

## FUNDING CONSTRAINTS IN STARTUPS USING PANEL DATA REGRESSION AND FINANCIAL ACCESSIBILITY ANALYSIS TECHNIQUES

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DOI: <https://doi.org/10.5281/zenodo.21187114>

### Keywords

Funding constraints, startup finance, panel data regression, financial accessibility, information asymmetry, credit rationing, Generalized Method of Moments (GMM), Pecking Order Theory, innovation financing, survival analysis

### Article History

Received: 25 April 2026

Accepted: 04 June 2026

Published: 21 June 2026

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### Abstract

Funding constraints represent the single most significant impediment to startup survival, innovation, and scalable growth, yet their measurement and causal identification remain analytically challenging due to endogeneity, unobserved heterogeneity, and survival bias. This review synthesizes theoretical foundations, econometric methodologies, and empirical findings on financial constraints in early-stage ventures. Theoretically, information asymmetry and adverse selection (Stiglitz-Weiss) explain why credit rationing disproportionately affects opaque, asset-light startups, while Pecking Order Theory and Trade-off Theory require substantial modification for the startup context where internal cash flow is negligible and debt tax shields offer little value. Methodologically, panel data regression techniques particularly Fixed Effects models controlling for time-invariant founder characteristics and System Generalized Method of Moments (GMM) addressing lagged-dependent variable bias have become essential for analyzing longitudinal firm-level datasets. The choice among financial constraint indices (Kaplan-Zingales, Whited-Wu, Size-Age) significantly influences empirical conclusions, with text-based measures derived from SEC 10-K filings offering novel predictive power for liquidity events. Innovation intensity, measured by R&D expenditure and patent counts, paradoxically increases financial constraints due to asset specificity, though successful product market entry serves as a credible signal reducing information asymmetry. Regional and cross-country comparisons (US vs. Nigeria, EU vs. Western Balkans) reveal that institutional maturity, venture capital density, and fintech infrastructure substantially moderate constraint severity. Empirical hazard ratio analysis indicates that debt financing reduces startup failure risk by 86% and angel investment by 71%, while government equity exhibits adverse selection effects. Emerging digital solutions AI-driven credit scoring, blockchain, and crowdfunding are democratizing access but face regulatory and cost barriers.

## Introduction

The economic landscape of the twenty-first century is increasingly defined by the dynamism of the startup ecosystem, where the translation of innovative concepts into scalable business models serves as a primary driver of productivity, employment, and wealth creation. However, the trajectory of these nascent ventures is frequently obstructed by financial constraints structural or operational frictions that impede a firm's ability to fund all value-enhancing investment opportunities (Manso Laso, 2024). Unlike established corporations, startups operate under conditions of extreme uncertainty and information opacity, rendering traditional capital structure theories only partially applicable and necessitating sophisticated econometric approaches to identify the causal mechanisms of credit rationing and capital misallocation (Abraham et al., 2023).

The analysis of funding constraints in the startup context requires a multi-dimensional lens that integrates theoretical foundations with advanced panel data regression techniques and financial accessibility assessments. Theoretical frameworks, including Pecking Order Theory and Information Asymmetry provide the conceptual basis for understanding why external investors demand a "lemon premium" or why banks are reluctant to lend without substantial collateral (Ahmed, 2023). Simultaneously, the application of panel data methodology incorporating Fixed Effects, Random Effects, and Generalized Method of Moments (GMM) allows researchers to control for unobserved heterogeneity and address the endogeneity inherent in the relationship between financial health and firm growth (Mele, 2026).

## Theoretical Foundations of Startup Capital Structure

The financing decisions of startups deviate significantly from the frictionless environment envisioned in early corporate finance models. While the seminal work of Modigliani and Miller (1958) suggested that capital structure is irrelevant to firm value in perfect markets, the presence of

taxes, agency costs, and asymmetric information creates a reality where the choice between debt and equity is a critical determinant of survival (Darmansyah et al., 2024).

## Information Asymmetry and Adverse Selection

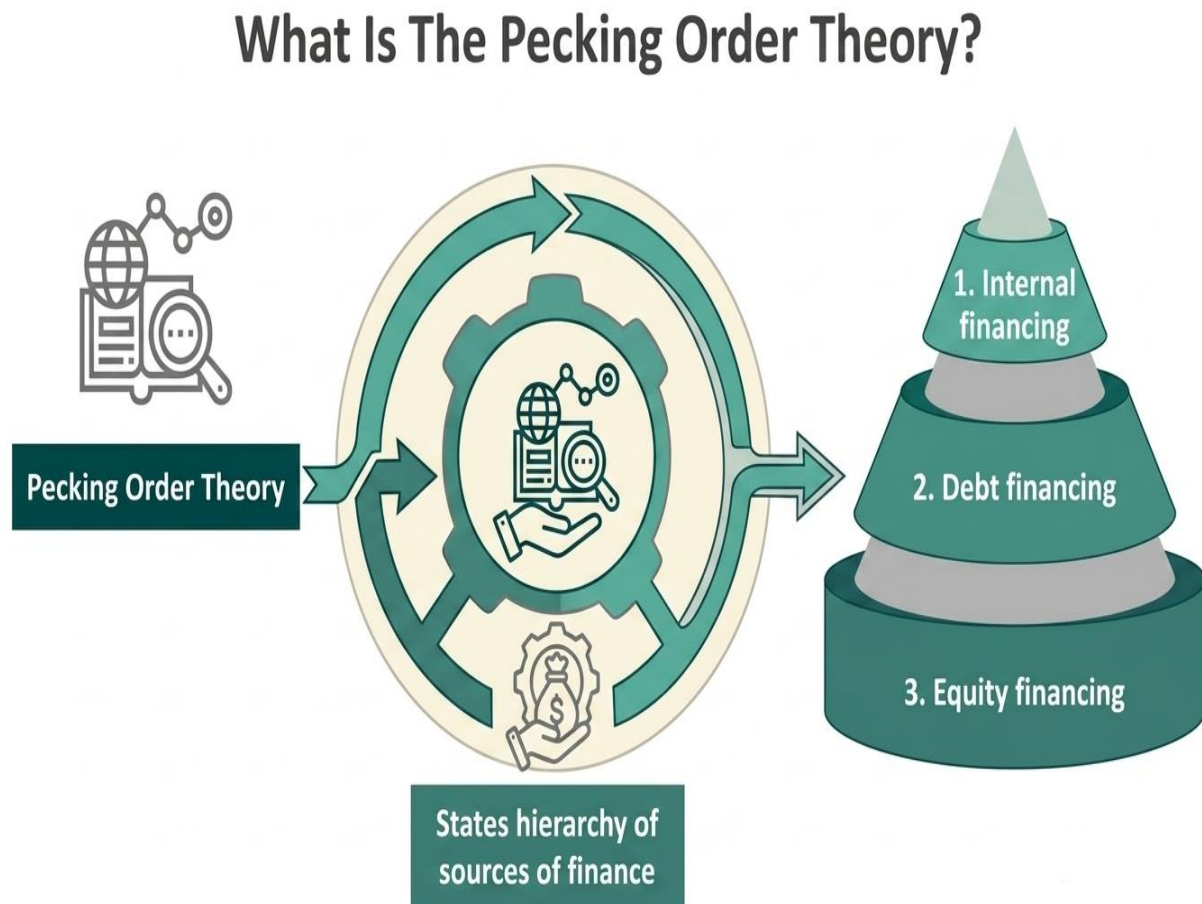
Information asymmetry remains the most pervasive challenge for early-stage ventures. This phenomenon occurs when entrepreneurs possess more granular knowledge regarding the technical feasibility and market potential of their innovation than potential financiers. This lack of transparency forces external investors to engage in intensive screening and monitoring, the costs of which are often passed on to the startup in the form of higher interest rates or significant equity dilution (Boadway & Sato, 2010).

In extreme cases, information asymmetry leads to adverse selection, where lenders, unable to distinguish between "high-quality" and "low-quality" projects, may withdraw from the market entirely or set interest rates so high that only the riskiest borrowers remain (Stiglitz & Weiss, 1981). This credit rationing is particularly acute for startups characterized as "informationally opaque," such as those that are small, unincorporated, or solo-operated for these firms, the "lemon premium" demanded by the market can make external finance prohibitively expensive, forcing a reliance on internal resources (Khataybeh, 2021).

## Pecking Order and Trade-off Theories in the Startup Lifecycle

The Pecking Order Theory (POT), proposed by Myers (1984), suggests a hierarchy of financing: internal funds are preferred first, followed by debt, and finally external equity as a last resort. For startups, however, this traditional hierarchy is often inverted or modified (Zaleski, 2010). Many new firms lack the internal cash flow necessary to fund operations, and their high risk and low collateral value frequently exclude them from traditional debt markets. Consequently, innovative

Figure 1: A Conceptual Flowchart of the Pecking Order Theory and its Hierarchical Capital Structure.



startups may seek external equity such as venture capital or angel investment earlier in their lifecycle than POT would predict for established firms (Cotei & Farhat, 2017).

The Trade-off Theory posits that firms choose a target debt-to-equity ratio by balancing the tax benefits of debt (the interest tax shield) against the costs of financial distress (Myers, 1984). This framework is often less applicable to startups because they typically do not generate sufficient taxable income in their early years to benefit from tax shields, while the potential costs of bankruptcy are exceedingly high given the 90% failure rate in the sector. Empirical evidence suggests that for most startups, bank debt remains an unviable option during the inception phase due to low profitability and high risk, leading to a "forced"

adherence to the pecking order where founder capital is the only accessible resource (Colombo et al., 2023).

### Asset Specificity and Liquidation Value

The tangibility and specificity of a startup's assets are primary determinants of its capital structure. Startups with high physical asset intensity or those led by serial entrepreneurs with existing business assets are more likely to secure external debt because these assets possess high liquidation values that can serve as collateral. Conversely, firms centered on human capital, R&D, or intellectual property (IP) face higher debt constraints because their assets are highly specific and hold little value to a lender in the event of bankruptcy (Cotei & Farhat, 2017).

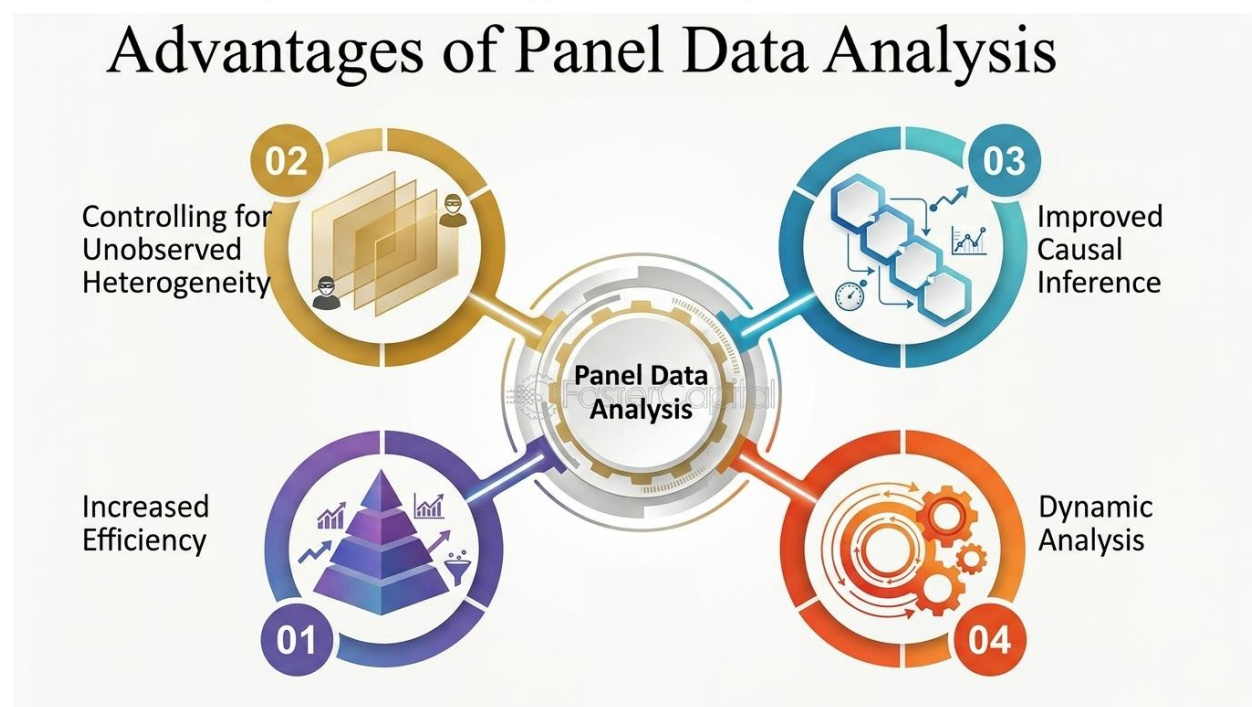
Asset Characteristic	Typical Startup Category	Financing Preference	Collateral Value
High Tangibility	Manufacturing, Infrastructure	External Debt, Bank Loans	High
High Asset Specificity	R&D, Biotechnology, Software	External Equity, Angels, VC	Low
Human Capital Intensive	Professional Services, Fintech	Founder Equity, Credit Cards	Minimal
Serial Entrepreneur Led	Diversified Tech, Market Leaders	Internal Equity, Bank Credit	High (Reputational)

**Econometric Methodologies in Panel Data Analysis**

The study of funding constraints relies heavily on panel data, which tracks multiple firms over multiple time periods. This methodology is

superior to cross-sectional analysis as it enables researchers to uncover dynamic patterns and control for unobserved factors that remain constant over time but vary across firms (Laborda et al., 2020).

Figure: 2 Benefits and Applications of Longitudinal Data Methods



**Static Models: Fixed and Random Effects**

In panel data regression, the choice between Fixed Effects (FE) and Random Effects (RE) models is often dictated by the relationship between unobserved heterogeneity and the explanatory variables (Hsiao & Pesaran, 2004). The Fixed Effects model is particularly robust for startup research as it controls for time-invariant characteristics such as a founder’s intrinsic

motivation, cultural background, or initial business practices that are difficult to measure but significantly impact a firm’s ability to raise capital. By focusing on "within-firm" variation, FE models reduce the risk of omitted variable bias (Fernandez-Val & Weidner, 2018). In contrast, the Random Effects model assumes that the unobserved heterogeneity is random and uncorrelated with the independent variables.

While RE allows for the estimation of coefficients for time-invariant variables (e.g., industry sector or founder gender), it may yield biased results if the "random" effects are actually correlated with factors like a firm's creditworthiness or investment intensity (Mundlak, 1978).

#### Dynamic Panel Models and the General Method of Moments (GMM)

Startups are characterized by dynamic processes where current financial constraints are often a function of past performance and past investment decisions. Standard static models like FE can produce biased and inconsistent results in the presence of lagged dependent variables, a phenomenon known as Nickell bias. To address this, researchers employ the Generalized Method of Moments (GMM), specifically the Arellano-Bond (Difference GMM) or the Blundell-Bond (System GMM) estimators (Momtaz, 2021).

System GMM is especially effective for startup panels with a "small T" (few time periods) and "large N" (many firms), as it uses lagged levels and lagged differences as instruments to address endogeneity. This method is critical when assessing how an increase in financial accessibility leads to economic growth, as it accounts for the reciprocal relationship between a firm's income and its access to credit (Anton & Bostan, 2017).

#### Correcting for Survival Bias

A major challenge in startup panel data is survival bias; failed firms often drop out of the sample, leaving only the most successful ventures and potentially skewing the results. Advanced econometric techniques, such as the instrumental-variable limited-information maximum likelihood (LIML IV) regression, are used to correct for this bias, ensuring that the estimated impact of financing on revenue and employment is representative of the entire population, including those that did not survive the study period (Fernandez-Val & Weidner, 2018).

#### Measurement and Indices of Financial Constraints

The identification of constrained firms requires the use of specific proxies, as financial constraint

itself is an unobservable latent variable. Several indices have been developed to categorize firms based on their likelihood of facing credit hurdles (Hsiao & Pesaran, 2004).

#### Traditional Indices: KZ, WW, and SA

The Kaplan-Zingales (KZ) index, Whited-Wu (WW) index, and Size-Age (SA) index are the most frequently cited measures in the literature. However, their reliability in the specific context of startups is frequently questioned (Steijvers & Voordeckers, 2011).

- **KZ Index:** Formulated using five accounting variables cash flow, Tobin's Q, leverage, dividends, and cash holdings the KZ index identifies firms as constrained if they have low dividends and high investment demand. Recent studies suggest the KZ index may be more indicative of financial distress than a simple lack of access to capital (Myers & Majluf, 1984).

- **WW Index:** This index focuses on firm characteristics that present external finance constraints, such as firm size and industry growth. In emerging markets like Vietnam, the WW index has proven more effective than the KZ index in reflecting actual restrictions on capital borrowing.

- **SA Index:** Developed by Hadlock and Pierce, this index models constraint as a non-linear function of firm size and age, based on the assumption that small and young firms are inherently more opaque and thus more constrained (Bollen & Brand, 2010).

#### The Investment-Cash Flow Sensitivity Debate

A cornerstone of financial constraint analysis is the sensitivity of a firm's investment to its internal cash flow. The traditional view, established by Fazzari, Hubbard, and Petersen (1988), suggests that constrained firms must rely more on internal funds, making their investment highly sensitive to cash realizations (Pirzada et al., 2023). However, this interpretation has been challenged by researchers who argue that high sensitivity may also reflect a firm's quality or growth opportunities rather than a lack of access to external credit. Furthermore, firms in extreme distress may show

low sensitivity because they have no capacity to respond to any cash flow changes (Sau, 2021).

**Textual Analysis of Financial Disclosures**

A significant innovation in the field is the use of natural language processing (NLP) to gauge financial constraints directly from the tone of management's reports. By parsing SEC 10-K filings

for a specific lexicon of 184 "constraining" words (e.g., "required," "obligations," "permitted"), researchers have created the "% Constraining" measure. This metric has shown a low correlation with traditional size-and-age-based indices but a high predictive power for future liquidity events, such as dividend omissions or pension underfunding (Fourati, 2021).

Predictive Measure	Correlation with Market Cap	Success in Predicting Dividend Omission	Identifies Mature Firm Constraints?
SA Index	Very High (-0.702)	Limited	No
WW Index	Very High (-0.839)	Limited	No
% Constraining (Text)	Very Low (0.036)	Strong (+10.32%)	Yes

**The Role of Innovation in Shaping Funding Constraints**

Innovation is the defining characteristic of startups, yet it is also the primary driver of their financial challenges. The nature of innovative activity whether focused on inputs like R&D or outputs like new products shifts the degree of information asymmetry and the corresponding access to finance (Spender et al., 2017).

**R&D Intensity and Informational Complexity**

Research and development (R&D) activities increase a firm's informational complexity, as the value of the knowledge being generated is difficult for external observers to quantify. High R&D expenditures are significantly associated with a decreased probability of using debt finance, as banks are typically unwilling to lend against intangible assets that cannot be recovered in a liquidation event. For these firms, owner finance and external equity are the primary and often only recourse (Criscuolo et al., 2021).

**Market Introduction as a Signal**

The successful introduction of a new product or process acts as a powerful signal to the capital market. It demonstrates the firm's ability to profit from its R&D investments and effectively reduces the level of asymmetric information. Consequently, startups that have transitioned from the R&D phase to the product-market stage

are more likely to gain access to traditional debt and less reliant on high-cost equity (Czarnitzki & Giebel, 2024).

**Survey Experiments on Innovation Constraints**

To distinguish between firms that do not innovate because they lack ideas and those that lack capital, researchers have employed survey experiments. For example, by comparing how German firms would use "unanticipated windfall profits" (zero marginal cost) versus "low-cost loans" (positive interest), studies have identified that "binding" constraints are most severe for young and highly innovative firms (Khataybeh, 2021). Many of these unimplemented innovation projects possess high social returns but low private returns at prevailing market interest rates, creating a potential role for government intervention (Arrow, 1962).

**Financial Accessibility Analysis: Regional and Global Perspectives**

Financial accessibility the availability of a robust infrastructure of resources and enablers varies significantly across geographic and economic contexts, shaping the success trajectories of local startups (Hall, 2008).

**Ecosystem Comparisons: US vs. Nigeria**

Startup ecosystems in the United States and Nigeria provide a study in contrasts regarding financial accessibility. US startups operate in an environment with deep venture capital markets, a

culture of risk-taking (the Lean Startup model), and a strong legal framework for intellectual property (Boadway & Sato, 2010). Conversely, Nigerian startups operate in a more constrained environment characterized by infrastructural deficiencies (e.g., unreliable electricity and internet) and limited access to formal capital, leading to a reliance on "resilient" and "creative" business models tailored to local challenges like financial inclusion (Hottenrott & Peters, 2012).

**Institutional Maturity: EU vs. Western Balkans**

Within Europe, a clear disparity exists between the institutional maturity of the EU and the Western Balkan countries. EU nations generally offer deeper venture capital markets and stronger investor protections. In contrast, startups in the Western Balkans face constraints in almost all

measured areas of financial accessibility, necessitating substantial reforms in regulatory frameworks and credit rating systems to bridge the gap with their Western counterparts (Manso Laso, 2024).

**Regional Factors and Meso-economics**

The local composition of firms and the regional economic context the "mesoeconomic" level play a crucial role in startup scaling. Research in the US indicates that the density of midsize and large firms in a region, along with local human capital and metropolitan classification, is significantly associated with the scaling of small businesses. Furthermore, startups in innovative states or those with high venture capital activity are more likely to have external equity in their financial structure (Abraham et al., 2023).

Regional Indicator	Impact on Startup Funding	Primary Financing Mechanism
High Regional Education	Increased Internal Debt Usage	Founder/Family Debt
High VC Activity Area	Higher External Equity Propensity	Venture Capital / Angel
Homogenous Industry Region	Harder to Attract "Unrelated" Finance	Bootstrapping
Urban/Metropolitan Hub	Better Access to Bank Loans	Commercial Banks

**Digital Innovation and Financial Inclusion**

The rapid evolution of fintech is transforming the landscape of financial accessibility for startups, particularly in underserved regions. Digital innovations are breaking down traditional barriers by providing new gateways for capital allocation (Ahmed, 2023).

**Fintech, AI, and Alternative Data**

The proliferation of mobile banking, digital wallets, and AI-driven credit scoring is democratizing access to finance. AI-driven solutions allow for credit scoring based on alternative data points such as transaction history and behavioral metrics that are more accessible to startups with no formal credit history. Digital lending platforms offer convenient and fast access to loans, bridging the gap left by traditional banks' reluctance to engage with early-stage ventures (Mele, 2026).

**Blockchain and Crowdfunding**

Blockchain technology is enhancing transparency and reducing transaction costs for cross-border payments, while crowdfunding platforms like Kickstarter have emerged as viable non-traditional sources of growth capital. These platforms allow founders to bypass traditional financial intermediaries, raising small amounts from a large, global base of users. However, these digital solutions often come with high fees and are navigating complex, evolving regulatory environments (Darmansyah et al., 2024).

**Determinants of Startup Longevity and Success**

The impact of funding constraints is most critically felt in the survival rates of startups. Econometric analysis of longitudinal data, such as the Kauffman Firm Survey (KFS), highlights how different financing strategies determine the risk of failure (Darmansyah et al., 2024).

**The Survival Impact of Financing Types**

Not all funding is created equal when it comes to ensuring firm longevity. For example, angel investments and debt financing have been identified as remarkable risk reducers, decreasing the risk of failure by 71% and 86% respectively. In contrast, government-provided equity has been identified as a predictor of closure in some studies, potentially reflecting a selection effect where only the most struggling firms seek this form of capital (Boadway & Sato, 2010).

**Interaction between Financing and Founder Capital**

Success is not a product of financing alone but an interaction between capital and the founder's human and social capital (Laborda et al., 2020).

- **Industry Experience:** The benefit of angel and venture capital investors depends heavily on whether the founders possess specific industry experience.
- **Education and Partnerships:** Highly educated founders are more successful at generating revenue when their startups are involved in university partnerships, suggesting a synergy between academic training and ecosystem collaboration (Cotei & Farhat, 2017).
- **Intellectual Property (IP):** While the mere presence of a patent may not be significant, the *quantity* of intellectual property patents, trademarks, and copyrights is strongly correlated with a reduced hazard of failure (Khataybeh, 2021).

**Hazard Ratio Analysis for Startup Longevity**

Variable	Hazard Ratio (Risk of Failure)	Significance
Angel Financing	0.2885	High (71% risk reduction)
Debt Financing	0.1381	Very High (86% risk reduction)
Government Lab Partnership	0.7629	Moderate
Founder Age (per 10 years)	~0.96	Small reduction
Patent Count	0.9998	Significant per unit
University Collaboration	0.6829	Significant (32% reduction)

**Conclusion**

The analysis of funding constraints in startups using panel data regression and financial accessibility techniques has matured into a sophisticated empirical discipline, yet persistent methodological and theoretical challenges remain. This review has demonstrated that information asymmetry constitutes the foundational friction separating startup capital structures from those of established corporations. Unlike mature firms that can credibly signal quality through audited financial statements and collateralizable assets, startups operate in a regime of extreme opacity where adverse selection forces lenders to either withdraw from the market or demand prohibitive premiums. Consequently, the traditional Pecking Order Theory which prioritizes internal funds, then debt, then equity is frequently inverted for early-stage ventures, forcing founders to rely on personal savings, credit cards, and dilutive external

equity long before generating positive internal cash flow. From an econometric perspective, the transition from cross-sectional analysis to dynamic panel data methods represents a substantial advancement. Fixed Effects models have proven invaluable for controlling time-invariant founder attributes (e.g., risk tolerance, prior experience) that correlate with both financing choices and survival outcomes. However, the persistent challenge of endogeneity whereby financial constraints simultaneously affect and are affected by firm performance necessitates the use of System GMM estimators that instrument lagged variables with deeper lags. Furthermore, survival bias remains a critical threat; startups that fail exit the sample, potentially concealing the most severe constraint effects. Advanced techniques such as limited-information maximum likelihood (LIML) IV regression with correction for non-random attrition are increasingly essential for valid

inference. The measurement of financial constraints via indices (KZ, WW, SA) reveals an uncomfortable truth: traditional accounting-based proxies may be poor instruments for startup-specific constraints. The Size-Age index, while convenient, assumes that all small, young firms are uniformly constrained ignoring variation in founder capital, industry dynamics, and regional ecosystems. Emerging text-based measures derived from management disclosures offer a promising alternative, capturing nuanced linguistic signals of financial distress that correlate strongly with future liquidity events while showing low correlation with size-based proxies. Substantively, the review confirms that innovation intensity particularly R&D expenditure and intellectual property generation systematically increases financial constraints due to asset specificity. Lenders cannot readily liquidate a failed startup's patent portfolio or human capital, rendering debt finance unavailable. Conversely, successful product market introduction acts as a powerful signaling mechanism, reducing information asymmetry and unlocking traditional debt. This insight carries important policy implications: public interventions (e.g., R&D tax credits, innovation grants, government equity) are most justified precisely where market failures are most acute namely, during the pre-revenue R&D phase when private returns at market interest rates are negative despite positive social returns. Regional and cross-national comparisons reveal stark disparities in financial accessibility. Deep venture capital markets (US), strong investor protections (EU), and digital fintech infrastructure (emerging economies) significantly moderate constraint severity. Conversely, startups in institutionally weak environments (Western Balkans, parts of Africa) face binding constraints across virtually all measured dimensions, requiring systemic regulatory reform rather than marginal policy adjustments. The hazard ratio analysis of startup longevity provides actionable empirical guidance: debt financing reduces failure risk by 86%, angel investment by 71%, while government equity exhibits perverse selection effects (potentially because only distressed firms seek it). However,

these findings should not be interpreted as prescriptive universals; the interaction between financing type and founder human capital (industry experience, education, partnerships) is critical. A patent held by an inexperienced solo founder conveys little credibility, whereas a portfolio of intellectual property managed by a serial entrepreneur with university collaborations substantially reduces failure hazard. Looking forward, several research priorities emerge. First, the integration of natural language processing and alternative data (transaction histories, social media activity, web traffic) into constraint measurement promises to overcome the limitations of traditional accounting indices. Second, the causal effects of digital financial innovations AI credit scoring, blockchain-based lending, crowdfunding require rigorous evaluation using quasi-experimental designs (difference-in-differences, regression discontinuity). Third, cross-country panel studies with harmonized definitions of "startup," "constraint," and "accessibility" are needed to separate institutional from cultural determinants. Finally, the rapid evolution of fintech necessitates updated regulatory frameworks that balance consumer protection with capital access.

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