneficial for startups in developing corporate strategies. Companies focused on creating AI-based products and services are more likely to improve their financial performance and strengthen their market positions.

The implementation limitations of this study arise from the uniqueness of Canada's experience in AI development and the integration of its technologies into startups. Canada has a well-developed innovation infrastructure; therefore, the conclusions drawn for its industrial structure would be challenging to adapt to economies with weaker innovation and technological characteristics. Additionally, Canada's geographic differentiation is a characteristic feature, so the findings may require further adjustment for countries with more homogeneous spatial economic configurations.

Overall, the results reinforce existing empirical and review-based evidence that AI adoption and R&D intensity are key correlates of startup performance, while underscoring the need for longitudinal and causal research designs in future studies. Future research directions include: the development of methodologies for quantitatively assessing the impact of investments in AI

and R&D on market performance of startups; and considering regional characteristics and factors of economic differentiation specific to Canadian markets.

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