South East European Journal
of Economics and Business
ISSN 2233-1999

Volume 21 (3) 2026, 119-134
DOI: 10.2478/jeb-2026-0023

FINANCIAL RESILIENCE AND INNOVATION INVESTMENT IN TIMES OF CRISIS

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Abstract

This paper investigates how financial resilience influences the intensity of innovation investment among firms that are already innovative. Using firm-level data for more than 32,000 Croatian enterprises with positive innovation records between 2014 and 2023, we estimate random-effects panel models linking innovation intensity—proxied by intangible asset investment—to liquidity, leverage, and crisis conditions. Results show that both liquidity and leverage positively affect innovation under normal circumstances, reflecting the enabling role of financial depth. During the COVID-19 crisis, however, leverage turned from a facilitator into a constraint, as indebted firms significantly reduced innovation, while liquidity retained its positive but stable influence. These findings contribute to the crisis–innovation literature by showing that liquidity and leverage play asymmetric roles during periods of systemic stress, revealing resilience as a conditional capability shaped not only by access to finance but also by the structure and flexibility of financial resources. The study provides new micro-level evidence from a small open economy and highlights policy implications for promoting balanced, crisis-resilient financing systems.

Keywords: Financial resilience; Innovation investment; Liquidity; Leverage; Economic crisis; Croatia

JEL codes: G32, O16, O32

1. Introduction

Periods of economic turbulence expose the fragility of firms and the uneven capacity of economies to withstand shocks. While crises often lead to contraction and uncertainty, they also serve as stress tests of resilience, separating firms that merely survive from those that adapt and grow stronger (Garrido-Moreno, Martin-Rojas, and Garcia-Morales 2024). In small open economies such as Croatia, where innovation systems remain shallow and access to capital is limited (Botric and Bozic 2017), the ability to sustain investment in intangible assets during downturns becomes crucial (Brancati, Minetti, and Zhu 2025). Innovation, manifested through research and development, acquisition of intellectual property, or digital transformation, forms the foundation of long-term competitiveness (Koporcic et al. 2025). Yet, when liquidity tightens and demand falls, such expenditures are among the first to be cut. Understanding why some firms persist with innovation despite adversity provides valuable insight into the mechanisms of resilience and the conditions under which innovation becomes a source of recovery rather than vulnerability (Xia et al. 2024).

The 2008 global financial crisis and the more recent COVID-19 shock highlighted that the consequences of systemic disruptions are not uniform. Some firms rapidly resumed or even increased innovation efforts after crises, while others abandoned them entirely. The difference often lies in financial resilience, the ability to absorb, adapt, and recover from adverse financial conditions (Arhinful and Radmehr 2023). Financial resilience encompasses liquidity and leverage structures that enable firms to withstand temporary revenue losses and sustain strategic investment. In economies with underdeveloped capital markets, such as many in Central and Eastern Europe, internal financial strength becomes a substitute for external funding (Ayalew and Xianzhi 2020). This makes the relationship between financial health and innovation particularly relevant. A deeper understanding of how financial configurations support or constrain innovation in turbulent periods is essential for designing effective policy responses that go beyond short-term liquidity assistance.

Existing research provides important but fragmented insights into this relationship. Studies following the 2008 crisis demonstrated that financially constrained firms tend to reduce R&D and delay innovation projects (Archibugi, Filippetti, and Frenz 2013). Others showed that innovation persistence, firms' ability to continue innovating over time, is strongly affected by internal financing capacity and access to credit (Czarnitzki and Hottenrott 2011). Evidence from emerging economies points to a dual challenge of limited innovation capability and restricted finance (Paunov 2013). More recent work highlights that resilience depends not only on financial resources but also on adaptive management and digital transformation (Bristow and Healy 2018; Martin and Sunley 2015). However, the micro-foundations of resilience, how specific financial indicators translate into innovation continuity during crises, remain underexplored, particularly in small transition economies (Czarnitzki and Giebel 2024). This study addresses that empirical gap using comprehensive firm-level data from Croatia.

The Croatian context offers a distinctive laboratory for this analysis. The economy combines features of advanced and emerging systems made of a modern service sector, deep tourism dependency, and a limited but growing base of technology-oriented firms. During the 2020-2021 pandemic crisis, GDP contracted sharply, yet some firms sustained innovation activities and even diversified through digital channels. These divergent trajectories raise questions about the role of internal financial buffers in maintaining innovation when external demand and liquidity collapse. Using firm-level panel data of more than 32,000 Croatian firms over a decade, we can observe how pre-crisis financial structures affected innovation investment during the downturn. This setting allows us to move beyond anecdotal case studies and offer generalizable evidence on the financial determinants of resilience.

Our conceptual approach integrates two complementary theoretical frameworks. The resource-based view (RBV) posits that sustained competitive

advantage stems from valuable and inimitable resources such as knowledge, technological capabilities, and organizational routines (Barney 1991; Grant 1991). Yet, developing and maintaining these assets requires continuous investment and financial slack that allows firms to experiment and absorb risk. The financial resilience perspective emphasizes the capacity of firms to withstand shocks while preserving strategic functions such as innovation (Xia et al. 2024; Pilav-Velic, Jahic, and Krndzija 2024). Within this integrated framework, liquidity and access to credit emerge as enablers of innovation, providing the flexibility and financing needed to support long-term capability building (Homayoun, Pazhohi, and Tamam 2024). However, during crises, the composition of financial resources becomes critical. Debt that supports growth in normal periods can transform into a constraint when revenues collapse (Nguyen, Giang, and Thu 2025). By empirically testing these mechanisms, the study contributes to a deeper understanding of how the structure and quality of financial resources condition firms' innovative effort under uncertainty.

The research problem addressed in this paper can therefore be stated as follows: to what extent does financial resilience shape the intensity of innovation investment among innovative firms during economic crises? Using a sample restricted to enterprises with positive innovation records, we examine how liquidity and leverage influence the scale of intangible asset investment before and during the COVID-19 shock. We hypothesize that both liquidity and leverage contribute positively to innovation intensity under stable conditions, reflecting resource availability and access to external finance. However, we expect that the role of leverage changes during crises, when indebted firms face heightened repayment obligations and reduced flexibility, leading to lower innovation effort. By identifying these relationships, the study clarifies how financial depth and structure, rather than mere access to funds, determine the resilience of innovation in small open economies.

This study contributes to the literature in three interrelated ways. First, unlike most prior research that examines the probability of firms engaging in innovation, we focus on the intensity of innovation investment among firms that are already innovative. This distinction is important because the mechanisms that determine whether firms innovate may differ substantially from those that shape the scale and continuity of innovation once firms have entered an innovation trajectory. Second, the paper advances the existing crisis–innovation literature by demonstrating the asymmetric behavior of liquidity and leverage under conditions of systemic stress. While both dimensions of financial depth support innovation under stable conditions, leverage becomes a source of fragility during crises whereas liquidity retains a stable enabling role. This highlights that financial resilience depends not only on the availability of financial resources but also on their structure and flexibility across changing macroeconomic environments. Third, the study provides evidence from a small, bank-based and service-oriented economy where innovation financing relies heavily on internal liquidity and debt-based funding rather than developed equity or venture capital markets. In such contexts, the relationship between financial structure and innovation resilience becomes particularly visible, offering insights that differ from those derived from large advanced economies with diversified financial systems.

The remainder of this paper is structured as follows. Section 2 reviews the theoretical background and prior empirical evidence on innovation persistence, financial constraints, and firm resilience. Section 3 presents the data, variable construction, and descriptive patterns across firms and sectors. It also outlines the empirical model and the estimation strategy. Section 4 discusses the main findings, highlighting how financial structures condition firms' innovation responses to crisis environments. Section 5 concludes with policy implications for supporting innovation resilience through financial instruments and crisis-response measures, particularly in economies with shallow capital markets. Taken together, the paper contributes to understanding how the financial anatomy of firms determines their capacity to sustain innovative activity when it is most threatened but also most needed.

2. Conceptual framework

2.1. Theoretical framework and literature review

The literature on innovation persistence emphasizes that innovation is not a one-time event but a cumulative and path-dependent process (Colombelli and von Tunzelmann 2011; Pham et al. 2018). Firms that innovate in one period are more likely to continue innovating in subsequent periods, as knowledge, routines, and organizational structures evolve incrementally. However, this persistence depends heavily on the stability of financial and managerial conditions (Santos, Cincera, and Cerull 2024). Empirical studies find that sustained innovation requires both absorptive capacity and internal financial resources to support uncertain returns. Disruptions in cash flow or external financing can interrupt this cumulative process, leading to long-term productivity losses. Consequently, the study of innovation persistence provides a useful lens for understanding how firms' financial characteristics determine whether they can maintain innovative activity through periods of stress and volatility.

A large body of research has investigated the relationship between financial factors and innovation outcomes. Theoretical models of finance and innovation (Hall and Lerner 2010) highlight the special nature of R&D investment and label it as risky, intangible, and often unsuitable as collateral. Therefore, firms rely heavily on internal finance and accumulated profits to fund innovation. Empirical evidence supports this argument, showing that firms with higher liquidity and profitability tend to invest more consistently in innovation (Hottenrott and Peters 2012). Conversely, high leverage and dependence on short-term credit increase vulnerability to shocks in credit supply (Manaresi and Pierri 2019). In this literature, the financial structure of firms functions as a channel through which macroeconomic fluctuations translate into changes in innovation behavior. Financially robust firms can smooth expenditures and maintain their innovation pipelines, while weaker firms are forced into contractionary strategies.

The crisis literature provides further insight into how these mechanisms operate under extreme conditions. During the global financial crisis of 2008–2009, firms in both advanced and emerging economies significantly reduced innovation spending, but the magnitude of reduction varied widely across financial profiles (Archibugi, Filippetti, and Frenz 2013). Firms with ample liquidity and strong internal funding capacities displayed higher innovation persistence, while those with high leverage or constrained access to credit withdrew from innovation activities altogether (Paunov 2013). In the aftermath, recovery trajectories diverged, with financially resilient firms regaining competitiveness more rapidly. Similar patterns were observed during the COVID-19 pandemic, where digital-oriented and financially healthier firms continued to invest in innovation as a survival strategy. These findings underline that crises amplify the importance of firm-level financial health, transforming it from a background condition into a decisive factor of adaptive capacity.

Recent literature increasingly examines resilience as a firm-level capability to absorb shocks while preserving strategic activities such as innovation (Bristow and Healy 2018; Martin and Sunley 2015). In the context of firms, resilience primarily reflects the ability to maintain operational continuity, adapt financial structures, and sustain long-term investment under conditions of uncertainty. Existing studies identify several determinants of resilience, including financial robustness, organizational flexibility, managerial capability, and network embeddedness. Among these, financial resilience occupies a central position because liquidity shortages and excessive debt exposure can rapidly constrain firms' strategic choices during crises. From this perspective, liquidity and leverage are not simply accounting indicators but observable expressions of firms' financial flexibility and vulnerability. Their configuration influences whether firms can preserve innovation investment when external conditions deteriorate.

Financial resilience should nevertheless be understood as a multidimensional concept that extends beyond the balance-sheet indicators employed in this study. In broader terms, resilience may also depend on factors such as the maturity structure of debt, firms' access to refinancing, ownership arrangements, relationships with financial institutions, public support mechanisms, and

managerial capacity to reorganize resources during crises (Liu, Chen, and Xiao 2025). The empirical analysis presented here captures only the financial dimension of resilience that can be consistently observed through firm-level accounting data, specifically liquidity and leverage positions. These indicators do not exhaust the concept of resilience, nor do they fully reflect firms' strategic adaptability or institutional embeddedness. Rather, they represent observable proxies for the degree of financial flexibility and exposure that condition firms' ability to sustain innovation investment under conditions of uncertainty. The findings should therefore be interpreted as evidence on the balance-sheet foundations of innovation resilience rather than as a comprehensive measure of resilience in its entirety.

In small open economies and transitional contexts, these relationships become particularly acute. Studies of Central and Eastern Europe highlight structural weaknesses in innovation financing due to underdeveloped venture capital markets, limited risk-sharing instruments, and a strong dependence on bank credit (Karsai 2023; Zavarska et al. 2024). During crises, credit rationing intensifies, and policy measures often prioritize short-term liquidity over long-term investment. Consequently, firms' survival depends largely on their own financial resilience. Moreover, the industrial structure of such economies, dominated by small and medium-sized enterprises (SMEs) and service-oriented activities, implies that innovation often takes the form of incremental improvements and digitalization rather than formal R&D (Vujanovic et al. 2022). This makes intangible investment an appropriate proxy for innovative effort (Romero-Alvarez et al. 2025). By examining how financial characteristics influence these investments, we can better understand the dynamics of resilience in peripheral innovation systems.

The theoretical synthesis of this literature suggests an integrative framework combining the Resource-Based View (RBV) and Financial Resilience Theory. The RBV posits that sustained competitive advantage arises from valuable, rare, and non-imitable resources, including technological knowledge and organizational routines (Barney 1991). Yet, developing and maintaining such resources requires financial slack of uncommitted internal funds that allow experimentation and risk-taking (Bourgeois 1981). Financial resilience theory complements this view by emphasizing the adaptive function of financial structures: firms with robust liquidity and low leverage can absorb external shocks and reallocate resources to protect strategic capabilities (Pham et al. 2018; Cevik and Miryugin 2020; Liu, Chen, and Xiao 2025). In contrast, over-leveraged firms face constrained decision-making, often prioritizing debt servicing over innovation. Together, these perspectives imply that financial resilience is a precondition for the continuity of innovation trajectories when external conditions deteriorate.

2.2. Hypotheses development

This subsection develops hypotheses on how financial structures condition the intensity of innovation investment among firms that are already innovative. The baseline hypotheses concerning liquidity and leverage primarily establish the expected relationship between financial depth and innovation under relatively stable economic conditions. While these relationships are well grounded in existing finance and innovation literature, they serve here as an analytical benchmark against which the crisis-period dynamics can be interpreted. The core contribution of the analysis therefore lies in examining whether the innovation effects of liquidity and leverage remain stable or become asymmetric during periods of systemic stress. Building on the resource-based view (RBV) and financial resilience theory, we argue that the composition of firms' financial resources, specifically liquidity and leverage, plays a crucial role in shaping firms' innovative behavior across changing macroeconomic environments.

The RBV highlights that financial slack and access to capital are prerequisites for building and maintaining valuable, inimitable resources such as knowledge, technology, and organizational capabilities. Financial resilience theory complements this perspective by focusing on firms' ability to adapt financial configurations to preserve strategic priorities under uncertainty. Together, these frameworks imply that liquidity and leverage can act both as enablers and constraints, depending on

the broader economic environment. The following hypotheses examine these relationships under stable and crisis conditions to identify how financial structures affect firms' innovation intensity.

Liquidity represents the most flexible form of financial resource and a fundamental component of resilience. It allows firms to smooth expenditures, absorb short-term shocks, and sustain long-term investments in innovation. Liquid firms are less dependent on external financing and can fund projects whose returns are uncertain or delayed. Prior empirical work consistently shows that higher liquidity reduces financial constraints and encourages investment in R&D and other intangible assets (Hottenrott and Peters 2012; Cowling et al. 2023). For firms that are already innovative, liquidity provides the buffer necessary to maintain and deepen innovation activities. We therefore expect a positive relationship between liquidity and the intensity of innovation investment. At the same time, it remains an open question whether the role of liquidity changes significantly during crises, when the broader economic contraction may limit opportunities for its productive use.

H1: Liquidity positively influences the intensity of innovation investment among innovative firms.

Leverage captures firms' reliance on external borrowing and represents another important dimension of financial resilience. Moderate levels of debt can facilitate innovation by expanding the pool of resources available for investment in technology, digitalization, and intangible assets. Access to credit may complement internal funds, enabling firms to scale projects that exceed their own financial capacity (Hall and Lerner 2010; Geelen, Hajda, and Morellec 2022). In this sense, leverage can act as a catalyst for innovation, especially in bank-oriented economies where equity markets are underdeveloped. We therefore expect a positive association between leverage and innovation intensity among innovative firms. Nevertheless, leverage also entails repayment obligations that can constrain flexibility when external conditions deteriorate. The net impact of debt on innovation thus depends on whether it functions primarily as a growth enabler or becomes a burden under stress.

H2: Leverage positively influences the intensity of innovation investment among innovative firms.

Economic crises offer a natural context in which to test how the effects of liquidity and leverage evolve when uncertainty and financial stress increase. Studies show that during downturns, firms' financial structures become decisive for their ability to continue innovation activities (Hardy and Sever 2021). Theoretical arguments suggest that the role of liquidity may remain largely stable, as it continues to provide a buffer but may not become significantly more influential if overall investment opportunities contract (Malamud and Zucchi 2019). Leverage, however, can quickly transform from a facilitator of growth into a source of vulnerability, as debt servicing absorbs cash flow and discourages risk-taking. Empirical evidence from crisis-period firm data confirms that excessive leverage amplifies vulnerability and limits firms' adaptive capacity (Iammarino, Sodano, and Vittorino 2021). These contrasting dynamics highlight the conditional nature of financial resilience: the same financial instruments that support innovation in stable periods may constrain it during downturns. Testing these relationships helps uncover whether the architecture of firms' financial resources strengthens or weakens their capacity to sustain innovation under pressure.

H3a: The effect of liquidity on innovation investment does not significantly change during crisis periods.

H3b: The effect of leverage on innovation investment weakens or turns negative during crisis periods.

3. Data, variables and descriptive analysis

3.1. Data and sample description

The empirical analysis is based on firm-level panel data obtained from the Financial Agency (FINA), which collects annual financial statements for all registered enterprises in Croatia. These statements provide detailed information on assets, liabilities, revenues, expenditures, and employment, enabling a comprehensive assessment of firms' financial and operational characteristics over time. From this

population, we construct a sample of innovative firms, defined as enterprises reporting positive investment in intangible assets during the observed period. This focus reflects the paper's central interest in the *intensity* rather than the *occurrence* of innovation. Once a firm engages in innovation, the key question becomes how financial structure shapes its ability to sustain and scale such activities. Analyzing only innovative firms therefore isolates variation in financial resilience among active innovators, rather than conflating it with structural differences between innovators and non-innovators.

To ensure comparability, the analysis is restricted to non-financial corporations and excludes enterprises operating in banking, insurance, public administration, agriculture, and mining. Financial institutions and public entities are omitted because their accounting frameworks, regulatory environments, and innovation incentives differ substantially from those of market-oriented firms. Agriculture and mining are excluded because they operate under distinct asset structures, strong dependence on natural resource endowments, and innovation patterns heavily shaped by regulation, seasonal cycles, and commodity price shocks. Including them would introduce heterogeneity unrelated to financial resilience or firm-level decision-making. The resulting dataset thus concentrates on sectors of manufacturing, construction, trade, and services where firm-level financial behavior and strategic investment choices can be meaningfully compared.

Table 1. Number of observations

Year	Number of firms
2014	11,002
2015	11,151
2016	11,719
2017	12,061
2018	12,627
2019	13,144
2020	13,437
2021	14,085
2022	14,782
2023	15,310
TOTAL	129,318

Source: Author based on FINA dataset

After applying these criteria and removing observations with missing or inconsistent financial data, the final unbalanced panel comprises more than 32,000 innovative firms observed between 2014 and 2023 (Table 1). This ten-year horizon encompasses both pre-crisis stability and the COVID-19 shock, providing an opportunity to examine how financial structures influence firms' ability to maintain innovation through changing macroeconomic conditions. The sample's breadth captures the diversity of Croatian industry while remaining focused on firms for which financial management and innovation investment are core strategic decisions. Its longitudinal design supports the use of panel econometric techniques that control for unobserved heterogeneity, allowing us to identify how liquidity and leverage contribute to resilience among active innovators over time.

To test the hypotheses developed in Section 2, we construct variables representing innovation investment, financial resilience, and control characteristics. The dependent variable, *innovation investment intensity*, is proxied by firms' expenditures on intangible assets such as development costs, patents, licenses, and software, scaled by total assets. In economies like Croatia, and more broadly across Central and Eastern Europe, innovation activity often relies on adoption and adaptation of external knowledge rather than on original R&D creation. As a result, intangible assets capture a broad spectrum of innovative efforts, including digitalization, process modernization, and capability upgrading. This measure is therefore a realistic and comprehensive indicator of innovation input in contexts where formal R&D spending is limited and frequently capitalized as an intangible asset rather than reported as current expenditure.

Nevertheless, the use of intangible assets as a proxy for innovation investment is not without limitations. Intangible asset positions may also reflect acquisitions, accounting capitalization practices, goodwill recognition, or strategic balance-sheet adjustments that are not directly linked to active innovation processes. This concern may become particularly relevant during crisis periods, when firms could alter capitalization behavior in response to liquidity pressures, tax considerations, or reporting incentives. The measure employed in this

study should therefore be interpreted as capturing firms' investment in knowledge-based and intangible capabilities more broadly rather than formal R&D expenditure alone. Despite these limitations, intangible assets remain one of the few consistently available firm-level indicators capable of capturing innovation-related investment across a large panel of firms in a bank-based economy where innovation frequently takes the form of incremental upgrading, software acquisition, digitalization, and technology absorption rather than formal research activity. The interpretation of results therefore focuses on changes in firms' commitment to intangible capability accumulation rather than on narrowly defined technological invention.

Key explanatory variables of liquidity and leverage represent the two main dimensions of financial resilience. Liquidity indicates the availability of immediately deployable resources, enabling firms to absorb short-term shocks and maintain investment continuity without depending on volatile credit conditions. Leverage captures access to external finance and reflects the capacity of firms to expand innovation activity beyond internally generated funds. Together, these variables describe the financial flexibility and depth that determine whether firms can sustain long-term, risk-bearing investment in knowledge and technology. Their inclusion directly operationalizes the concepts of resource slack and adaptive financial structure drawn from the resource-based view and financial resilience theory.

The model also includes several control variables to isolate the effects of financial structure from other firm-specific and macroeconomic factors. Firm size (measured as the natural logarithm of number of employees) controls for scale advantages and greater access to finance typically enjoyed by larger firms. A crisis dummy equals one for the years 2020–2021, capturing the systemic shock caused by the COVID-19 pandemic and its potential effect on investment decisions. Although the binary specification simplifies the crisis into a common macroeconomic shock, the actual intensity and mechanisms of disruption differed substantially across sectors and stages of the pandemic. Some industries experienced abrupt demand collapses and mobility restrictions, while others faced supply-chain disruptions, labor shortages, or accelerated digitalization pressures. The crisis dummy should therefore be interpreted as capturing the broad systemic environment of heightened uncertainty and economic disruption rather than a homogeneous financial shock affecting all firms equally. The inclusion of year and sectoral controls partially accounts for this heterogeneity, but the estimated effects inevitably reflect the interaction of financial pressures with broader demand, regulatory, and operational constraints.

In addition, we include sectoral dummies at the NACE Rev. 2 two-digit level to account for structural heterogeneity in innovation patterns across industries, and year dummies to control for

Table 2. Variable definitions

Variable	Symbol	Definition
Innovation investment intensity	Innov	(Intangible assets / total assets) × 100 – natural logarithm
Liquidity ratio	Liq	Current assets / Current liabilities
Leverage ratio	Lev	Total debt / total assets
Firm size	Size	Number of employees – natural logarithm
Crisis dummy	Crisis	Categorical – 1 for years 2020-2021, 0 otherwise
Year dummies	Year	Categorical variables for years covered by the sample
Industry dummies	Ind	Categorical variables for NACE Rev. 2 industries included in the sample

Source: Author based on FINA dataset

time-specific influences such as macroeconomic fluctuations, policy interventions, and technological trends. These controls ensure that estimated relationships reflect firm-level financial resilience rather than broader cyclical or sectoral dynamics. Finally, all financial ratios are winsorized at the 1st and 99th percentiles to reduce the influence of outliers. Table 2 provides definitions of variables.

3.2. Descriptive analysis and stylized facts

Before turning to econometric estimation, it is useful to examine the main characteristics of the dataset and the distributional patterns that motivate the empirical analysis. Descriptive statistics (Table 3) reveal pronounced heterogeneity in both financial indicators and innovation intensity. On average, intangible assets represent around 21.5% of total assets, though the standard deviation of 30.4 percentage points indicates substantial variation across firms. Some companies record negligible investment, while others allocate nearly all assets to intangibles, reflecting different stages of digital and technological maturity. The broad range illustrates the coexistence of traditional, asset-based business models and a smaller group of firms increasingly oriented toward knowledge and technology.

The financial indicators also show wide dispersion. The average leverage ratio is 0.72, suggesting that debt finances roughly three quarters of total assets on average, though the maximum value above ten points to pockets of very high indebtedness. The mean liquidity ratio of 3.06 indicates a comfortable short-term solvency position, but the large standard deviation (5.77) reflects marked differences across sectors and firm sizes. Some firms operate with very lean working capital, while others maintain substantial cash or receivable reserves. The average firm size, measured by the number of employees, is around 38, confirming the dominance of small and medium-sized enterprises in the Croatian economy. However, the wide variation, ranging from single-person microenterprises to firms employing more than 14,000 workers, illustrates the structural duality of the business sector, where a limited number of large firms coexist with a broad base of smaller companies characterized by tighter financial constraints and more volatile innovation spending.

3.3. Estimation strategy and model summary

The empirical model formalizes the relationships hypothesized in Section 2 by estimating the following random-effects specification:

$$Innov_{it} = \alpha + \beta_1 Liq_{it} + \beta_2 Lev_{it} + \beta_3 Crisis_t + \gamma X_{it} + \varepsilon_{it} \quad (1)$$

where $Innov_{it}$ denotes the innovation investment intensity of firm i in year t, Liq_{it} and Lev_{it} are indicators of financial resilience, $Crisis_t$ captures the COVID-19 years (2020–2021), X_{it} represents a vector of control variables (firm size, sector, and year dummies) and ε_{it} is the idiosyncratic error term. The empirical specification is estimated using a random-effects panel model. The choice of random effects reflects the structure and objectives of the analysis, which seeks to examine both within-firm and between-firm variation in innovation investment intensity across a large and heterogeneous sample of innovative enterprises. A fixed-effects

Table 3. Descriptive statistics of continuous variables

Variable	Mean	Std. dev.	Min	Max
Innov	21.51	30.36	0	100
Lev	0.72	0.80	0.0039	10.27
Liq	3.06	5.77	0.0037	121.65
Size	38.22	224.10	1	14,060

Source: Author based on FINA data

specification would absorb a substantial share of persistent cross-sectional variation related to firms' financial structures and long-term innovation orientation, thereby limiting the ability to identify how differences in liquidity and leverage relate to innovation intensity across firms. At the same time, the use of random effects raises the possibility that unobserved firm characteristics such as managerial quality, strategic orientation, or organizational capability may be correlated with financial variables. Restricting the sample to firms with positive innovation records partially mitigates this concern by reducing heterogeneity between innovators and non-innovators, though it does not eliminate it entirely. The inclusion of sectoral and year controls further reduces omitted heterogeneity linked to structural industry differences and macroeconomic conditions. The results should therefore be interpreted as identifying conditional associations between financial structure and innovation intensity rather than strict causal effects.

The estimation proceeds in three stages to capture the incremental contribution of crisis interactions. In the baseline model, innovation intensity is regressed on liquidity, leverage, and controls, providing an assessment of how financial resilience relates to innovation under normal conditions. The second model introduces the interaction between liquidity and crisis years to examine whether the importance of liquidity changed during the pandemic. The third model replaces this interaction with the term between leverage and crisis years, testing whether indebted firms exhibited weaker innovation performance under heightened uncertainty. This stepwise approach isolates the distinct mechanisms through which financial configurations condition innovation behavior before and during the crisis period, ensuring transparency and interpretability of results.

4. Empirical results and discussion

Table 4 reports the results of the random-effects estimation for the relationship between financial resilience and innovation investment intensity among Croatian innovative firms. The dependent variable is the natural logarithm of the share of intangible assets in total assets (expressed in percentages). The model is estimated in three steps. The first specification includes liquidity and leverage as key indicators of financial structure along with firm size, sectoral, and year dummies and controls for crisis period. The second introduces an interaction between liquidity and the COVID-19 crisis dummy to capture whether financial slack became more relevant during the pandemic. The third replaces this term with the interaction between leverage and the crisis dummy, testing whether indebtedness constrained firms' ability to sustain innovation when revenues and liquidity pressures intensified.

Across all specifications, the results confirm that financial resilience plays a decisive role in shaping the intensity of innovation investment among innovative firms. The coefficients on liquidity and leverage are positive and statistically significant throughout, while the crisis dummy is negative, reflecting an overall contraction of innovation during the pandemic period. These findings are consistent with the view that both internal and external financial resources act as enablers of innovation under normal circumstances, yet crises impose systemic constraints that reduce aggregate innovation activity. However, the conditional effects differ across the two financial dimensions as liquidity remains broadly stable in its impact, while leverage turns from an enabler in normal times into a liability during crisis years.

Table 4. Results of estimation

Variable	Model (1)	Model (2)	Model (3)
Lev	0.16*** (0.008)	0.16*** (0.008)	0.17*** (0.009)
Liq	0.002** (0.001)	0.002* (0.001)	0.002** (0.001)
Crisis	-0.20*** (0.018)	-0.21*** (0.019)	-0.17*** (0.020)
Size (ln)	-0.42*** (0.007)	-0.42*** (0.007)	-0.42*** (0.007)
Liq*Crisis	-	0.001 (0.002)	-
Lev*Crisis	-	-	-0.05*** (0.012)
Year dummies	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes
Constant	Yes	Yes	Yes
Wald	10,109***	10,109***	10,123***

Note: ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels of significance. Standard errors in brackets.ource: Author

The positive and significant coefficient on liquidity ($\beta \approx 0.002$, $p < 0.05$) indicates that firms with stronger liquidity positions allocate a slightly larger share of assets to intangible investment. Although the magnitude appears modest, the elasticity is meaningful given the logarithmic transformation of the dependent variable. A one-unit increase in the current ratio corresponds to roughly a 0.2 percentage points increase in innovation intensity, after controlling for firm size, sector, and time effects. This result confirms the theoretical expectation that liquid firms can better sustain investment in knowledge and technology, as they rely less on volatile credit conditions and can finance riskier or longer-term projects internally. In small open economies like Croatia, where capital markets remain shallow and access to external funding is uneven, liquidity effectively substitutes for underdeveloped financial infrastructure. Firms capable of maintaining liquidity buffers can shield strategic expenditures from short-term volatility, reinforcing the role of financial slack as a microfoundation of resilience.

Leverage also exerts a positive and economically substantial influence on innovation intensity in the baseline model ($\beta \approx 0.16$, $p < 0.01$). This indicates that moderate indebtedness supports innovation by expanding the pool of resources available for investment and enabling firms to exploit economies of scale in R&D and digitalization. In a context where retained earnings and equity financing are limited, debt serves as an important catalyst for innovation. This finding aligns with prior evidence that external finance allows firms to pursue growth-oriented and risk-bearing strategies that exceed their internal liquidity capacity. The result also resonates with the resource-based perspective, according to which innovation depends on the ability to mobilize and reconfigure both tangible and financial resources in pursuit of competitive advantage. For Croatian firms, access to credit appears to have played a supportive role in fostering investment in intangible assets during the pre-crisis period of economic expansion.

The crisis dummy is negative and statistically significant ($\beta \approx -0.20$, $p < 0.01$), reflecting a

broad contraction of innovation investment during 2020–2021. This decline mirrors the collapse of tourism and related service activities, supply-chain disruptions, and pervasive revenue uncertainty that compelled firms to prioritize liquidity preservation. However, the interactions between financial structure and crisis years provide a clearer picture of how financial resilience conditioned innovation behavior during this period.

The liquidity–crisis interaction is statistically insignificant, suggesting that while liquidity continued to support innovation investment, its relative importance did not increase during the pandemic period. One possible interpretation is that the broader contraction in demand and heightened uncertainty reduced firms' incentives to expand innovation investment even when liquid resources were available. However, alternative mechanisms may also explain this stability. Firms may have adopted precautionary liquidity hoarding strategies, preserved cash buffers in anticipation of prolonged uncertainty, or become more risk-averse in allocating resources to long-term projects during the crisis. Because the empirical analysis cannot directly distinguish between these behavioral channels, the results should be interpreted cautiously as evidence that liquidity retained a stable enabling role rather than becoming a stronger counter-cyclical driver of innovation.

In contrast, the interaction between leverage and crisis years is negative and significant ($\beta \approx -0.05$, $p < 0.01$), indicating that indebted firms curtailed innovation more sharply during the pandemic. This finding highlights the asymmetric nature of financial resilience: leverage that serves as an enabler of innovation in normal times may become a source of vulnerability when external shocks reduce cash inflows, weaken demand conditions, disrupt operations, and tighten financial constraints simultaneously. The balance-sheet measure employed in the analysis does not distinguish between short-term and long-term debt structures, which may carry different implications for innovation resilience. Short-term liabilities are likely to generate more immediate liquidity pressures during crises, whereas longer-term debt may provide greater adjustment space and refinancing flexibility. The estimated negative interaction should therefore be interpreted as reflecting the overall burden of indebtedness rather than the specific effects of particular debt maturities.

The result is, however, consistent with financial fragility theory (Minsky 1986), which posits that periods of stability encourage higher leverage, but crises expose the unsustainability of debt-dependent growth. For Croatian firms, the pandemic revealed this dynamic vividly as companies that expanded through borrowing during the preceding growth phase were more likely to retract investment in intangibles once liquidity pressures mounted. The negative leverage–crisis interaction thus highlights that resilience depends not only on the availability of finance but also on its structure and timing.

Firm size, measured by the number of employees, is negatively associated with innovation intensity ($\beta \approx -0.42$, $p < 0.01$), indicating that smaller firms allocate a higher proportion of assets to intangibles. This pattern may reflect greater agility and willingness to experiment among smaller enterprises, while larger firms may exhibit inertia, complex decision processes, and longer investment cycles. Sectoral and year dummies are jointly significant, confirming that industry composition and macroeconomic trends play an important role in explaining variation in innovation investment. Together, the model's results account for both structural heterogeneity and cyclical factors, yielding a coherent picture of how firm-level financial conditions interact with broader economic dynamics.

These findings contribute several important insights to the literature on innovation resilience in small open economies. First, they confirm that financial depth as reflected in liquidity and access to credit remains a fundamental precondition for sustaining innovation. Yet, liquidity's protective role is steady rather than counter-cyclical, while leverage's benefits are highly contingent on economic stability. This asymmetry suggests that resilience is a conditional capability. It depends on the interaction between firm-level financial architecture and the external environment. Second, the evidence questions the notion that crises necessarily reward prudence alone. Firms that had built up debt during expansionary periods were not punished for

doing so ex ante. Rather, their vulnerability was exposed when macroeconomic shocks reduced revenue streams. This temporal dimension reveals that resilience is dynamic and path-dependent. It emerges not only from the accumulation of buffers but also from the ability to recalibrate financial exposure as conditions change.

Finally, the results carry broader policy implications. For economies like Croatia, where external shocks frequently originate outside domestic control, fostering innovation resilience requires balanced financial development. Credit expansion can stimulate growth but must be accompanied by mechanisms that prevent excessive leverage, such as equity financing incentives, loan restructuring frameworks, and policies that encourage reinvestment of profits into innovation. Similarly, instruments that enhance liquidity through working capital guarantees, accelerated VAT refunds, or deferred tax payments can help firms maintain innovation continuity when crises strike. The evidence suggests that neither liquidity nor credit alone ensures resilience; rather, the composition and flexibility of financial resources determine whether firms can sustain knowledge accumulation under pressure. By understanding and addressing this financial anatomy, policymakers can strengthen the microeconomic foundations of innovation systems and reduce the vulnerability of firms to future crises.

5. Conclusions and policy implications

Crises are critical junctures that compress time, magnify uncertainty, and expose the underlying architecture of firm resilience. They reveal not only which enterprises possess the resources to endure but also which can adapt and continue investing in the future when short-term survival dominates attention. This paper examined how financial resilience, captured through liquidity and leverage, shapes the ability of innovative firms to sustain investment in intangible assets during periods of economic distress. Using a large panel of Croatian enterprises over 2014–2023, the analysis shows that both liquidity and leverage are positively associated with innovation intensity under normal conditions. Yet, the relationship between debt and innovation turns fragile when uncertainty peaks. During the COVID-19 crisis, leverage lost its enabling role, and indebted firms reduced innovation significantly. Liquidity, while still beneficial, did not become more decisive, suggesting that the crisis restricted opportunities to use financial buffers productively rather than exposing their absence.

Theoretically, these findings integrate the resource-based view (RBV) and financial resilience theory, highlighting that the capacity to innovate depends not only on owning strategic assets but also on maintaining the financial elasticity needed to protect them. From an RBV perspective, firms rely on valuable and hard-to-imitate resources such as knowledge, routines, and technological capabilities that require long-term investment. Financial resilience complements this by emphasizing adaptability. Firms with sufficient liquidity and balanced leverage structures can absorb shocks, redeploy resources, and avoid disruptive retrenchment. However, the evidence shows that resilience is not a static attribute but a conditional capability. Financial structures that foster innovation in expansionary periods can become liabilities under stress. In other words, the strength of a firm's balance sheet lies not only in its magnitude but in its flexibility to shift from growth-oriented to survival-oriented modes without dismantling its innovation capacity.

Empirically, the study contributes to the growing body of research on the micro-foundations of innovation resilience by shifting attention from the occurrence of innovation to the intensity and continuity of innovation investment among already innovative firms, while simultaneously demonstrating how liquidity and leverage exhibit asymmetric effects under crisis conditions in a small bank-based economy. Most prior evidence on this topic stems from advanced innovation systems with diversified financing channels and established venture ecosystems. In contrast, Croatia represents a bank-dependent, service-oriented economy where access to capital markets is limited and innovation capacity is concentrated among a few technology-intensive firms. In such environments, liquidity and moderate leverage play an outsized

role in supporting innovation continuity. The findings demonstrate that during stable periods, both internal financial strength and external borrowing stimulate investment in intangibles, but under crisis conditions, debt transforms from a growth driver into a vulnerability. This asymmetry illustrates a key insight for emerging innovation systems. Resilience is financial before it becomes technological, resting on firms' ability to balance short-term solvency with long-term strategic investment.

The policy implications of these findings are multiple. First, crisis-response frameworks should recognize that measures aimed at maintaining liquidity such as working capital guarantees, temporary tax deferrals, and accelerated public payments indirectly preserve firms' innovation potential. By preventing liquidity shortages from turning into insolvencies, such instruments protect the intangible capital base that underpins recovery. Second, the results highlight the dangers of debt-driven expansion. While access to credit remains crucial for innovation financing, unchecked leverage magnifies vulnerability in downturns. Policymakers should therefore complement credit programs with mechanisms that promote equity-type financing and profit reinvestment, particularly for SMEs that lack capital buffers. Third, targeted incentives such as innovation-linked loan guarantees or interest subsidies tied to R&D investment could align debt financing with long-term development objectives, mitigating the pro-cyclical nature of leverage.

At the firm level, the findings reinforce the importance of strategic financial management as an integral component of innovation strategy. Managers often perceive liquidity as idle capital and prioritize leverage to maximize expansion. Yet, the evidence suggests that balanced liquidity positions and moderate indebtedness jointly enhance resilience. Liquidity provides flexibility, while sustainable leverage broadens resource availability until a crisis tests the balance between them. Firms that manage this equilibrium effectively are better positioned to sustain knowledge accumulation, avoid innovation retrenchment, and emerge stronger from adversity. This requires not only prudent financial planning but also the ability to interpret macroeconomic signals, adjust debt exposure, and treat innovation expenditure as a long-term asset rather than a discretionary cost. During crises, such strategic agility differentiates resilient innovators from firms that enter defensive stagnation.

The results also suggest several broader considerations for economic policy and institutional design in small bank-based economies. Although the analysis focuses specifically on liquidity and leverage dynamics at the firm level, the findings indirectly point to the importance of financing diversity for sustaining innovation under crisis conditions. Heavy dependence on debt financing may increase vulnerability when external shocks disrupt cash flows and tighten credit conditions. In this context, the development of complementary financing mechanisms, including equity-based instruments, venture financing, and public co-investment schemes, may represent a longer-term avenue for strengthening the resilience of innovation systems. However, these broader institutional implications should be interpreted as forward-looking considerations rather than direct empirical conclusions derived from the analysis itself.

While the findings are robust, several limitations open avenues for future research. Innovation was measured through intangible asset investment, a comprehensive but imperfect proxy that captures knowledge absorption and technological upgrading more than formal R&D creation. Future studies could complement this approach with survey-based data on process, marketing, or organizational innovation to provide a more nuanced picture. Second, the crisis dimension analyzed here refers specifically to the COVID-19 shock, characterized by a sudden halt in mobility and demand. Comparative analyses of financial crises, energy disruptions, or geopolitical shocks could determine whether the same mechanisms hold under different forms of systemic stress. Finally, integrating qualitative insights on firm decision-making, particularly how managers prioritize innovation when liquidity tightens, would deepen understanding of resilience as a behavioral as well as financial phenomenon.

In conclusion, this study demonstrates that financial resilience constitutes the hidden infrastructure of innovation continuity. Firms that maintain liquidity buffers and manage debt exposure prudently are not merely better equipped to survive

crises but also more capable of converting uncertainty into renewal. The interplay between liquidity, leverage, and innovation is thus not a technical feature of balance sheets but a determinant of long-term competitiveness. For small open economies such as Croatia, where vulnerability to external shocks is structural, fostering resilient financial architectures at the firm level can generate stability at the national level. Policymakers and business leaders alike should therefore regard financial discipline and innovation investment not as opposing imperatives but as mutually reinforcing strategies. Aligning prudent financial management with sustained investment in knowledge and technology transforms resilience from a defensive posture into a proactive engine of sustainable development.

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