The Leveraging of Silicon Valley*

Jesse Davis, Adair Morse, Xinxin Wang†

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Abstract

Early-stage firms utilize venture debt in one-third of financing rounds despite their general lack of cash flow and collateral. In our model, we show how venture debt aligns incentives within a firm. We derive a novel theoretical channel in which runway extension through debt increases firm value while potentially lowering closure. Consistent with the model's mechanism, we find that dilution predicts venture debt issuance. Empirically, treatment with venture debt lowers closure hazard by 1.6-4.4% and increases successful exits by 4.3-5.3%. Back-of-the-envelope calculations suggest $41B, or 9.4% of invested capital, remains productive due to venture debt.

JEL Classification: G24, G32, L26, O3

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†Davis: University of North Carolina - Chapel Hill (jesse_davis@kenan-flagler.unc.edu); Morse: University of California - Berkeley & NBER (morse@haas.berkeley.edu); Wang: University of California - Los Angeles (xinxin.wang@anderson.ucla.edu) respectively. Corresponding author: Adair Morse, University of California at Berkeley, Haas School of Business, 2220 Piedmont Ave, Berkeley, CA 94720, (510) 643-1425.

1 Introduction

Entrepreneurial ventures foster technological development, drive competition, and create economic growth. Because early-stage entrepreneurs are almost always liquidity-constrained, the financing of entrepreneurial ventures is an essential determinant of real economic effects. Economic theory would generally predict that external debt is an unlikely vehicle for the financing of early-stage startups given their general lack of cash flow and collateral.[1] Despite this, the venture debt market has grown rapidly in recent years. Tykvová [2017] finds that nearly a third of venture-backed companies utilize venture debt, supported by our evidence herein. In this paper, we provide theoretical foundations on the optimal use of venture debt and the implications for firm outcomes, which we then take to a survival and exit analysis across 92,236 rounds of financing.

To understand how venture debt is utilized, consider the example of EValve, a medical devices startup. It raised a total of $117 million dollars in both equity and debt finance and was ultimately acquired by Abbott for $410 million in 2009. Shortly after raising $12 million dollars in a Series B equity round, EValve raised $4 million in venture debt from Western Technology Investments. After, EValve raised a Series C round of $20 million dollars followed by another debt round of $10 million dollars (again from WTI).[2] When asked why the company took on debt, Ferolyn Powell, Evalve's CEO stated "by allowing us to hit a critical milestone with that extra run time, ... our experience was that it paid for itself by increasing valuation and avoiding dilution."[3]

Venture debt is generally structured as a short-term (three-year) loan. While a small portion of the payoff comes from warrants for company stock, venture debt is primarily a debt vehicle. This is a notable departure from the now-ubiquitous convertible note contract (the standard early-stage seed financing contract), whose primary feature is its conversion

[1] Hochberg et al. [2018] and González-Uribe and Mann [2017] do document a role for intellectual property in lending to start-ups; however, the startup ecosystem contains many firms without such assets (or assets of sufficient value), leaving the ubiquity of venture debt a puzzle.

[2] http://splitrock.com/2004/05/25/evalve-raises-20-million/

[3] https://www.wsgr.com/news/medical device/pdf/venture-debt.pdf

to equity at a later stage. It also does not resemble traditional debt loans in that it is a debt instrument for venture equity-backed companies that commonly lack either collateralizable assets or cash flows.[4] Instead, venture debt is secured (with uncertainty) by future rounds of equity finance. Industry proponents argue that venture debt's primary role is to provide capital to extend the runway of a startup, allowing them to achieve the next milestone while minimizing equity dilution for both the founders and equity investors. The argument, however, that venture debt is used to avoid dilution is inconsistent with Modigliani and Miller [1958], who show that the value of the firm should be unaffected by whether the firm is financed using debt or equity. Our model captures the crucial intuition that venture debt helps startups avoid dilution but deviates from M&M by introducing a principal-agent problem between an entrepreneur and an insider (incumbent) venture capitalist.

In the model, a startup owns an intangible asset of uncertain quality. We analyze the firm's financing and strategy decisions within a staging interval. The firm is owned by an entrepreneur ("he") and an insider venture capitalist ("she"): both are risk-neutral. At the start of the stage, the firm must raise capital to avoid closure, e.g., to pay employees or cover expansion expenses. Within the stage, the firm observes a signal about the likelihood it will achieve its milestone. At the end of the stage, the firm's current valuation is revealed, and the firm raises the next round of capital needed for survival, if possible.

The venture capitalist decides which securities to issue (equity and/or venture debt) and when to raise capital. She can either raise the capital required to reach the next stage or she can extend the startup's runway and raise what is needed to observe the milestone signal. After the signal is revealed, the firm raises any remaining required capital and the entrepreneur implements the firm's strategy. The firm has access to a set of strategies that increase both expected firm value and the riskiness of the firm's valuation. When the entrepreneur chooses chooses the firm's strategy, he accounts for the strategy's impact on

[4] While venture debt is distinct from traditional bank loans, the latter has also been documented to be an important source of capital for young firms. Robb and Robinson [2014] finds that nascent firms heavily rely on external debt and that firms with bank finance have greater likelihood of success.

both the value of his equity claim as well as the non-pecuniary utility he derives from his control rights. This additional, non-pecuniary utility creates a wedge between the venture capitalist's and entrepreneur's incentives.[5] When the entrepreneur's stake is excessively diluted, and when the marginal benefit of risk-taking is low, he chooses the low-risk (low-value) strategy. In contrast, the VC always prefers the high-risk (high-value) strategy and so makes her financing decisions to incent the entrepreneur to choose the value-maximizing strategy.

We show that venture debt can help the VC achieve her objective through two channels, thus providing us with a foundation for how debt can increase value in early-stage firms. First, we show that by issuing debt at the start of the stage, the venture capitalist can increase the entrepreneur's skin-in-the-game. As a result, his payoff is more sensitive to his strategy choice, which increases the marginal benefit of risk-taking. This result is the standard levered equity channel of debt. While this channel is well-known in the literature, the application of this channel to the staged finance ecosystem is unique to our model.

Second, we derive a novel theoretical channel through which runway extension, in combination with debt, can increase firm value: the "anti-dilution" channel. By extending the runway, the venture capitalist delays raising capital with the hope that the signal reveals good news. If positive information is revealed, the remaining required capital can be raised less expensively. This reduces the dilution experienced by the entrepreneur, thereby incentivizing him to implement the high-risk (high-value) strategy. On the other hand, extending the runway also creates the possibility of failure if good news fails to materialize. Even with this potential downside, we show that, in some cases, venture debt is strictly preferable from the venture capitalist's perspective. We emphasize the distinction between the two channels: a runway loan can align incentives even *after* the debt has been repaid because it allows the firm to raise (relatively) cheap equity when good news is revealed.

[5] This wedge utilizes the well-documented fact that while both venture capitalists and entrepreneurs seek to maximize firm value, venture capitalists often prefer higher volatility in their investments relative to entrepreneurs. Qualitatively similar results would arise in the canonical setting where the entrepreneur bears some private cost (e.g., effort) from implementing the high-value strategy.

The model generates several testable predictions, setting up our empirical analysis and facilitating our interpretation of the role of leveraging for the innovation economy. Because venture debt aligns the entrepreneur's incentives with the firm's, it increases both the expected value of the firm, conditional on survival, and long-term survival rates. Runway extension generates additional closure risk since the realization of a low milestone signal may lead the firm to shut down before the end of the stage. The model also provides insight into the conditions under which venture debt is most likely to be utilized. First, all else equal, venture debt is more likely to be optimal when the entrepreneur faces high potential dilution. Second, we expect to see venture debt utilized by firms when the required runway is shorter as this increases the benefit of delaying the capital raise until good news has been revealed.

We gather 92,236 Crunchbase rounds of financing and track these rounds over 449,134 round-survival year observations, using the lack of news information as a supplement to identify closures. As in the theory, we differentiate between venture debt used to extend the runway (runway loans), and debt used in conjunction with equity (levered equity). In our baseline model, applying a loglogistic survival model, we find that the use of levered equity and runway loans positively increases the odds of survival. This estimate levels firms on quality by the level of current and prior investment, the pre-money valuation, the number of employees, year, industry, and reputation of the investor firm. The effect is robust across seed and series A-C rounds. This baseline effect has a 3.8 times greater effect on the log odds of survival for levered equity as compared to runway loans, consistent with the prediction that runway loans create an added layer of closure risk.

Despite the baseline efforts to control for quality, residual concerns remain that selection into treatment might drive our results. Thus, we implement what is referred to in biostatistics as a frailty survival model. Frailty models allow for estimation of "how frail" a subject is in selecting into treatment for a medical therapy, and is a standard biostatistic way of absorbing subject-level heterogeneity for parametric survival function estimation. In our case, since we have multiple rounds of financing per company, we can apply such a model to implement a "within" analysis to disentangle firm-level selection from treatment. We use such language throughout, with the caveat that there may be other time-varying firm attributes that correlate with the choice of capital structure. However, for robustness, we also show that an estimation of the frailty model that accounts for frailty at the firm-capital structure level yields similar results.[6]

Our main survival estimation shows that selection accounts for 60% of the effect, on average, across debt types and staging. Nevertheless, the issuance of debt positively and significantly impacts survival even after controlling for frailty. The treatment of levered equity results in a 0.044 lower hazard of closure each year, and the treatment of runway loans results in a 0.016 lower hazard of closure each year. The optimal use of early-stage leverage suggests an increase in the productive risk-taking within the innovation economy as venture debt provides a valuable channel through which closure is reduced for early-stage firms. A back of the envelope calculation applying the predicted survival function by stage and survival time suggests that, of the $439 billion in invested capital in our sample, an additional $41.1 billion remains productive because of the change in strategy induced by debt.

Next, we show that conditional on surviving, firms that raise capital through levered equity or runway loans have better exit outcomes. Following the spirit of our proportional odds survival model, we model exits in an ordered logit with the descending order: IPO, acquisition with price, acquisition without price disclosure, and ongoing. In addition, we consider a mixed logit (random effects) model of any exit relative to ongoing. Interpreting this latter model, which again allows us to alleviate selection by controlling for firm-level heterogeneity, we find that levered equity (runway loan) increases the likelihood of an acquisition or IPO exit by 0.71% (0.88%). Given that only 16.52% of the startup-round observations eventually

[6] For example, a lingering concern may be that time-varying firm quality affects both capital structure and survival. The firm-capital structure frailty model accounts for this unobserved heterogeneity by allowing the frailty (the random factor) to vary not only across firms, but across the capital structure (runway loan, levered equity, equity) of a particular firm.

exit via acquisition or IPO, this corresponds to a 4.3% (5.3%) percentage increase.

We discuss several alternative mechanisms that could potentially push startups to utilize venture debt, including asymmetric information. We argue that the patterns of utilization and the impact on outcomes do not necessarily arise given such frictions: for instance, we are unlikely to find a reduction in closures if startups are utilizing venture debt and engaging in risk-shifting. However, in light of these alternatives, we bolster our support for the proposed mechanism by analyzing whether the model's proposed mechanism is consistent with the data. We show that, consistent with the model's predictions, potential dilution is a strong predictor of the decision to raise venture debt instead of venture equity. A one standard deviation increase in dilution increases the likelihood of levered equity issuance, sample-weighted across series, by 1.83%, which is a 3.89% increase relative to the sample mean. Similarly, dilution significantly and positively predicts the use of runway loans in early-stage rounds. Both entrepreneurs and investors value "skin-in-the-game" and the additional capital provided by a venture loan allows startups to achieve more progress before raising additional equity. Further, if good information is revealed about the firm's prospects, runway extension through venture debt minimizes the dilution that occurs relative to securing all required external capital at an earlier time.

Our evidence also supports the model's intuition of venture debt as a tool for extending the firm's runway. Theoretically, as the required runway shrinks (i.e., as the required time until information about the firm's prospects are revealed), venture debt becomes a more valuable product. While we cannot obtain an ex-ante measure of this required runway, we show that the expected time until the next round of financing decreases after venture debt issuance. After controlling for the firm's prior use of capital, the use of a runway loan decreases the days until the next round of financing by 13.3%, sample-weighted across stages, or 46 days. This suggests that, consistent with industry intuition, such firms are using venture debt as an extension (having failed to reach a needed milestone) and that they return to the market after more information is revealed about the firm's future prospects.

Our research adds to the current finance literature in several areas. While equity is the dominant form of financing for high-growth startups (Kortum and Lerner [2000], there is a growing literature documenting the use of venture debt. The existing literature has focused on determinants of the lending decision. Hellmann et al. [2008] argue that banks use their venture capital investments to build relationships for their future lending activities. de Rassenfosse and Fischer [2016] finds that venture capitalist backing is a substitute for startups cash flow in the lending decision while Hochberg et al. [2018] documents that venture capitalist credibility is an important driver of venture lending. González-Uribe and Mann [2017] provides contract-level data on venture loans and finds that intellectual capital and warrants are important features. These results support the earlier market survey by Ibrahim [2010] who finds that venture debt provides additional runway between early-stage rounds and are repaid through future equity raises. Similarly, his research also points to the importance of intellectual property as collateral for the loan. Missing from this, however, is a consideration of the risk implications of the leveraging of venture capital funded startups. Our paper documents the impact of venture debt on startup outcomes comparable to the extensive literature studying the effect of venture equity on firm outcomes (e.g. Lindsey [2008], Chemmanur et al. [2011], Puri and Zarutskie [2012], Nanda and Rhodes-Kropf [2013], Kerr et al. [2014], Bottazzi et al. [2016] and Bernstein et al. [2016]).

Secondly, our paper contributes to the broader literature on venture capital contracting and the financing of high growth startups. Kaplan and Strömberg [2003, 2004], Hsu [2004], Cumming [2008], and Bengtsson and Sensoy [2011] explore VC contracting and the economics behind contractual terms. Gornall and Strebulaev [2020]shows the importance of contractual terms in firm valuation. Ewens et al. [2020] model the endogenous matching between venture capitalists and entrepreneurs and the resulting equilibrium contract terms. Our paper, on the other hand, documents a different mechanism for accessing financial markets and thus, a different set of incentives for investors and entrepreneurs.

On the theoretical side, several papers have highlighted how staged financing can improve firm value in the presence of moral hazard, including Wang and Zhou [2004] and Bergemann and Hege [1998].[7] Our model shares the existing literature's emphasis on the importance of moral hazard and staging. However, we prove the existence of a new theoretical channel through which debt, in combination with runway extension, can preserve the entrepreneur's skin-in-the-game, aligning his incentives with the firm's. This runway extension channel also sets our model apart from the existing theoretical literature, e.g., Innes [1990], that emphasizes the security design benefits of debt in the presence of moral hazard. This channel is also distinct from the benefits of convertible debt, as analyzed in Cornelli and Yosha [2003], Schmidt [2003], and Yang and Zeng [2019].[8] Recently, both Fulghieri et al. [forthcoming] and Malenko and Tsoy [2020]) have shown that equity financing may be preferable for early-stage firms who then turn to debt financing when they mature.[9] We note that, while venture debt commonly follows an equity round, these debt rounds are then followed by more equity financing, a feature that is difficult to reconcile with the predictions of either paper.[10]

The remainder of the paper is organized as follows. We describe the institutional details in 2. We present the model and develop testable empirical predictions in Section 3. Section 4 describes data sources, sample construction, and presents the main empirical results. Section 5 concludes the paper. All proofs are found in Appendix A.

2 The Venture Debt Market

While debt has traditionally been an important source of external finance for public corporations, the prominence of debt in the high-risk innovation economy has largely been tied to

[7]Other papers have considered these features separately: both Casamatta [2003] and Repullo and Suarez [2004] focus on the financing implications of a two-sided moral hazard problem in which both the venture capitalist and the entrepreneur can exert effort to improve firm value, while Neher [1999] and Dahiya and Ray [2012] focus on how stage financing can improve firm outcomes.

[8]While convertibility features prominently in start-up financing, such securities are typically utilized later, relative to venture debt, in the firm's life cycle. Moreover, as we discuss below, the warrants included with venture debt typically constitute a very small portion of the security's value.

[9]These papers are related to a longer literature establishing conditions under which equity can be optimal for financing, including Fluck [1998] and Fulghieri and Lukin [2001].

[10]Specifically, from the perspective of these papers, the difficulty is in explaining the issuance of debt (which is utilized by mature firms) *between* equity rounds (which is utilized by early-stage firms).

the fluctuations in the role of fixed assets. Going back in time, trade-related venture assets such as ships, mills, and resource-processing equipment attracted the interest of creditors looking for high-yield, risky investments. These assets provided creditors with collateral and a positive expected cash flow in a determinant time horizon. In the 1970s, venture debt again rose to prominence with the rise in equipment breakthroughs in the semiconductor, communications, computer hardware, and military technology industries.

In the innovation economy of today, however, many startups lack tangible collateral and positive (if any) cash flow in the short term. In a frictionless market, existing models suggest that startups characterized by high failure rates, lack of collateralizable assets, and no cash flows generally do not have access to debt markets.[11] Thus, the emergence of a large market of early-stage venture debt is a bit of a puzzle: what enables startups to overcome these hurdles? If we look to industry for guidance, it is commonly argued that startups use venture debt in order to avoid dilution from equity issuance. These arguments purport to show that the firm faces no downside from delaying their capital raise and potential upside if positive information is revealed. Yet, under the seminal theory of Modigliani and Miller, absent any frictions, the value of the firm should be unaffected by whether the firm is financed by debt or equity. Further, delaying the startup's capital raise also creates the risk that good news will not be revealed: this would be a *negative* signal about the firm's prospects that make raising equity *more* costly. Taken together, this suggests that understanding the role of venture debt requires a new model that (i) reconciles the motivation of industry insiders with economic theory while (ii) incorporating the unique features of venture debt, which we detail next.[12]

[11] Exceptions exist, including some theories that suggest frictions such as asymmetric information or disagreement. As we discuss in our empirical analysis below, however, the predictions of such theories are largely inconsistent with the firm outcomes we observe in the data. Moreover, asymmetric information, is generally unable to generate the observed pattern of financing (equity followed by debt followed by equity) absent strong assumptions on the cyclicality of the information environment.

[12] It is important to distinguish venture debt from commonly used convertible notes in seed rounds. Although technically the convertible note is debt, the key features of these seed contracts are the features governing the price of conversion of the note capital to equity shares at the first equity round of finance. Venture debt, however, is primarily a debt vehicle, albeit with some warrants to provide upside payoffs. The warrants generate a small fraction of expected payoffs.

2.1 Venture Debt Contracts

Venture debt is structured as short-term loans with sizes ranging from $1-10 million, interest rates of 10-15%, and term of 24-36 months. As a debt obligation, venture debt is senior in the priority structure and thus, repaid first in the event of a liquidation or exit. Loans may include warrants of approximately 5-15% of the loan size, but remain primarily debt instruments. Ibrahim [2010] 's survey provides a depiction of venture loan contract terms.

The first unique feature of venture debt is that the source of cash to repay the loans is not revenues, but rather is the next round of equity financing. According to Silicon Valley Bank, "Venture debt emphasizes the borrower's ability to raise additional capital to fund growth and repay the debt." Thus, the decision to provide venture debt capital rests not directly on the ability of the venture to generate cash flows from revenues, but the ability of the firm to hit a milestone to convince equity investors to provide stage financing.[13] According to Stephen Levin from Leader Ventures, "such milestones are important in venture debt because they serve as the basis for a relationship that lenders ideally look for as providing identifiable targets that can be achieved using debt."

The second unique feature of venture debt is that because of its reliance on the next equity financing round, the ability of a startup to raise venture debt relies on the reputation of VCs in a repeated game (Hochberg et al. [2018]). The insider VC actively participates in requesting a loan from the venture debt provider. As Andy Hirsch, a venture finance transaction lawyer, states, "with those seed-stage and Series A companies, lenders look at the track records of the VCs and assess the company's trajectory as to the likelihood that there's going to be a Series B; that's really what they are lending against."

[13] Venture capital valuation is typically based on achieving milestones. Series A, B, C, etc refers to both the round of financing as well as the development stage of the startup. As the startup achieves major milestones such as product development or revenue growth, it is rewarded with an increase in valuation. This implies that raising outside capital immediately following a milestone leads to the least amount of equity dilution.

2.2 Venture Debt Providers

The majority of venture lenders in the United States are either banks or specialty debt funds (or a similar incentive structure of ever-green vehicles). Top banks participating in venture lending include Silicon Valley Bank, Square 1 Bank, and Bridge Bank. Investment banks and financial service companies like Goldman Sachs, Comerica Bank, and Wells Fargo have also moved into the space. Banks have lower cost of capital, but also face a higher aversion to risk, stemming from regulation. Ibrahim [2010] attributes banks' incentive to lend to being able to secure the startup's future banking needs, in line with the relationship banking literature (see, for example, Hellmann et al. [2008]).

Venture debt funds include firms such as Horizon Technology Finance, Lighter Capital, Trinity Capital Investment, and Western Technology Investment. Debt funds are structured similarly to venture capital funds. They raise capital from limited partners such as institutional investors, endowments, and wealthy individuals. Although their payoff structure is less risky that venture capital, their investment portfolio is considered riskier than that of venture banks. Compared to venture banks, debt funds charge higher interest rates, are less likely to implement financial covenants, and can demand more warrants and other equity-like add-ons.

One final feature of industry practice, which we do not model explicitly, is necessary for the existence of the venture debt market. In our model, firms earn a competitive interest rate on the loans they make. In practice, many have observed that the price of debt is lower than would be expected given the failure risk of startups. This is true because of three features. First, many venture debt (VD) issuers gain future banking services from those startups that they funded. Second, VD lenders have warrants on the equity of the startup, especially the VD issuers who are not banking services providers. Third and most importantly, venture debt contracting is a repeated game between VCs and VD lenders, implying that the VC is only going to recommend startups to VD lenders if the VC expects survival. We note that while we do not incorporate these features into our model, their impact would be independent of the economic channel we analyze. Moreover, it is straightforward to show that allowing for a lower interest rate actually strengthens the impact of the channel we propose.[14]

3 Model

Our model of the use of venture debt emphasizes the unique features of startup financing. First, in staged finance, additional rounds of investment are necessary for continuation, as the firm has not yet reached a maturity where revenues alone can support growth. Thus, the next round of finance becomes the source of cash to pay off existing debt. Second, the entrepreneur controls the firm's strategy. While he holds an equity stake, we allows his strategy choice to depend upon the utility he derives from his control rights. This creates a potential misalignment with the insider venture capitalist (VC), who always prefers high-risk/high-value strategies. Third, as is common in practice, it is the VC who controls the financing decisions due to the drag-along rights found in the previous term sheets.[15] The VC can utilize venture debt to increase the entrepreneur's "skin-in-the-game," which can incentivize the entrepreneur to choose the VC's preferred strategy.

Within this unique setting, we analyze the impact of venture debt using both the standard "levered equity" debt product as well as a novel "runway extension" product. Consistent with industry intuition but new to the theory literature, this latter channel improves firm value by allowing the firm to "extend the runway to realize a milestone" signal. We consider venture debt's impact on startup valuation as well as firm closure rates. Finally, we generate predictions about the utilization of venture debt given the model's proposed mechanism.

[14]If early-stage firms are able to borrow at a lower interest rate, this reduces their cost of capital which would reduce dilution and the risk of closure.

[15]This is consistent with both the survey evidence from Ibrahim [2010] and Sage [2010].

3.1 Startup Valuation

The model begins at any stage $s \in \{1, ..., N\}$. We analyze the events within a single staging interval, i.e., those which occur between stage s and the next stage $s+1$. At each stage, the startup must raise capital from outside investors to continue operations.[16] We assume these required investments $\{X_1 ..., X_s, X_{s+1}, ..., X_N\}$ are necessary for continuation (to pay employees and to produce goods or services) and hence treat them as exogenous, given the firm's industry and product. If the startup fails to make the required investments, it will shut down with no liquidation value.

The startup owns an intangible asset which at stage $s+1$ has valuation $Y_{s+1} = \gamma Y$. Y is a constant which reflects some underlying characteristics of the intangible asset. The realization of the multiple, γ, reflects both the within-stage resolution of uncertainties about the product and market value as well as information about the startup's likelihood of growth or closure in the future. In our model, γ is revealed at the end of the staging interval, immediately before the VC needs to raise capital X_{s+1}. The distribution of the multiple (γ) is driven by two factors – the milestone achievement signal (p) and the riskiness of the firm's strategy (τ).

Information on the likelihood of achieving a milestone (p) is revealed in between the two stages, at s^*. For example, this information is akin to the firm receiving market signals from their product launch. For tractability, we model this milestone signal as binary: $p \in \{p_h, p_l\}$, with $0 \leq p_l \leq p_h \leq 1$,and assume that $\mathbb{P}[p = p_h]$, which lies between zero and one, is known before raising capital at stage s. If the milestone is not achieved before $s+1$, which happens with probability $1-p$, then $\gamma = 0$ and the firm is shuttered. Otherwise, the firm hits the milestone and

[16] The entrepreneur cannot self-finance: he has no wealth or outside labor income. The results would be unchanged if future equity capital came from the inside venture capitalist, but for ease of exposition (and consistent with practice), we focus on this setting.

$$\gamma = \begin{cases} \widetilde{\gamma} + \delta & \text{with probability } \rho\tau \\ \widetilde{\gamma} & \text{with probability } p - \tau \\ \widetilde{\gamma} - \delta & \text{with probability } (1-\rho)\tau \end{cases} . \quad (1)$$

where $\frac{1}{2} < \rho < 1$. The riskiness of the firm's strategy, $\tau \in [0, \tau_h]$ (where $\tau_h \leq p_l$), is chosen after the milestone achievement signal is revealed. The notion is that the startup either targets a more secure, smaller market ($\tau = 0$), or the startup adjusts its product and revenue model to go after a "unicorn-like" market disruption ($\tau = \tau_h$). The latter is much riskier but yields a higher expected valuation (since $\rho > \frac{1}{2}$). Both the market potential and firm risk-taking are non-verifiable and thus non-contractable.[17] Given τ, δ determines the startup's benefit from risk-taking, while ρ captures the relative likelihood of success of the risky strategy.[18]

3.2 Startup Financing and Firm Strategy

The firm is owned by an entrepreneur and an insider VC, both of whom are risk neutral. Before raising capital at stage s, the insider VC owns a fraction θ of the startup, the entrepreneur owns $1 - \theta$, and no debt is outstanding.[19] The assumption that the startup has no existing debt on its balance sheet simplifies the analysis without affecting the economic mechanisms analyzed. The price of any equity or debt issued is set such that outside investors

[17] We also take as given that the entrepreneur cannot be relieved of his role – for instance, he may possess unique human capital, specific to the firm's asset.

[18] The likelihood that the firm hits the milestone at $s + 1$, i.e., p, is exogenous and is unaffected by the firm's within-stage risk-taking, τ. However, in practice, p (and its distribution) is likely affected by previous strategic choices made by the firm. Consistent with this, we interpret τ as affecting the firm's valuation at $s + 1$, which incorporates its ability to hit *future* milestones. In a previous version of this paper, we restricted ourselves to a setting in which the strategy taken was a mean-preserving spread with respect to the distribution γ, or equivalently, i.e., $\rho = \frac{1}{2}$. We showed that, when the firm faced the risk of closure at $s+1$, such risk-taking can increase the expected value of the firm. Specifically, under our assumptions regarding the firm's financing requirements, the value of equity was convex in γ - as a result, a mean-preserving spread over the distribution of γ increased the expected value of equity.

[19] The existence of additional investors from previous financing rounds would not change any of the model's predictions.

break even in expectation, conditional on the information available on that date.[20]

3.2.1 VC's Financing Decision

The VC decides the startup's capital structure, specifically choosing the extent to which the startup takes on leverage. Her objective is to maximize her payoff at stage s+1, by setting the optimal capital structure. At stage s, the startup must raise X_s to survive to the next stage. The VC can raise the required investment by issuing only equity or use venture debt in one of two forms:

1. *"Levered equity" venture debt*: The startup raises the entire X_s immediately by issuing equity along with zero-coupon debt with face value D to be repaid at the start of stage $s+1$.

2. *"Runway extension" venture debt*: The startup extends their runway at the beginning of stage s by raising a fraction, ΔX_s ($\Delta < 1$) of the required capital immediately via a loan with face value $L > 0$. The remaining investment, $(1-\Delta)X_s$, in addition to the required loan repayment, are raised at s^* after the milestone signal has been revealed.[21] In this case, $D = 0$.

Let α_s denote the percentage of the firm sold at stage s to new equity investors, with pro-rata dilution between the VC and entrepreneur. At stage $s+1$, the startup must raise its required investment, X_{s+1}, to survive; moreover, if it issued "levered equity" venture debt, it must also raise sufficient extra capital (D) to repay lenders. Without loss of generality, we assume the startup does this through the equity market, and thus the startup sells a fraction:

$$\alpha_{s+1} = \frac{X_{s+1} + D}{\gamma Y_s}, \tag{2}$$

[20]This is equivalent to assuming (i) competitive capital markets, (ii) risk-neutral investors and (iii) a perfectly elastic supply of the risk-free asset.

[21]In a previous version, we also allowed the entrepreneur to extend the runway using equity. We showed that while this can also be valuable to the venture capitalist, it is not always sufficient to raise firm value, at which point the VC chooses to use venture debt as we model it here.

of its equity. We assume that, if the firm has successfully reached its milestone, it will be able to raise the next round of capital at $s+1$.[22] The VC chooses the firm's capital structure to maximize the expected payoff from her equity claim at stage $s+1$,

$$\theta\left(1-\alpha_{s}\right)\mathbb{E}\left[\left(1-\alpha_{s+1}\right)Y_{s+1}\right]. \tag{3}$$

3.2.2 Entrepreneur's Risk Strategy Choice

The entrepreneur chooses the firm's strategy. In addition to the value of his equity stake, we assume that the entrepreneur receives non-pecuniary utility from his control rights. Consistent with practice, this occurs if the entrepreneur is sufficiently diluted, i.e., if $\gamma \leq \underline{\gamma}$. We model the value of these rights in a stylized fashion, so that at s^{*}, after the firm has reached its milestone, the entrepreneur chooses the firm's strategy, τ, to maximize

$$\underbrace{\left(1-\theta\right)\left(1-\alpha_{s}\right)\mathbb{E}\left[\left(1-\alpha_{s+1}\right)Y_{s+1}\,|\,p,\tau\right]}_{\text{entrepreneur's expected payoff}}+\underbrace{b\mathbb{P}\left[\gamma>\underline{\gamma}|\,p,\tau\right]}_{\text{value of control rights}} \tag{4}$$

where $b>0$ parameterizes the relative utility received from the entrepreneur's control rights. This non-pecuniary utility is a source of potential misalignment between the entrepreneur and the VC. To highlight the role of this friction, we focus on settings where $\tilde{\gamma}-\delta<\underline{\gamma}<\tilde{\gamma}$.[23]

It is straightforward to see that the venture capitalist always prefers to take risk, since

$$\mathbb{E}\left[\left(1-\alpha_{s+1}\right)Y_{s+1}|p,\tau\right]=p\left(\tilde{\gamma}Y-\left(X_{s+1}+D\right)\right)+\underbrace{\delta Y\left(2\rho-1\right)\tau}_{>0}. \tag{5}$$

For the entrepreneur, however, this risk-taking increases the likelihood that he will be diluted

[22] This implies that $\alpha_{s+1}\leq 1$: investors would not contribute funds that exceeded the firm's valuation. This assumption is consistent with practice - milestones are defined, at least in part, to convey the valuation necessary to reach the next round. We note that this places an implicit constraint on the amount of venture debt the firm can issue at stage s, consistent with both practice and our empirical analysis, below.

[23] If the entrepreneur's control rights were preserved when $\gamma=\tilde{\gamma}-\delta$, then the firm's strategy would not affect the entrepreneur's control rights. If the entrepreneur's control rights were only preserved when $\gamma=\tilde{\gamma}+\delta$, then the entrepreneur could only preserve these control rights by taking risk. In both settings, given his risk-neutrality and since the risky strategy is a positive NPV investment, the would always choose $\tau=\tau_{h}$, regardless of the VC's issuance decision at stage s.

and forced to forfeit his control rights, since

$$\mathbb{P}\left[\gamma > \underline{\gamma} | \, p, \tau\right] = p + \underbrace{(\rho - 1)\,\tau}_{<0}. \tag{6}$$

With this, we state the entrepreneur's trade-off conditions and his optimally chosen strategy.

Lemma 1. *Let $\tau(\alpha_s)$ be the entrepreneur's optimal choice of risk as a function of his equity stake. Then, $\tau(\alpha_s) = \tau_h$ if and only if*

$$(1-\theta)(1-\alpha_s) \geq \left(\frac{b}{\delta Y}\right)\left(\frac{1-\rho}{2\rho - 1}\right). \tag{7}$$

Otherwise, he optimally sets $\tau(\alpha_s) = 0$.

Intuitively, the entrepreneur only chooses to risk-up (i.e., set $\tau = \tau_h$), if he has sufficient "skin-in-the-game", $(1-\theta)(1-\alpha_s)$, i.e., if he holds a large enough stake in the firm. The threshold for taking risk trades off the marginal benefit of risk-taking, $\delta Y(2\rho - 1)$, against the marginal utility the entrepreneur's receives from preserving his control rights, $b(1-\rho)$. In the next section, we explore how the use of venture debt can favorably alter the entrepreneur's incentives by preserving his equity claim.

The key friction in our model is the private cost borne by the entrepreneur from risk-taking: if b were zero, the VC and entrepreneur's incentives would always align. We have chosen to model this private cost as the potential loss of control rights from risk-taking, which we think captures an important friction within early-stage startups. However, we emphasize that our results do not rely on this particular modeling assumption and can be generalized to many other types of private costs.[24] For instance, our predictions are robust to an alternative in which the high-value strategy is not risky ($\rho = 1$) but the entrepreneur must bear some private cost in implementing it, as in the canonical models of moral hazard. While this

[24] In a previous version of this paper, we also considered an alternative private cost: the disutility experienced by the entrepreneur when the high-value/high-risk strategy leads to increased closure at $s+1$. While we believe that such strategies can play an important role within a *given* early-stage startup, our empirical analysis (which shows a reduction in closure) suggests that their *aggregate* impact is more muted.

cost is often referred to as the "effort" required to implement the new strategy, given our setting, alternative interpretations are equally appropriate. For example, pursuing the high-value strategy may force the entrepreneur to forfeit other objectives he valued. These could include the abandoning the pursuit of a previously-targeted market, letting sustainability goals lapse, or even a reduction in the entrepreneur's status within the start-up as new leaders are introduced.

3.3 Financing Solution using "Levered Equity"

Understanding the entrepreneur's propensity to take risk, we now show how the VC uses her financing decision to influence the strategy, τ, chosen by the entrepreneur.

The venture capitalist must raise the required capital (X_s) at the start of stage s. If she chooses to issue "levered equity" venture debt, then she issues debt with face value D (to be repaid at $s+1$) plus the raises the additional necessary capital via equity, which requires the firm to sell an ownership fraction

$$\alpha_s = \frac{X_s - \mathbb{P}\left[\gamma > 0\right] D}{\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y \mid \tau\left(\alpha_s\right)\right]}. \tag{8}$$

Note that debt investors must break even in expectation. Since the firm can only repay D if it successfully achieves its milestone before stage $s+1$, debt investors only supply $\mathbb{P}\left[\gamma > 0\right] D$ in financing at the start of stage s. Equity investors contribute the rest of the required capital, $X_s - \mathbb{P}\left[\gamma > 0\right] D$, and demand a fraction α_s of the firm, given their expectation of the firm's value, $\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y \mid \tau\left(\alpha_s\right)\right]$.

Recall that the VC's objective is to induce the entrepreneur to take risk. If (7) holds when $D = 0$, Lemma 1 tells us that the entrepreneur is going to choose the high-risk/high-value strategy: venture debt cannot improve the startup's value. Suppose instead that this is not the case. As we show in the proof of Proposition 1, as the face value increases, the firm can sell less equity: $\frac{\partial \alpha_s}{\partial D} < 0$. Thus, the entrepreneur's equity stake, $\left(1-\theta\right)\left(1-\alpha_s\right)$ grows as D

increases. If sufficient debt can be issued, this relaxes the entrepreneur's IC constraint, (7), inducing him to choose the high-risk/high-value strategy. This theoretical channel is closely related to well-known security design benefits of debt when a principal is faced with a moral hazard problem and leads directly to the following proposition.

Proposition 1. *If an all-equity issuance at stage s leads to the low-risk strategy, the VC always prefers to issue "levered equity" venture debt, sometimes strictly.*

Our model provides a unique insight on the relationship between debt and the desirability of managerial risk-taking. The need to meet a valuation threshold (or milestone), induced by the entrepreneur's desire to maintain his control rights, creates a setting that rewards any mechanism (in our case, leverage) that increases the entrepreneur's appetite for risk. This stands in contrast to the use of levered equity within a mature firm.

As discussed in our model setup, the parameter γ is a proxy for stage $s+1$ beliefs about the expected value of the startup. This proxy accounts not only for beliefs about market potential but also future rates of closure. From this perspective, then, not only can "levered equity" venture debt increase the expected value of the firm, but it can also decreases the firm's likelihood of closure. Somewhat surprisingly, however, we show that the issuance of "levered equity" venture debt can also reduce closure at stage s. In some cases, when the firm's prospects for success are sufficiently poor, it will not be able to raise capital at all unless the entrepreneur chooses to take risk. In such settings, the use of venture debt (instead of equity) can induce such risk-taking, thereby preventing the firm from closing at stage s. We formalize this intuition in the proof of the following proposition.

Proposition 2. *The issuance of "levered equity" venture debt increases the expected value of the firm, conditional on survival, and decreases closure both contemporaneously and at future stages.*

3.4 Financing Solution using "Runway Extension"

If the VC instead chooses runway extension, the startup raises a fraction, ΔX_s ($\Delta < 1$) of the required capital immediately (at the start of stage s) via a loan with face value L. Then, after the milestone signal is realized (i.e., p is revealed at s^*), the startup must issue equity to raise the remaining capital ($(1-\Delta)X_s$) along with the required debt repayment in order to continue operations. Given the information provided by the milestone, this implies that equity investors demand a fraction

$$\alpha_s(p) = \frac{(1-\Delta)X_s + L}{\mathbb{E}\left[(1-\alpha_{s+1})\gamma Y \mid p, \tau(\alpha_s)\right]} \tag{9}$$

of the firm's equity at s^*. Crucially for this channel, the revelation of the milestone signal affects the price equity investors are willing to pay for a stake in the firm, which then affects the *entrepreneur's* stake in the firm, $(1-\theta)(1-\alpha_s(p))$. Waiting for information to be revealed alters the extent to which the entrepreneur is diluted which can affect, therefore, his choice of strategy.

Consider a setting in which the entrepreneur's chooses the low-risk strategy if the VC chooses to issue equity (only) at stage s. If the VC decides to extend the runway, the firm can raise the remaining required capital after p, the milestone signal, is realized. There are two possible scenarios:

1. If a low milestone signal ($p = p_l$) is revealed, this signals a higher probability that the firm will not reach its milestone by $s+1$; as a result, outside equity investors at s^* will demand a larger stake in the firm. This implies that the entrepreneur's marginal benefit from risk taking is even lower than at s since his equity is even more diluted than it otherwise would have been. Thus, if $p = p_l$, the entrepreneur does not alter his strategy and continues to choose $\tau = 0$.

2. If a high milestone signal ($p = p_h$) is revealed, then outside equity investors will demand a smaller stake in the firm since they are more optimistic about the firm receiving

financing at $s+1$. This implies that the entrepreneur will emerge with higher skin-in-the game. If sufficiently high, then by Lemma 1, the entrepreneur will optimally choose to take the high risk strategy, i.e., $\tau = \tau_h$, when $p = p_h$. In expectation, therefore, the VC benefits from extending the runway and waiting for information to be revealed. Venture debt increases the expected value of the firm at the start of stage s.

The proof of the following lemma shows this result formally.

Proposition 3. *If (i) the issuance of "levered equity" venture debt leads to the low-risk strategy and (ii) the firm can raise capital at s^* when the milestone signal is revealed, the VC always prefers to extend the runway, sometimes strictly.*

Our model offers a unique observation on the relationship between debt and the *timing* of managerial risk-taking. The novel channel, described above, implies that the issuance of debt can help solve problems of moral hazard, *even when the debt is no longer outstanding.* By altering the entrepreneur's skin-in-the-game, staging in combination with information revelation can align the VC and entrepreneur's interests so that firm value is maximized. We emphasize that this "anti-dilution" channel is distinct from the standard manner in which debt aligns incentives: in this case, debt allows the VC to raise more equity at a higher price (i.e., when $p = p_h$) which, in turn, maximizes the entrepreneur's skin-in-the-game. This mechanism holds even when the debt has already been repaid.

There is, however, a potential downside to extending the runway with a milestone loan emerges. In some cases, when the firm realizes a low milestone signal ($p = p_l$), the venture capitalist is unable to raise capital. In order for the firm to successfully raise capital at s^*, it must be the case that $\alpha_s(p) \leq 1$. This implies that, in order for the firm to receive financing without taking risk,

$$p \geq \frac{(1-\Delta) X_s + L}{[\tilde{\gamma} Y - X_{s+1}]} \equiv \overline{p}. \tag{10}$$

If a sufficiently large runway extension loan must be issued at date zero, and $p_l < \overline{p}$, the firm defaults when the milestone is missed. This risk notwithstanding, in some settings, the expected value of the firm increases despite this default because of the risk-taking induced when the $p = p_h$. As a result, the VC may rationally choose to extend the runway even when the information revealed at s^* potentially leads to closure.

Finally, as in the setting above, we show that using venture debt to extend the runway can be necessary to avoid closure at stage s. In some circumstances, the firm cannot raise the entire X_s at stage s, even when utilizing a combination of debt and equity. However, we show that the firm can raise the capital required to observe the realization of the milestone signal (ΔX_s) and, if good news arrives ($p = p_h$), the firm can raise the remaining capital required to reach the next stage. Thus, as with "levered equity" venture debt, extending the runway can prevent closure at stage s while also reducing closure in the future (captured by the increase in the expectation of γ).

Proposition 4. *(1) The issuance of "runway extension" venture debt increases the expected value of the firm, conditional on survival, and can decrease closure both contemporaneously and at future stages.*
(2) Runway extension venture debt can increase closure when the milestone signal is realized, i.e., at s^* when $p = p_l$.

As a result, all else equal, the latter statement implies that we expect to runway extension to generate relatively higher closure rates when compared to "levered equity" venture debt.

3.5 Venture Debt Utilization

Finally, we establish conditions under which venture debt is more likely to be utilized. The core benefit of venture debt is that it preserves the entrepreneur's stake in the firm, which can lead the entrepreneur to make decisions in the firm's best interest. All else equal, increased dilution at the start of stage s (driven by $1 - \theta$, X_s, and $\mathbb{E}[p]$) makes it more likely that the entrepreneur will choose the low-risk strategy, conditions under which venture debt is a valuable alternative for the VC. Further, as the required runway (Δ) decreases, the firm is able to raise more capital after information about the milestone is revealed which amplifies the benefit of delay (and therefore, venture debt).

Corollary 1. *All else equal, venture debt is more likely to be utilized when*

(1) A firm's initial dilution $(1-\theta)$ *and required investment* (X_s) *increases and*

(2) the required runway (Δ) *and expected milestone signal* $(\mathbb{E}[p])$ *are small.*

4 Empirical Analysis

Our empirical analysis analyzes the impact of the capital structure of early-stage investments on startup survival and firm value conditional on survival, as predicted by the theoretical model. Then we examine conditions under which startups choose to take on venture debt to provide evidence of the proposed model mechanism.

4.1 Data

Our main source of data is Crunchbase, one of the most comprehensive datasets of early-stage startup activity.[25] Crunchbase tracks startup financings using crowdsourcing and news aggregation and provides detailed information on startups, funding rounds, and investors, all linkable with disambiguated firm and investor identification numbers. The firm characteristics of interest from Crunchbase include: founding date, industry categories, current status (ongoing, inactive), and exit outcomes (IPO, acquired, closed). We also have round level data on each financing event. The round level characteristics include: announcement date, investor name and type, investment amount, firm valuation, and stage of financing (Series A, B, C, etc.).

Our sample initially consists of 123,374 funding rounds with non-missing round investment amount from 1999 to 2016. We limit the sample to 2016 to allow for three years of ex-post performance. We also restrict our sample to early-stage investments, defined as Seed and Series A - C rounds. Thus, we drop Series D and later rounds (6,458 observations). To

[25] For more information on the use of this dataset, refer to Wang [2017].

focus on equity and debt investments, we drop 5,038 observations with the type of round consisting of: grants, post-IPO, initial coin offering, assistance, and product crowdfunding. We also drop pre-seed investments, those with money raised less than $10,000 (854 observations), and financing rounds with pre-money valuation of less than $100,000 (2,438 observations). Finally, we drop a handful of duplicate observations and collapse when multiple investors participate in a round. Our final sample is 92,236 unique rounds of funding, reflecting 54,000 startup firms. When we turn these funding rounds into a panel of survival, we have 449,134 yearly observations from funding round to exit (or to being truncated to ongoing status at the end of our data pull in 2018).

To identify which rounds are equity only, levered equity, or runway loans, we first start with Crunchbase's categorization of equity or debt. When Crunchbase uses these terms, we can categorize the money raised cleanly as debt, equity, or a mixture. We code convertible notes as equity. When the type of capital is missing, we instead use the investors' financing histories to predict security type. We code an investor as a debt investor if it is among the main venture debt providers listed in Wikipedia as of 2018 or if the majority of other investments by this investor are coded debt. Venture debt investors consists of specialized funds such as Lighter Capital and banks such as Silicon Valley Bank. Consistent with our data, Lighter Capital bills itself as the "largest provider of non-dilutive debt capital to early stage startups". In our sample, Lighter Capital has financed 200 debt deals while Silicon Valley Bank is a close second with 181 debt deals.[26]

Lastly, we need to identify the financing stage. The series is usually identified in Crunchbase. When missing, we utilize the idea that startup capital is raised in sequential rounds of financing as startups mature to assign the stage of financing. For example, we classify the first round of financing as a seed round and the second round of financing as a Series A round, irrespective of capital structure. For debt rounds, since series is not a debt concept,

[26] We do not have contract-level data on the loans providing interest rates or associated warrants. However, we take comfort in knowing from González-Uribe and Mann [2017] that the contracts of venture loans are relatively standard across firms.

we assign staging as the would-be round had the firm issued an equity round instead.

4.2 Summary Statistics

Table 1 presents round-level summary statistics, dividing all statistics into stage. As Panel A reports, more observations are in seed rounds (50%) than series A (27%), series B (16%), or series C (7%), as one would expect with firm failure. Equity financing make up the bulk of Seed rounds (78.5%), but this decreases across the stages with levered equity becoming increasingly more common. This heavy bias toward equity at the Seed round reflects the risk and uncertainty in valuing early-stage companies. Across all rounds, equity is utilized in 67% of rounds, levered equity in 19%, and runway loans in 14%.

Panel B reports the industry distribution. We utilize Crunchbase product market descriptions and industry categories to classify firms into five broad industry sectors (biotechnology/pharmaceuticals, software, energy, finance, and other). Compared with later-stage institutional investor databases such as VentureXpert, our sample skews towards high-tech companies with software and biotechnology/pharmaceuticals representing 60% and 19.3%, respectively.

The employee size distribution of Panel C reflects the growth of firms over time. Very early stage rounds go pervasively to companies with 1 to 10 employees (43.9%) or 11 to 50 employees (40.2%). By the time companies progress to Series C, only 8.6% have less than 10 employees.

Panel D of Table 1 presents round level characteristics by both series and capital structure. The average (median) seed round financed with equity raises $700,000 ($383,000) while the average (median) seed round financed with levered equity raises $1.5 million ($1.2 million). This difference in capital raised suggest differences in the underlying quality of the firm.

In addition to the employment indicators and current and prior investments, our empirics include two other measures of company quality. First, we use an estimate of the value of the company. In VC investing language, a "post-money" valuation is company valuation implied by the equity stake given up in an investment. For example, a $2 million investment for 10% of the company implies the company is worth $20 million post-money. The "pre-money valuation" is the valuation accruing to founders and prior investors as implied by the valuation of the current investment (i.e., the post-money minus the investment). Ideally, we would level firms using this value measure. However, these notions do not apply to debt, and furthermore many observations do not reveal pre-money or, equivalently, the equity stake provided for the investment round. For rounds involving debt or missing values of pre-money, we use the average pre-money valuation for the industry-year-series in Pitchbook.[27] This calculation for debt rounds amount to saying approximately how much equity a company would have to give up in that industry and that year if the founders had chosen to issue with equity alone. Even taken together, these are imperfect measures of quality, which is why we also show within-firm analysis.

Across all series, the startups raising levered equity appear "better" in terms of pre-money valuation. For example, in seed rounds, levered equity investment have average (median) pre-money valuations of $6.0 million ($4.7 million) compared to $2.9 million ($1.6 million) for equity investments. Runway loan investments, however, are quite similar in size and valuation to equity rounds. This ranking pattern across capital structures is apparent in every financing stage.

The final row of summary statistics is the proportion of financing rounds that include at least one high volume investor, a measure both of firm size, quality, and reputation of the VC. We define a high volume investor as an investor that has financed an above-median number of deals in the prior year. There is large heterogeneity depending on financing stage and security type. Across all three security types, the likelihood of raising money from high volume investors is larger for later stage rounds where the amount of capital needed is much

[27] One potential way to disentangle models of effort versus risk-taking (discussed in Section 3.2) would be to study the impact of venture debt on the dispersion of next-round firm valuations. However, we are unable to do this with the limited data on valuations.

larger. Across all stages, the likelihood of raising money from high volume investors is larger for levered equity and runway loans suggesting that both specialization and reputation is a key component of the venture debt ecosystem.

4.3 Univariate Outcomes: Survival and Exits

We now turn to univariate resolution of companies results– survival and exits – by capital structure. We begin by studying survival in section 4.3.1 and exits in section 4.3.2.

4.3.1 Univariate Survival

Closures are notoriously hard to identify in startups. One distinct benefit of Crunchbase for our research is that it collects and aggregates all relevant startup data from the greater Web. If a startup receives press coverage regarding executive employee change or new strategic partnership, for instance, Crunchbase will incorporate this information and timestamp the event. Given that many startups rarely (and potentially endogenously) self-report closures, this provides us with a way to distinguish inactive firms from ongoing firms. In addition to those explicitly classified as closed in Crunchbase, any firm that goes without an "update" for two years (and remains without an update until the end of our sample) is classified as inactive.

Table 2 reports closure and exit rates by capital structure and series. In our sample, 37% of all financing rounds result in startup closure. While this statistic seems low at first glance, relative to the adage that six or seven out of ten startups will not survive, the deviation stems from two factors. First, most of the surviving firms have not had any resolution because of the recent timing of their entry into the dataset. Second, this statistic measures closure for a given round of financing, not a given firm. As expected, we observe that the rate of closure decreases as firms mature. For example, the likelihood of closure is 45% after a seed round while only 21% after a series C round.

It is also immediately clear from Table 2 that survival rates differ depending on capital structure. Survival rates are higher for levered equity and runway loans, irrespective of stage. For instance, in seed rounds, firms financed with equity have a 48% likelihood of closure while firms financed with levered equity have only a 23% likelihood of closure. Across all series, firms that are financed with equity have higher closure rates than firms financed with levered equity or runway loans.

To put more perspective on these univariate patterns, we plot the Nelson-Aarlen non-parametric cumulative hazard function by the capital structure of the round in Figure 1. The x-axis is survival time measured as the lapse of time since the round funding year. At each year, the interpretation of the graph is the cumulative failure risk, conditional on having survived to that year. The high year-15 cumulative hazard not only picks up the high total failure, but also the fact that, by that time, successful firms have been truncated out of the sample with exit. Thus, the failure rate continues to increase, even past the early years, capturing the selection of firms that are not able to exit by an M&A or IPO.

Figure 1 makes clear that the survival of startups after a levered equity round is much higher than that for startups receiving an equity-only round. This difference in hazards is large from the first year and increases slowly for about a decade. Figure 1 also illustrates that firms receiving runway loans face more promising survival relative to those getting all-equity financing, but to a much lower degree when compared to a levered equity round.

It is important to note that we are not controlling for any round-level differences in this specification, and these results do not make any statement as to whether the firms receiving different securities are simply different. This selection story is, however, interesting in itself as it speaks to the use of venture debt. To disentangle selection and treatment, we do a more complete survival analysis in section 4.4.

4.3.2 Univariate Exits

Table 2 also reports the resolution of the firm conditional on survival by capital structure. The majority of firms in our sample are still ongoing. Among those that have exited, any patterns across differences in capital structure are not nearly so stark as with closures. On average, 74% of our sample rounds are in startups that are still alive at the end of our sample period, 17% have exited via an undisclosed-price acquisition, and 6% have exited via a price-disclosed acquisition. The venture literature has noted that when prices are disclosed or leaked, the acquisition is usually a premium acquisition. Finally, 4% of rounds resulted in a firm that has successfully gone public.

4.4 Empirical Results

4.4.1 Survival Function

The cumulative hazard figures, described above, suggest that capital structure may impact firm survival. In this section, we develop a more formal survival test, taking into account selection into capital structure type.

We begin by discussing the choice of the survival function for analysis. Let us denote a survival function by $S(t)$:

$$S(t) := 1 - F(t) = P(T > t) \quad \text{for } t > 0, \tag{11}$$

where $F(t)$ and $f(t)$ are cumulative and probability distribution functions over failure, and t and T are the time lapse since the funding round and firm closure time, respectively. $S(t)$ indicates the cumulative probability that closure has not yet occurred by time t. The survival function dictates a hazard function $h(t)$, given by

$$h(t) = \frac{f(t)}{S(t)}, \tag{12}$$

which captures the immediate risk of failure given that the firm has survived until time t.

Having a well-specified parametric survival analysis depends on the survival function chosen, as the hazard varies over time in unique ways. For example, in medicine, some treatments increase in effectiveness as time elapses while others decrease. Two of the most commonly-utilized parametric survival functions are the Weibull and loglogistic distributions, both offering a flexibility in survival patterns. The Weibull hazard function is monotonic over time for a given (estimate) shape parameter, which determines the direction of the survival pattern. The hazard of failure is either increasing over time, decreasing over time, or constant (in which case it becomes the exponential distribution, the specification of the much-used Cox proportional hazard model). In contrast, the loglogistic provides a functional form over which the shape of the hazard can increase and then decline. In practice, it is intuitive that the hazard of closure for a startup should be higher in the near term and then decline as the startup continues to demonstrate its viability. However, rather than impose one of these forms, we allow the data to determine that decision.

Figure 2 reports diagnostics to assess the fit of the models. Panel A plots the AIC and log-likelihood statistics from the models, demonstrating that across all stages, the loglogistic fits better than the Weibull, as it exhibits the smallest AIC and largest log likelihood. The difference is particularly pronounced in the seed stage.[28] A characteristic of the loglogistic is that it is a proportional odds model, which provides both another test for goodness of fit and an ease in interpreting coefficients of interest. To see this, define the odds ratio of failure as $OR = \frac{1-S(t)}{S(t)}$. The survival function for the loglogistic is $S(t) = \frac{1}{1+\lambda t^{\gamma}}$, where the λ is the parameterization of predictor variables and the γ is the estimated shape parameter. Thus, taking logs, $logOR = \log\left(\frac{1-S(t)}{S(t)}\right) = \log(\lambda t^{\gamma}) = \log(\lambda) + \gamma \log(t)$. Utilizing this formulation, the Lee (2003) goodness-of-fit check for a loglogistic survival model is that $logOR$ should be linear in a plot against $log(t)$. Figure 2, Panel B graphs this plot by staging, showing that the log odds ratio is, indeed, almost precisely linear in the log of time.

[28]In an additional, unreported test, we apply the Schoenfeld test of proportional hazard, used to test that variables follow a proportional hazard effect on survival as would be implied by the well-known Cox proportional hazard model. The results show that we can reject that our capital structure variables and most of the quality controls follow a proportional hazard, except in series C estimations.

4.4.2 Treatment versus Selection Methodology

Our objective with a more complete survival model is to level startups on quality at the time of the financing round and then follow over time the effect of the treatment (i.e., the capital structure) on survival, as in medical trials. The primary concern with this statement is, of course, that there may be selection into treatment. Startups may sort into capital structure for a host of reasons (risk, expected future multiplier on the idea, etc.). We are interested in this selection effect as much as the treatment; thus, we do not want to discount any magnitude differences due to selection. However, to make clear the role of the capital structure choice, we undertake two approaches to disentangle selection from treatment.

First, we control for quality using observable variables. Financial researchers are in the habit of thinking this approach is incomplete, and indeed it is. Signals are very sparse in early-stage investing, and the trajectory is at least partially determined by successes in the past as the company steps from milestone to investment to milestone and so on. Thus, for startups, two important variables that proxy for startup quality at a given financing round are the startup's current investment and the cumulation of prior investments. We also include an indicator for whether the investor is a high-volume investor, a proxy for VC reputation. We also include the pre-money valuation at the current round, but note that this variable is a (potentially) noisy estimate itself. Importantly, we include the year of the fundraising, to capture the perceived opportunity space and supply-demand environment. We also include the number of employees (in fixed effect buckets as shown in Table 1), to capture the completeness of the team. We include industry fixed effects, to capture a number of differentials including the size of the potential market and the capital-intensity of the startup's path. Finally, to account for differences across rounds, we estimate these specifications separately for each staging.

Despite our inclination that these covariates of quality will empower a level survival analysis across capital structure treatments, it is possible that an omitted quality variable still differentiates those rounds treated with equity from ones treated with a debt capital structure. For guidance in dealing with this issue, we return to the medical science literature. In medicine, those receiving one treatment might be more or less failure-prone ("frail") than those receiving another treatment. Scientists, specializing in medical survival statistics, thus developed techniques to account for individual heterogeneity, leveling individuals on frailty. A frailty model specifies an individual (or in our case, a firm) unobservable multiplicative effect α on the hazard. The resulting hazard conditional on frailty is: $h(t|\alpha) = \alpha h(t)$. If a firm has a frailty $\alpha > 1$, the firm is more frail, which acts multiplicatively on the firm throughout the lifespan. We estimate α as a gamma distribution, one of two standard specifications to understand and parameterize firm-specific risk.[29] In our setting, we include the frailty parameter to absorb any underlying, static heterogeneity within each firm. To do this, we pool our data across stagings so that we have multiple observations to estimate the firm-level frailty term.

4.4.3 Survival Results

Table 3 examines the role of capital structure on startup survival after each stage of financing. In all columns, we control for the covariates described immediately above. Columns 1-4 present the estimates of the loglogistic model with standard errors clustered by firm. Columns 5-7 present the frailty model estimates, with observations pooled across stages (with stage fixed effects) so that we can estimate a model with firm frailty heterogeneity removed to parse out treatment from selection.

Columns 1-4 show that, compared to the offset equity-only rounds, survival is higher for rounds financed with leverage equity (with a coefficient ranging between 0.384 and 0.500 depending on the series) and runway loans (with coefficients ranging from 0.118 to 0.217). Translating these log odds to odds ratios by simple exponentiation and taking the weighted average across rounds, we find that levered equity is associated with a higher survival odds

[29] The first economics incorporation of frailty models was, to our knowledge, Lancaster (1979). His *Econometrica* article uses frailty methods to estimate the length of time that unemployed job seekers stayed out of work. His underlying frailty heterogeneity (and the future thousands of citers of this work) include rational variables such as opportunity wage level as well as behavioral parameters of preferences and search intensity.

of 1.57 relative to equity-only investment (i.e., 57% higher in odds each year). Likewise, the survival odds of runway loans is 1.16 compared to equity-only rounds.

Our preferred frailty model is that of column 7. (For robustness, we compare levered equity and runway loans in isolation to equity rounds in columns 5-6, and find similar results.) Column 7 reports that the treatment effect of levered equity is 0.197 in higher log odds of survival, or an increase in 22% in odds ratio of survival compared to equity rounds at any point in time. For runway loans, the treatment of a runway loan implies a modestly higher survival log odds of 0.056, or a 6% increase in the odds ratio of survival relative to equity only. The coefficients on levered equity and runway loans in column 7 are still economically and statistically significant after controlling for firm-specific risk.

The frailty model allows us to absorb unobserved firm-level heterogeneity. Comparing the sample-weighted average coefficient estimate over columns 1-4 to the capital structure coefficient estimates in column 7, we find that selection accounts for 56% of the levered equity effect, leaving 44% for a treatment effect. For runway loans, the selection: treatment breakdown is 64% : 36%. To further account for time-varying firm attributes that correlate with the choice of capital structure, we re-estimate the model in column 8 with frailty estimated at the firm-capital structure level instead of just the firm-level. The firm-capital structure frailty model utilizes variation across rounds of the same firm and the same capital structure investment type (runway loan, levered equity, equity). Thus, any residual quality that is time-varying for a firm and correlated at the point of time of investment with the capital structure choice will be absorbed. As column 8 shows, the results are both quantitatively and qualitatively similar. If anything, the results are economically larger, but we conservatively interpret the column 7 results in all of our magnitude calculations.

In short, firms with better ex-ante expected survival positively select into investments utilizing debt, even conditional on observables and investor reputation. Selection is the primary driver of the magnitude differences in survival. Nevertheless, the infusion of debt impacts survival, increasing the odds ratio by 22% and 6% for levered equity and runway loans respectively. These positive capital structure effects align directly with our model's predictions, where the VC uses leverage to align the entrepreneur's actions so that firm value is maximized. The observation that the overall treatment effect of improving survival is 3.6 times greater for levered equity as compared to that for runway loans also aligns with the model. For the runway loan structure, the risk that bad information may be revealed before the firm is able to reach its next milestone implies that the runway loan creates increased closure risk relative to the levered equity product.

With an understanding of the selection and treatment breakdowns of the Table 3 results, we can move to our main economic magnitude prediction – an interpretation of magnitudes in terms of the treatment effect on probability of failure. In the survival model, the effect on probability of closure varies over survival times. The four panels of Figure 3 depict plots of the predicted hazard over survival time, from the estimates in columns 1 to 4 of Table 3, by capital structure type. We use the non-frailty model so that we can plot these relationships by staging. The black (darkest) line is that of equity-only investment; the red (medium) line is of levered equity investment; and the yellow (lightest) line is for runway loan investment. After the first two years of raising capital, hazard is decreasing over time, reflecting the idea that the longer a firm survives, the lower the risk of closure. While the likelihood of closure in any given year is the highest for rounds financed exclusively with equity irrespective of series, the relative hazard between equity and levered equity rounds decrease as startups mature, consistent with incentive alignment being most valuable in the early-stages of the startup's life cycle.

The staging patterns are intuitive in the yearly closure risk being largest for seed rounds in particular. Since we cannot disentangle selection versus treatment within stages, we interpret magnitudes in Figure 4, where we pool the predicted hazards from columns 1 to 4. Figure 4 shows that, weighted across stagings, the overall hazard of closure is 0.101 (0.044) lower for levered equity rounds (runway loans) as compared to the hazard following equity rounds. Applying the percentage selection-treatment breakdown from the frail model implies that the treatment of levered equity results in a 0.044 lower hazard of closure each year, and the treatment of runway loans results in a 0.016 lower hazard of closure each year.

For each stage and each capital structure type, we calculate the percentage change in investment that remains productive (does not close) according to the predicted survival function from Table 3. We then impose our selection-to-treatment breakdown, allowing only 44% and 36% of the magnitude of our prediction to be a treatment effect, to arrive at a predicted percentage of capital salvaged from closure. Finally, we simply apply this salvage rate to the overall money raised in each of the stages. We find that, of the $439 billion in our dataset, spread across Seed - Series C, our estimates imply that the use of debt in the capital structure of investments resulted in survival of an additional $41.1 billion, or 9.4% of funds. Our theory and the empirical evidence supports the idea that this capital is value improving. Yet, in this back-of-the-envelope calculation, we try to be conservative in interpretation in that the mechanism of debt changing strategies that increase survival may forestall some optimal creative destruction.[30]

4.4.4 Exits Conditional on Survival Results

Table 4 examines eventual exit outcomes for startups conditional on survival. In columns 1-4, we implement an ordered logistic regression where the dependent variable is exits in the following descending order: IPO, priced acquisition, acquisition with undisclosed price, and ongoing. We chose this specification to mirror that of the log logistic survival model in its odds ratio interpretation.[31] Each observation is a financing round. We again control for the natural logarithm of the amount of capital raised, the natural logarithm of prior investment, the natural logarithm of the pre-money valuation, high volume investor dummy, employee quintiles, and industry and year fixed effects. The interpretation of coefficients in an ordered

[30] For example, it may be that startup ideas that have failure sooner (creative destruction) cause more productive uses of future investment rounds into other companies.

[31] We can implement a survival-time analysis with the "hazard" of an IPO, for example, being the dependent variable that takes duration into account. Our results are not materially different than in the one-observation per round results which we present instead.

logit is the effect of an independent variable on moving the outcome from one level to the next; i.e., from ongoing to acquisition, from acquisition without price to acquisition with price, or from acquisition with price to IPO. The ordered logit model parameterizes an equal proportional odds ratio effect across these orderings.

Columns 1 and 2 shows that debt increases positive outcomes at an early stage. For firms financed with levered equity as opposed to equity only in the Seed and Series A round, we find a 0.437 and 0.278 increase in the log odds of being in a higher level of exit, respectively. Similarly, for firms financed with runway loans as opposed to equity only in the Seed and Series A round, we find a 0.194 and 0.266 increase in the log odds being in a higher level of exit. Alternatively, we can interpret the coefficients using odds ratios. For example, we find that for firms financed with runway loans in the Series A round, the odds of exiting through acquisition with undisclosed price, acquisition with price, or an IPO versus ongoing (i.e. positive exit) is 1.305 times that of firms financed with equity. In Series B and C, the effect of levered equity is economically and statistically insignificant while runway loans continue to have a positive effect on the likelihood of exit. Notice, however, that the effect of levered equity on outcomes monotonically declines from Seed to Series A, and then is insignificant in Series B and C. Levered equity does not increase value in later stages, consistent with an interpretation of our model being about early-stage innovation strategy choices. Runway loans continue to have a positive effect on the likelihood of exit; the delay-for signal effect appears to persist.

To consider robustness to the constant proportional odds effect and to draw direct inference with respect to the probability to exit, we report the marginal effects results from a logistic specification in columns 5-9. The dependent variable is an indicator equal to one if a startup eventually achieves an acquisition or IPO. As column 5 shows, we find that the likelihood of an acquisition or IPO increases by 5.04% (2.11%) if the startup raises levered equity (runway loan) in the seed round. Column 6 reports that, following a series A round, the likelihood of an ultimate acquisition or IPO increases by 5.36% (5.53%) if the startup raises levered equity (runway loan).

The most important column is perhaps that of column (9), where we implement a mixed (random effects) logit model to absorb firm effects. We pool the Seed, Series A, B, and C rounds and including series fixed effects. The random effects model allows us to control for unobserved heterogeneity under the assumption that the heterogeneity is constant over time and not correlated with the independent variables. We find that the treatment effect of levered equity (runway loan) is to increase the likelihood of a positive exit by 0.71% (0.88%). As in our survival analysis, selection accounts for the a portion of the magnitude of the outcome (comparing columns 5-8 to column 9). Yet, debt capital structures still have a treatment effect on the likelihood of successful exits in a statistically and economically meaningful level. Given that only 16.52% of the startup-round observations eventually exits via acquisition or IPO, our column 9 result translates into a 4.3% (5.3%) percentage increase in exit from the treatment of debt. For levered equity, a comparison with Table 2 and the results in columns 1-8 of Table 4 shows that this result is entirely driven by the use of levered equity in seed rounds increasing acquisitions without price disclosures. Overall, our results suggest that levered equity and runway loans lead to more favorable firm outcomes. This pattern is consistent with our theory that these products are utilized to preserve entrepreneurial "skin-in-the-game" so that incentives are aligned within the firm.

4.4.5 Alternative Mechanisms

One alternative hypothesis suggested for the use of venture debt is hidden (or asymmetric) information. Theoretically, in such settings, debt is often optimal as it minimizes the discount outside investors require to provide capital. For similar reasons, when insiders and outsiders disagree about the firm's growth potential, debt is generally optimal.[32] While these channels may play a role in the use of venture debt, it struggles to explain the pattern that the vast majority of debt rounds are subsequently followed by an equity round, then debt round,

[32] We note that disagreement about other aspects of the firm's value, for example, its value in liquidation, may actually make debt *suboptimal* when there is a difference of opinions.

and so on. Such an alternating pattern is not found in capital structure theories based on asymmetric information.[33]

Moreover, it is unclear that these mechanisms should lead to a reduction in closures and an increase in successful exits. One story, which could reconcile these observed outcomes, is that venture debt is utilized when the entrepreneur and insider VC know, but cannot credibly convey, that good news about the firm is likely to be revealed soon. We note, however, that the presence of an insider VC implies that it would be better, in general, for the insider to contribute their own capital rather than bear the discount required by outsiders, especially when the capital required to get to the information revelation is modest.

Another alternative hypothesis around our closure results, consistent with practice, is that venture debt is commonly associated with "high-quality" venture capitalists. In this case, reduced closure is not a function of the treatment but is, instead, a selection story: high-quality VCs, who expect to need debt financing in the future, only encourage higher-quality startups to borrow, since the VC is engaged in a multi-period reputation game with the lender. Figure 5 presents evidence that, to the extent that this is true, it does not explain the patterns we observe. Utilizing financing volume as a measure of VC reputation/quality, the figure illustrates two effects. First, demonstrating that volume is a proxy for reputation, "high-volume" investors exhibit lower hazard rates across all three types of capital structure. Second, we show that the relative hazard rates do not depend upon whether the VC is high- or low-volume, consistent with a treatment effect of venture debt.[34]

Finally, one concern that arises with the utilization of debt in an early-stage startup, given their inherently risky nature, is risk-shifting. For one, this concern supports the utilization of venture debt by start-ups that are backed by high-quality/high-volume venture capitalists. Since such VCs are implicitly putting their own reputations on the line, we are less likely to

[33] As described in our literature review, there are now several papers which predict that equity can be the optimal security in the presence of asymmetric information. However, these papers do not predict the equity/debt/equity pattern that is almost universally found in practice.

[34] While we note that the hazard rate of runway loans with low-quality financiers is higher after year two than equity-only, this effect is outweighed, cumulatively, by the reduction in year one.

observe risk-shifting by such firms. The *relative* impact of venture debt, however, does not depend upon the type of venture capitalist backing the firm, suggesting that risk-shifting is not driving our positive exit results. Moreover, risk-shifting in the presence of debt also implies increased risk of closure which, as we argued above, is not borne out in the aggregate data.

To be clear, we do not mean to suggest that these alternatives cannot play a role in the utilization of venture debt but simply that they do not tell the whole story. To strengthen this argument, in the following section, we provide further evidence that is consistent with and novel to the model's proposed channel.

4.4.6 Mechanism Results

Next, we establish conditions under which which firms are more likely to issue venture debt to provide evidence of the proposed model mechanism. Recall that, pursuant to Corollary 1, a startup is more likely to take on venture debt (i) when the current dilution increases and (ii) the required runway decreases.

We first consider whether the choice of capital structure is affected by the dilution of the round. Specifically, Table 5 reports estimates from a mixed logit model with firm-level random effects, where, in columns 1-4, the dependent variable is the choice of levered equity as opposed to an equity round, dropping the runway loan rounds. The main independent variable of interest is the natural logarithm of dilution, which we calculate as the log of the current investment divided by the post-money valuation. We control for the total prior investment, the pre-money valuation, whether the investor is high volume, and employee quintile, industry and year fixed effects.

Consistent with the predictions of the model, as dilution increases, the likelihood of issuing venture debt becomes more likely. A one standard deviation increase in dilution increases the likelihood of levered equity issuance, sample-weighted across stages, by 1.83%, which is a 3.89% increase relative to the sample mean. Similarly, an increase in prior investments (a potential proxy for *past* dilution) is also positively associated with increased issuance of venture debt. Finally, as expected given the structure of the venture debt market, firms backed by high volume (reputation) investors are more likely to issue venture debt. This is consistent with the notion, discussed above, that venture debt is feasible in part due to the backing of high-quality VCs which help to ensure that borrowers do not risk–shift or engage in other inefficient investments.

In Table 5, columns 5-8, we estimate the potential determinants of runway loan issuance where, as above, the alternative issuance strategy is equity only. The key difference, however, is that for the runway loans, we estimate a model in which our current dilution proxy is forward dilution. In the model, the variable of interest is the total dilution the firm potentially faced under an equity only issuance. This is not captured by the dilution created with runway extension: the firm borrows less ($\Delta < 1$) in order to borrow the remaining required capital after positive information is revealed.[35] Instead, we utilize a measure of dilution that accounts for both the current and next round's investment, capturing the total amount of investment required to get to the next stage.

As expected, this is generally positively associated with the choice of venture debt, though only with statistical significance for the seed round and Series C. As with the levered equity product, an increase in prior investment (past dilution) makes a runway extension loan more likely and high reputation investors are more likely to pave the way for runway extension. Interestingly, in this case, and in contrast to the setting with levered equity, an increase in pre-money valuation negatively predicts the use of the runway extension product. This is consistent with the idea that firms which have struggled to reach prior milestones and are waiting for good information to be revealed are more likely to need a runway extension.

Finally, in Table 6, we report estimates of the future duration runway until the next round, i.e., how long does the startup go until the next funding round. We implement two

[35] The model suggests (as we discuss below) that if the firm can extend their runway with a small amount of capital, runway loans are more attractive. This would be consistent with a negative relationship to the original log dilution measure, which we find in unreported results.

models of duration, a linear mixed model (random effects) in the odd numbered columns and an AR(1) mixed model in the even columns. Our decision to incorporate the lagged term reflected a concern that there might persistence in the duration, whereby some companies take longer to meet milestones because of early-stage hurdles in innovation. Alternatively, firms may simply differ in their burn rate and so including lagged duration allows us to account for this heterogeneity. We also include the aforementioned control variables and fixed effects. Using theAR(1) model, we find that the issuance of a runway loan decreases the days until the next round of financing by 13.3%, sample-weighted across stages, or 46 days.

The model suggests that as the required period of time until the firm reaches (or fails to reach) its next milestone falls, runway debt becomes more attractive. Suppose a startup needs to raise a fixed amount of capital. The sooner information about the product is revealed, the less money the startup has to raise at the unconditional, relatively expensive price today, and the more money it can potentially raise at the relatively cheap price if it achieves its milestone. As we show in our theoretical analysis, this is exactly when venture debt is most valuable. Of course, obtaining an ex-ante estimate of the required runway is not feasible and so we adopt the alternative perspective: conditional on the product chosen, how long until the next funding round?

We find that the impact of runway extension on forward duration is negative. Even controlling for past burn rates only modestly attenuates its impact on time until next financing round. In contrast, with levered equity, controlling for the past burn rate leads to a statistically insignificant effect for early-stage (Series A or earlier) firms. Finally, and unsurprisingly, we find that the forward duration is increasing in the current investment level since this provides more leeway for the firm before it goes back to investors.

5 Conclusion

In this paper, we provide theoretical foundations and empirical evidence on the optimal use of venture debt and its implications for firm outcomes. In the model, an entrepreneur chooses the startups strategy, trading off the financial benefits of risk-taking with the utility he forfeits if he loses his control rights. If the entrepreneur's equity is too diluted, he favors a low-risk, low-value strategy. Yet, we show that venture debt can increase the entrepreneur's "skin-in-the-game" which incents the entrepreneur to choose a high-risk (high-value) strategy. Debt can play this role both in a "levered equity" structure, where equity and debt are issued concurrently, and in a "runway loan" structure, where the firm delays equity financing until a milestone is (potentially) met.

Empirically, firms financed with levered equity (runway loans) have a 22% (6%) increase in the odds ratio of survival relative to equity financing. We further find that the use of levered equity (runway loans) results in a 4.3% (5.3%) percentage increase in the likelihood of acquisition or IPO. Moreover, consistent with the model mechanism, we show that venture debt is more likely to be utilized when expected dilution is high and when the required runway is short. Our analysis demonstrates that the introduction of venture debt has not only changed the start-up financing landscape, but has also created a valuable channel through which financing decisions can improve outcomes for early-stage firms. A back of the envelope calculation suggests that the use of venture debt saves $41.1 billion, or 9.4% of invested capital, by preventing closure in early-stage firms.

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A Proofs

Proof of Lemma 1

First, we confirm:

$$\mathbb{E}\left[(1-\alpha_{s+1})\,\gamma Y\,|\,p,\tau\right] = \rho\tau\left[\left(1-\frac{X_{s+1}+D}{(\tilde{\gamma}+\delta)\,Y}\right)(\tilde{\gamma}+\delta)\,Y\right] + (p-\tau)\left[\left(1-\frac{X_{s+1}+D}{\tilde{\gamma}Y}\right)\tilde{\gamma}Y\right] \tag{13}$$

$$+\,(1-\rho)\,\tau\left[\left(1-\frac{X_{s+1}+D}{(\tilde{\gamma}-\delta)\,Y}\right)(\tilde{\gamma}-\delta)\,Y\right] \tag{14}$$

$$= p\left[\tilde{\gamma}Y-(X_{s+1}+D)\right]+\tau\left[(2\rho-1)\,\delta Y\right] \tag{15}$$

The first term is positive since, conditional on reaching the milestone, the firm can raise capital at $s+1$ (and note that this happens with probability p) The second term is positive since $\rho > \frac{1}{2}$, capturing the expected increase in firm value, given τ. Rewriting the entrepreneur's objective function yields

$$(1-\theta)\,(1-\alpha_s)\left(p\left[\tilde{\gamma}Y-(X_{s+1}+D)\right]+\tau\left[(2\rho-1)\,\delta Y\right]\right)+b\,(p+(\rho-1)\,\tau) \tag{16}$$

This is linear in τ, implying a corner solution: $\tau* \in \{0,\, \tau_h\}$. The entrepreneur's utility is weakly increasing in τ as long as

$$(1-\theta)\,(1-\alpha_s)\left[(2\rho-1)\,\delta Y\right]-b\,(1-\rho)\geq 0 \tag{17}$$

Thus, as long as (7) holds, the entrepreneur chooses $\tau^* = \tau_h$ which completes our proof.

□

Proof of Proposition 1

First, we need to show that $\frac{\partial \alpha_s}{\partial D} < 0$. At the start of stage s, given the information available,

$$\alpha_s = \frac{X_s-\mathbb{P}\left[\gamma>0\right]D}{\mathbb{E}\left[(1-\alpha_{s+1})\,\gamma Y\,|\,\tau\,(\alpha_s)\right]} \tag{18}$$

$$= \frac{X_s-\mathbb{E}\left[p\right]D}{\mathbb{E}\left[p\right]\left[\tilde{\gamma}Y-X_{s+1}\right]+\tau\,(\alpha_s)\left[(2\rho-1)\,\delta Y\right]-\mathbb{E}\left[p\right]D} \implies \tag{19}$$

$$\frac{\partial \alpha_s}{\partial D} < 0 \iff \tag{20}$$

$$X_s < \mathbb{E}\left[p\right]\left[\tilde{\gamma}Y-X_{s+1}\right]+\tau\,(\alpha_s)\left[(2\rho-1)\,\delta Y\right] \tag{21}$$

This is always true since, if the firm could successfully raise equity at stage s without debt, $\alpha_s = \frac{X_s}{\mathbb{E}[p][\tilde{\gamma}Y-X_{s+1}]} < 1$. Thus, increasing the amount of debt issued lowers α_s which increases the left-hand side of the IC constraint. Thus, if there exists some D^* such that

$$(1-\theta)\left(1-\frac{X_s-\mathbb{E}\left[p\right]D^*}{\mathbb{E}\left[p\right]\left[\tilde{\gamma}Y-X_{s+1}\right]+\tau\,(\alpha_s)\left[(2\rho-1)\,\delta Y\right]-\mathbb{E}\left[p\right]D^*}\right)\geq \tag{22}$$

$$\left(\frac{b}{\delta Y}\right)\left(\frac{1-\rho}{2\rho-1}\right), \tag{23}$$

then the issuance of venture debt will induce the entrepreneur to choose the high-risk/high-value strategy which is strictly preferred by the VC.

□

Proof of Proposition 2

Suppose the firm cannot raise capital via pure equity at the start of stage s, i.e., $X_s > \mathbb{E}[p](\tilde{\gamma}Y - X_{s+1})$. In this case, the logic above still hold since it is feasible for (21) to hold as long as risk-taking is sufficiently beneficial, i.e. if $\tau_h[(2\rho-1)\delta Y]$ is sufficiently large. By the same logic, if there exists some D^*such that (7) holds, then the issuance of debt to be repaid at the start of stage $s+1$ will allow the firm to raise capital instead of closing.
Note that levered equity venture debt is only issued if it leads to $\tau(\alpha_s) = \tau_h$ which implies that it increases $\mathbb{E}[\gamma Y]$. As discussed in the main text, γ serves as a proxy both for stage $s+1$ beliefs about increased future market value as well as a decrease in the likelihood of closure (going forward). Thus, in our setting an increase in $\mathbb{E}[\gamma Y]$ suggests lower future closure rates.

□

Proof of Proposition 3

We begin by rewriting (7) to establish a threshold milestone achievement signal; specifically, if the firm issued runway extension debt then the entrepreneur chooses the risky strategy as long as

$$(1-\theta)\left(1-\frac{X_s}{p[\tilde{\gamma}Y - X_{s+1}] + \tau_h[(2\rho-1)\delta Y]}\right) \geq \left(\frac{b}{\delta Y}\right)\left(\frac{1-\rho}{2\rho-1}\right) \implies \tag{24}$$

$$p \geq \frac{\frac{X_s}{\left(1-\left(\frac{b}{(1-\theta)\delta Y}\right)\left(\frac{1-\rho}{2\rho-1}\right)\right)} - \tau_h[(2\rho-1)\delta Y]}{[\tilde{\gamma}Y - X_{s+1}]} \tag{25}$$

$$\equiv p_e \tag{26}$$

Because the statement of the proposition includes the condition that the agent is able to *obtain financing* at s^* regardless of the milestone reached, this threshold for risk-taking applies ex-ante under all-equity financing (and replacing p with $\mathbb{E}[p]$) *and* once the milestone is realized. Under this same assumption, we can also write the threshold over which the agent can raise capital with no risk-taking as

$$p \geq \frac{X_s}{\tilde{\gamma}Y - X_{s+1}} \equiv \underline{p} \tag{27}$$

Note that it is always the case that $p_h > \mathbb{E}[p] > p_l$. The assumption that the VC can raise capital regardless of the milestone implies that $p_l > \underline{p}$ and we adopt that assumption throughout the rest of the proof. It is straightforward to see that p_e can be higher or lower than $\underline{p}$: for instance, if $b = 0$, $p_e < \underline{p}$, but as b increases, so does p_e (and for sufficiently high b, it must be the case that $p_e > \underline{p}$). In what follows, we show the implications of an increase in p_e increases for the VC's expected earnings.

If $p_l > p_e$, then the entrepreneur always takes risk and is indifferent between equity financing and extending the runway. To see this, note that with equity financing the VC earns in expectation,

$$\theta \left(1 - \frac{X_s}{\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1} \,|\, p_s, \tau = \tau_h\right]}\right) \mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1} \,|\, \tau = \tau_h\right] = \tag{28}$$

$$\theta \left(\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1} \,|\, \tau = \tau_h\right] - X_s\right) = \tag{29}$$

$$\theta \left(\mathbb{E}\left[p\right]\left[\tilde{\gamma} Y - X_{s+1}\right] + \tau_h \left[\left(2\rho - 1\right)\delta Y\right] - X_s\right) \tag{30}$$

while with a runway extension she earns

$$\theta \left[\mathbb{P}\left[p = p_h\right]\left(\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1} \,|\, p = p_h, \tau = \tau_h\right] - X_s\right)\right] + \tag{31}$$

$$\theta \left[\left(1 - \mathbb{P}\left[p = p_h\right]\right)\left(\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1} \,|\, p = p_l, \tau = \tau_h\right] - X_s\right)\right] = \tag{32}$$

$$\theta \left(\left[\mathbb{P}\left[p = p_h\right] p_h + \left(1 - \mathbb{P}\left[p = p_h\right]\right) p_l\right]\left[\tilde{\gamma} Y - X_{s+1}\right] + \tau_h \left[\left(2\rho - 1\right)\delta Y\right] - X_s\right) = \tag{33}$$

$$\theta \left(\mathbb{E}\left[p\right]\left[\tilde{\gamma} Y - X_{s+1}\right] + \tau_h \left[\left(2\rho - 1\right)\delta Y\right] - X_s\right). \tag{34}$$

Thus, she is indifferent between the two issuance policies. Suppose instead that $\mathbb{E}\left[p\right] > p_e > p_l$. Then nothing changes if the VC issues equity but extending the runway generates a lower payoff:

$$\theta \left[\mathbb{P}\left[p = p_h\right]\left(p_h \left[\tilde{\gamma} Y - X_{s+1}\right] + \tau_h \left[\left(2\rho - 1\right)\delta Y\right] - X_s\right) + \left(1 - \mathbb{P}\left[p = p_h\right]\right)\left(p_l\left(\tilde{\gamma} Y - X_{s+1}\right) - X_s\right)\right] = \tag{35}$$

$$\theta \left(\mathbb{E}\left[p\right]\left[\tilde{\gamma} Y - X_{s+1}\right] + \mathbb{P}\left[p = p_h\right] \tau_h \left[\left(2\rho - 1\right)\delta Y\right] - X_s\right), \tag{36}$$

since $\mathbb{P}\left[p = p_h\right] < 1$. On the other hand, if $p_h > p_e > \mathbb{E}\left[p\right]$, then issuing equity only yields

$$\theta \left(\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1} \,|\, \tau = 0\right] - X_s\right) = \tag{37}$$

$$\theta \left(\mathbb{E}\left[p\right]\left[\tilde{\gamma} Y - X_{s+1}\right] - X_s\right). \tag{38}$$

In this case, extending the runway is strictly preferred because the payoff is (36). Thus, holding fixed $\mathbb{E}\left[p\right]$ while increasing $\mathbb{P}\left[p = p_h\right]$ (for instance by lowering p_l) makes venture debt more valuable. Finally, if $p_e > p_h$, then the VC is once again indifferent because her payoff with runway extension is reduced to

$$\theta \left[\mathbb{P}\left[p = p_h\right]\left(p_h\left(\tilde{\gamma} Y - X_{s+1}\right) - X_s\right) + \left(1 - \mathbb{P}\left[p = p_h\right]\right)\left(p_l\left(\tilde{\gamma} Y - X_{s+1}\right) - X_s\right)\right] = \tag{39}$$

$$\theta \left(\mathbb{E}\left[p\right]\left[\tilde{\gamma} Y - X_{s+1}\right] - X_s\right). \tag{40}$$

□

Proofs of Proposition 4

We first consider the case when the firm cannot obtain financing if it is revealed that $p = p_l$, i.e. $\overline{p} > p_l$. Under this assumption, the firm must issue debt with face value $\frac{\Delta X_s}{\mathbb{P}[p=p_h]}$ to account for this risk. As a result, the venture capitalist must raise $X_s\left(1+\Delta\frac{1-\mathbb{P}[p=p_h]}{\mathbb{P}[p=p_h]}\right)$ at s^* which implies that her expected payoff becomes

$$\theta\left(\mathbb{P}\left[p=p_h\right]\left(\mathbb{E}\left[\left(1-\alpha_{s+1}\right)\gamma Y_{s+1}\,|\,p_h,\tau\right]-X_s\left(1+\Delta\frac{1-\mathbb{P}\left[p=p_h\right]}{\mathbb{P}\left[p=p_h\right]}\right)\right)\right). \tag{41}$$

There are two scenarios to consider.

First, suppose that $p_e > \mathbb{E}[p] > \overline{p}$. In this case, the firm can obtain financing at the start of stage s but the entrepreneur will choose the low-risk strategy. If extending the runway leads to default when $p = p_l$, then venture debt can only be valuable if the entrepreneur chooses the high-risk strategy when $p = p_h$. In this case, the VC's payoff becomes

$$\theta\left(\mathbb{P}\left[p=p_h\right]\left[p_h\left[\tilde{\gamma}Y-X_{s+1}\right]+\tau_h\left[\left(2\rho-1\right)\delta Y\right]\right]-X_s\left(\mathbb{P}\left[p=p_h\right]+\Delta\left(1-\mathbb{P}\left[p=p_h\right]\right)\right)\right) \tag{42}$$

This exceeds the payoff under equity financing as long as

$$\mathbb{P}\left[p=p_h\right]\left[p_h\left[\tilde{\gamma}Y-X_{s+1}\right]+\tau_h\left[\left(2\rho-1\right)\delta Y\right]\right]-X_s\left(\mathbb{P}\left[p=p_h\right]+\Delta\left(1-\mathbb{P}\left[p=p_h\right]\right)\right)> \tag{43}$$

$$\mathbb{E}\left[p\right]\left[\tilde{\gamma}Y-X_{s+1}\right]-X_s \iff \tag{44}$$

$$\mathbb{P}\left[p=p_h\right]\tau_h\left[\left(2\rho-1\right)\delta Y\right]+X_s\left(\left(1-\Delta\right)\left(1-\mathbb{P}\left[p=p_h\right]\right)\right)> \tag{45}$$

$$\left(1-\mathbb{P}\left[p=p_h\right]\right)p_l\left[\tilde{\gamma}Y-X_{s+1}\right] \tag{46}$$

It is straightforward to see, for instance, that this must hold when $p_l \to 0$. It is also clear that this is more likely to hold when the required investment (X_s or X_{s+1}) increases, when the required runway (Δ) decreases, or when the benefits of risk-taking (δ, or τ_h) increase. Now we must establish the condition under which the entrepreneur actually chooses the high-risk strategy. The threshold has changed since the financing terms are different. We must now write the IC constraint as

$$1-\frac{X_s\left(1+\Delta\frac{1-\mathbb{P}[p=p_h]}{\mathbb{P}[p=p_h]}\right)}{p_h\left[\tilde{\gamma}Y-X_{s+1}\right]+\tau_h\left[\left(2\rho-1\right)\delta Y\right]}\geq\left(\frac{b}{\left(1-\theta\right)\delta Y}\right)\left(\frac{1-\rho}{2\rho-1}\right)\implies \tag{47}$$

$$p_h\geq\frac{\frac{X_s\left(1+\Delta\frac{1-\mathbb{P}[p=p_h]}{\mathbb{P}[p=p_h]}\right)}{1-\left(\frac{b}{(1-\theta)\delta Y}\right)\left(\frac{1-\rho}{2\rho-1}\right)}-\tau_h\left[\left(2\rho-1\right)\delta Y\right]}{\tilde{\gamma}Y-X_{s+1}} \tag{48}$$

$$> p_e \tag{49}$$

Because the firm must raise more money if it reaches the milestone, the threshold for taking the high-risk strategy is higher than before. However, it is clear that as $\Delta \to 0$, for instance, that this threshold approaches p_e. Suppose that $\Delta \to 0$, $p_l \to 0$ and $p_e \to \mathbb{E}[p]$. Then it is surely the case that the entrepreneur chooses $\tau = \tau_h$ if $p = p_h$ and the VC prefers runway extension (despite the risk of closure if $p = p_l$). Finally, we note that (48) is more likely to hold when the required runway (Δ) decreases, or when the benefits of risk-taking (δ or τ_h) increase.

Second, suppose that $\overline{p} > \mathbb{E}[p]$. In this case, the firm cannot obtain financing at the start of stage s using equity. Extending the runway must lead to default when $p = p_l$, but we will show that venture debt can be valuable if $p = p_h$, regardless of whether or not the firm chooses the high-risk strategy. If the entrepreneur chooses not to take risk then the VC's expected payoff would be

$$\theta\mathbb{P}[p = p_h]\left(p_h[\tilde{\gamma}Y - X_{s+1}] - X_s\left(1 + \Delta\frac{1 - \mathbb{P}[p = p_h]}{\mathbb{P}[p = p_h]}\right)\right) \tag{50}$$

Moreover, investors are willing to provide equity at s^* as long as

$$\frac{X_s\left(1 + \Delta\frac{1-\mathbb{P}[p=p_h]}{\mathbb{P}[p=p_h]}\right)}{p_h[\tilde{\gamma}Y - X_{s+1}]} \leq 1 \implies \tag{51}$$

$$p_h \geq \frac{X_s}{\tilde{\gamma}Y - X_{s+1}}\frac{\mathbb{P}[p = p_h] + \Delta(1 - \mathbb{P}[p = p_h])}{\mathbb{P}[p = p_h]} \tag{52}$$

The firm's inability to raise equity at s implies only that

$$\mathbb{E}[p] < \frac{X_s}{\tilde{\gamma}Y - X_{s+1}} \tag{53}$$

Note that since $p_h > \mathbb{E}[p]$ if $\Delta \to 0$ and $\overline{p} \to \mathbb{E}[p]$, then both (52) and (53) will hold, i.e., the firm can only obtain financing through the issuance of venture debt, thereby preventing closure at stage s. Finally, as discussed in the proof of proposition 2, runway extension with venture debt is associated with higher $\mathbb{E}[\gamma Y]$, which is associated with lower rates of closure in the future.

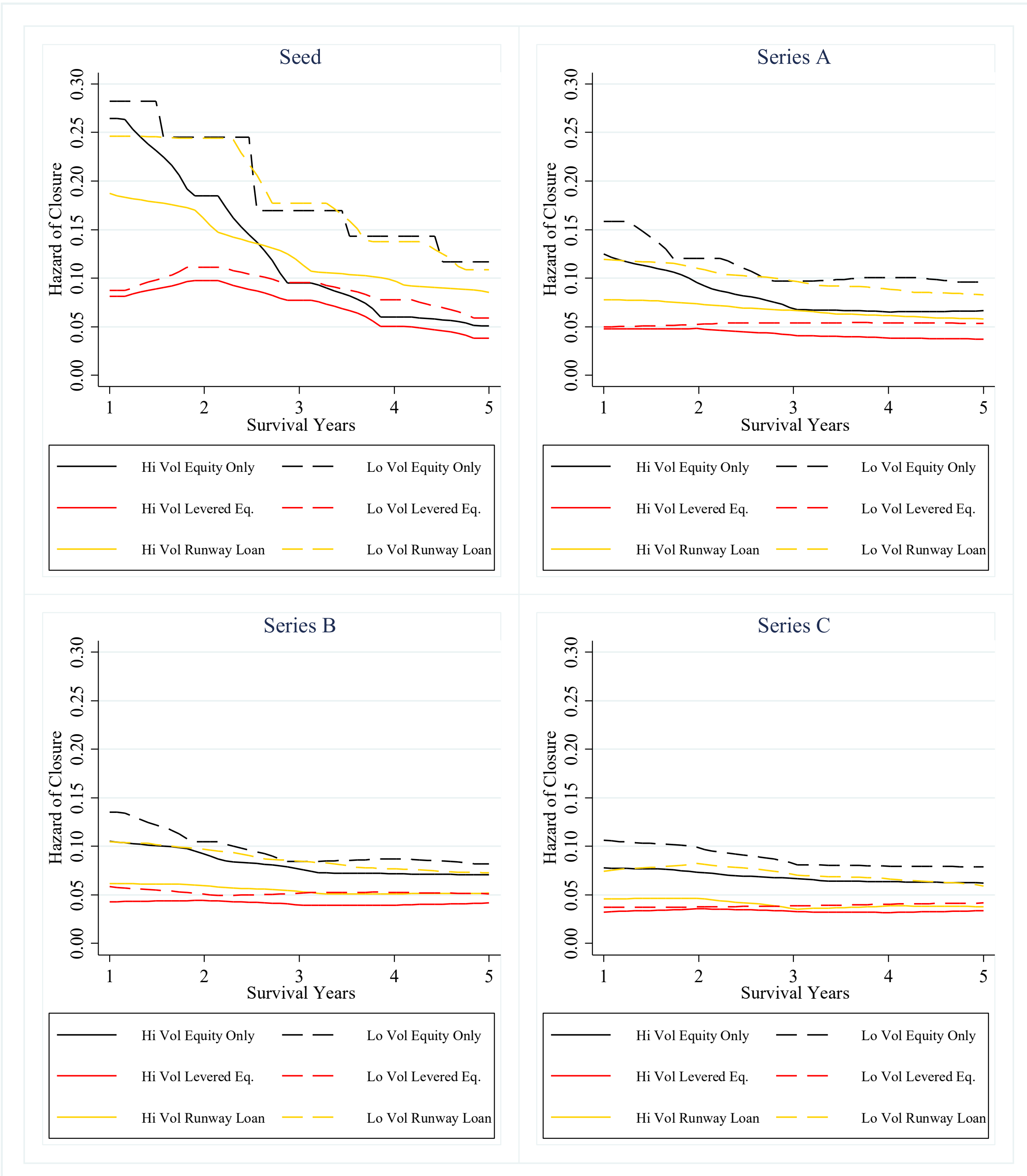
□

Proof of Corollary 1

These results were established in previous proofs. We establish that a shorter required runway (Δ) allows venture debt to prevent closure and makes runway extension more valuable in the proof of proposition 4). An increase in initial dilution $(1 - \theta)$ and required investment (X_s) and a decrease in $\mathbb{E}[p]$ make it more likely that $p_e > \mathbb{E}[p]$, i.e. the VC cannot get the entrepreneur to choose the high-risk strategy. Proposition 1 show that the use of venture debt in this case is always optimal, sometimes strictly.

□

Appendix Figure 1: Predict Hazard of Closure by Series, by high/ low volume (reputation) investors



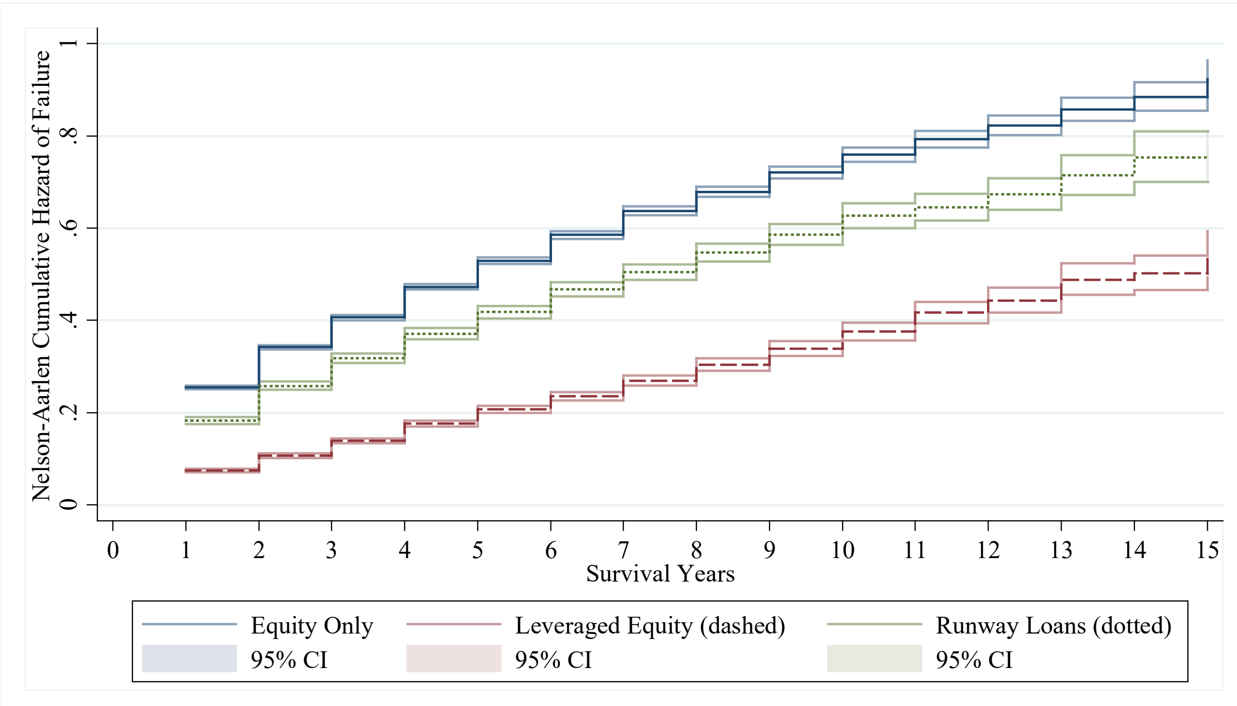
Plotted are the hazard functions of closure by series by high and low volume financiers. The estimation is akin to that of Table 3, Columns 1-4, but subsampled by high and low volume financiers.

Appendix Table 1: Mechanism Variables Summary Statistics

This table presents the summary statistics for the dilution and runway variables in our sample. We report statistics by series and by capital structure. Observations are rounds of financing. The sample period is 1999-2016. Dilution is defined as the current investment divided by the post-money valuation.We add 1 when we take the logs. Forward dilution is the dilution of the next round, if any. Duration is the time in days until the next financing round.

	Equity Only				Levered Equity				Runway Loan			
	Mean	St Dev	Median	Obs.	Mean	St Dev	Median	Obs.	Mean	St Dev	Median	Obs.
					Seed							
Dilution	0.200	0.042	0.202	36,502	0.201	0.027	0.202	5,015	0.201	0.038	0.202	4,962
Forward Dilution	0.199	0.043	0.186	13,576	0.210	0.032	0.223	2,486	0.203	0.046	0.223	2,366
Forward Runway Duration Days	433	385	346	13,849	395	293	338	2,509	369	325	295	2,413
					Series A							
Dilution	0.268	0.033	0.260	14,789	0.272	0.031	0.267	5,594	0.273	0.029	0.270	4,099
Forward Dilution	0.211	0.026	0.202	6,328	0.214	0.027	0.210	3,197	0.214	0.025	0.210	2,314
Runway Duration Days	558	459	442	6,379	527	377	456	3,212	471	365	384	2,328
					Series B							
Dilution	0.232	0.028	0.223	7,267	0.239	0.034	0.234	4,519	0.234	0.025	0.224	2,695
Forward Dilution	0.181	0.028	0.174	3,099	0.187	0.031	0.181	2,541	0.183	0.027	0.174	1,424
Runway Duration Days	528	461	416	3,160	605	438	521	2,592	491	368	414	1,445
					Series C							
Dilution	0.190	0.028	0.182	2,842	0.200	0.036	0.191	2,541	0.191	0.026	0.182	1,411
Forward Dilution	0.189	0.028	0.181	204	0.182	0.027	0.174	301	0.197	0.037	0.201	124
Runway Duration Days	473	409	367	1,341	577	436	492	1,401	428	368	345	812

Figure 1: Cumulative Hazard of Closure



This figure depicts the Nelson-Aarlen cumulative hazard of failure over survival years. Observations are at the round-year level. Note that the observations at risk do not stay constant, as rounds get truncated out of the sample when they experience an exit other than closure.

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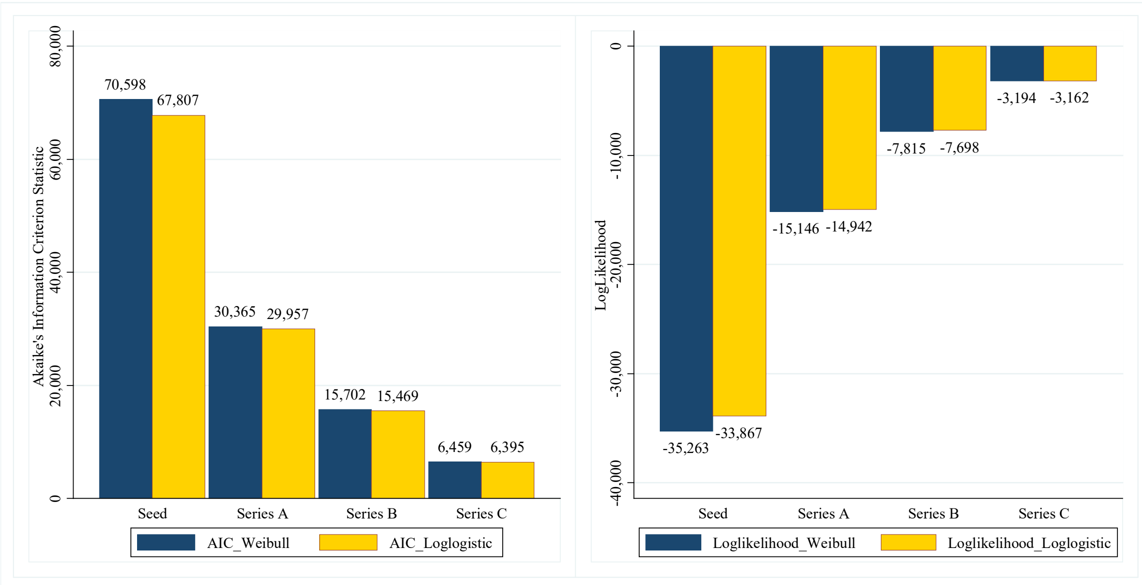
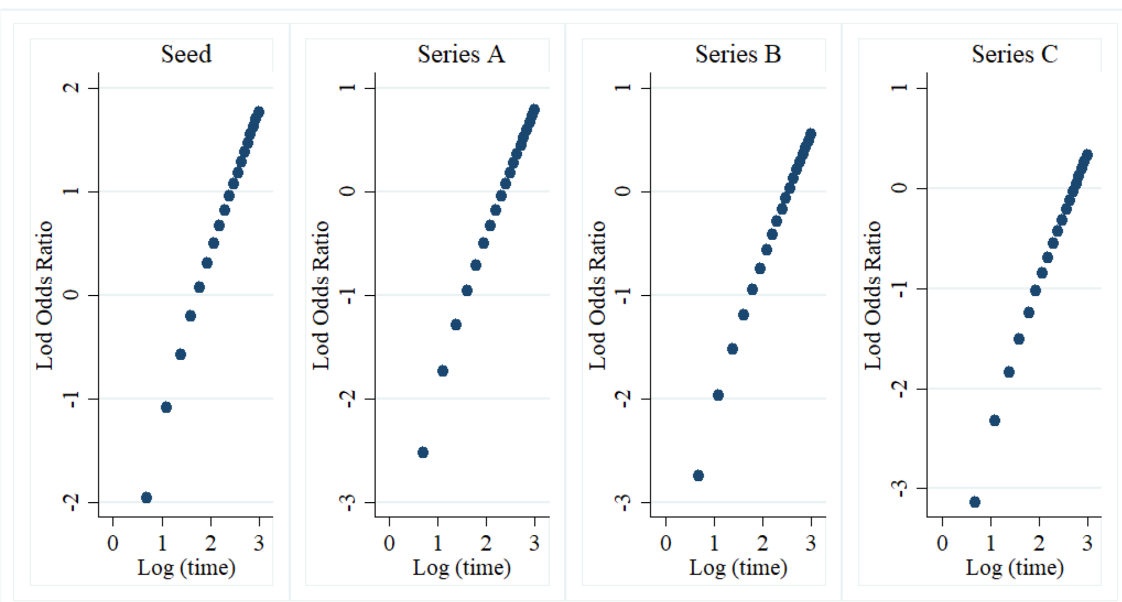
Figure 2: Diagnostic Tests for Survival Analysis



Panel A

Depicted are the Akaike's information criterion (AIC) statistic and the loglikehood from parametric survival models of the Weibull distribution (dark/blue) and thel Loglogistic distribution (light/gold) by staging. A smaller AIC statistic and a larger loglikelihood statistic indicate a better goodness-of-fit. The estimations include the controls used in the main estimation (Table 3).



Panel B

Panel B follows Lee (2003) and plots the log odds ratios from a loglogistic survival. The log odds ratio, even in a model without covariates, should be linear in log time. We fit the no covariate survival model and plot log odds ratio against log time for each stage.

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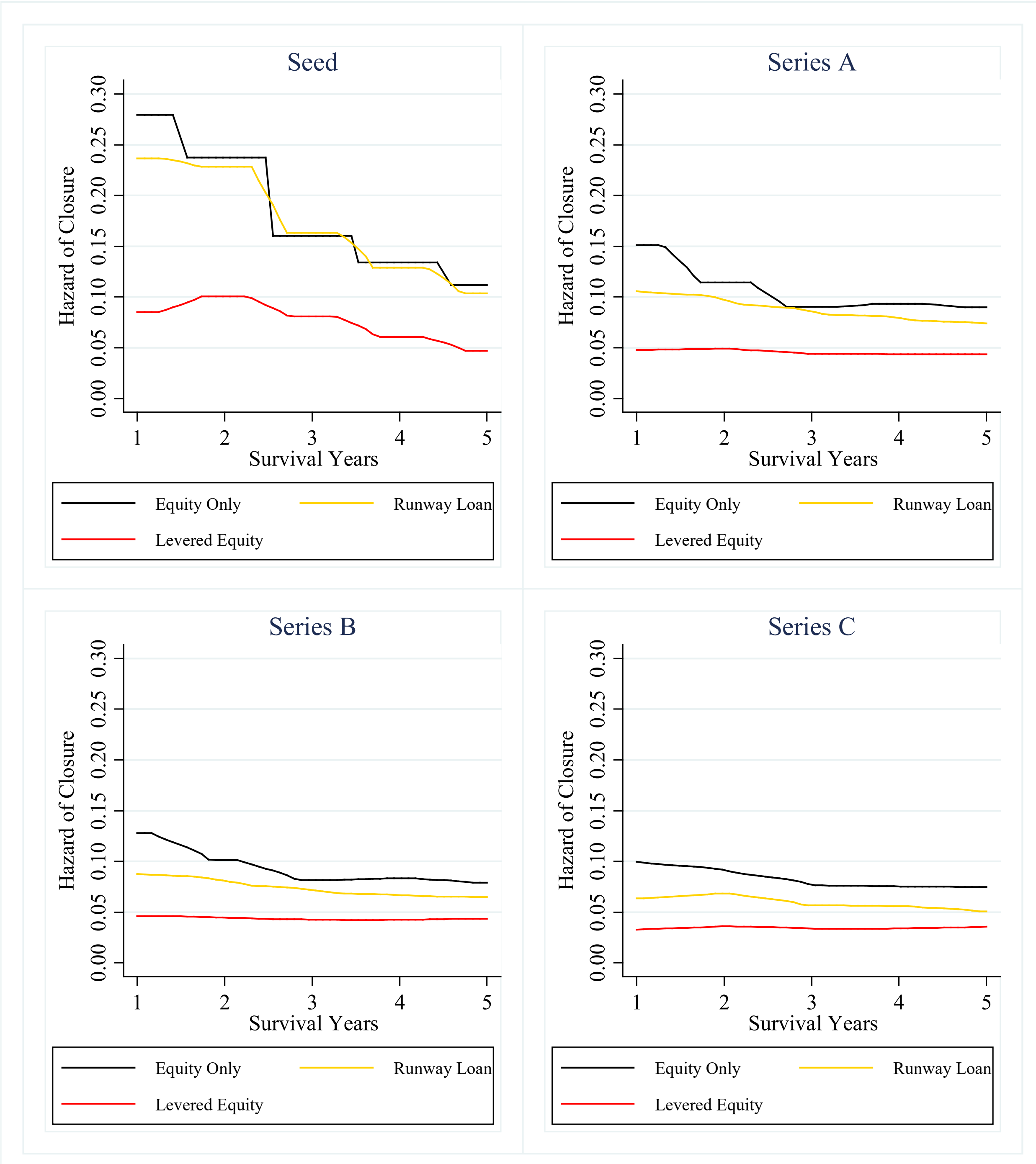
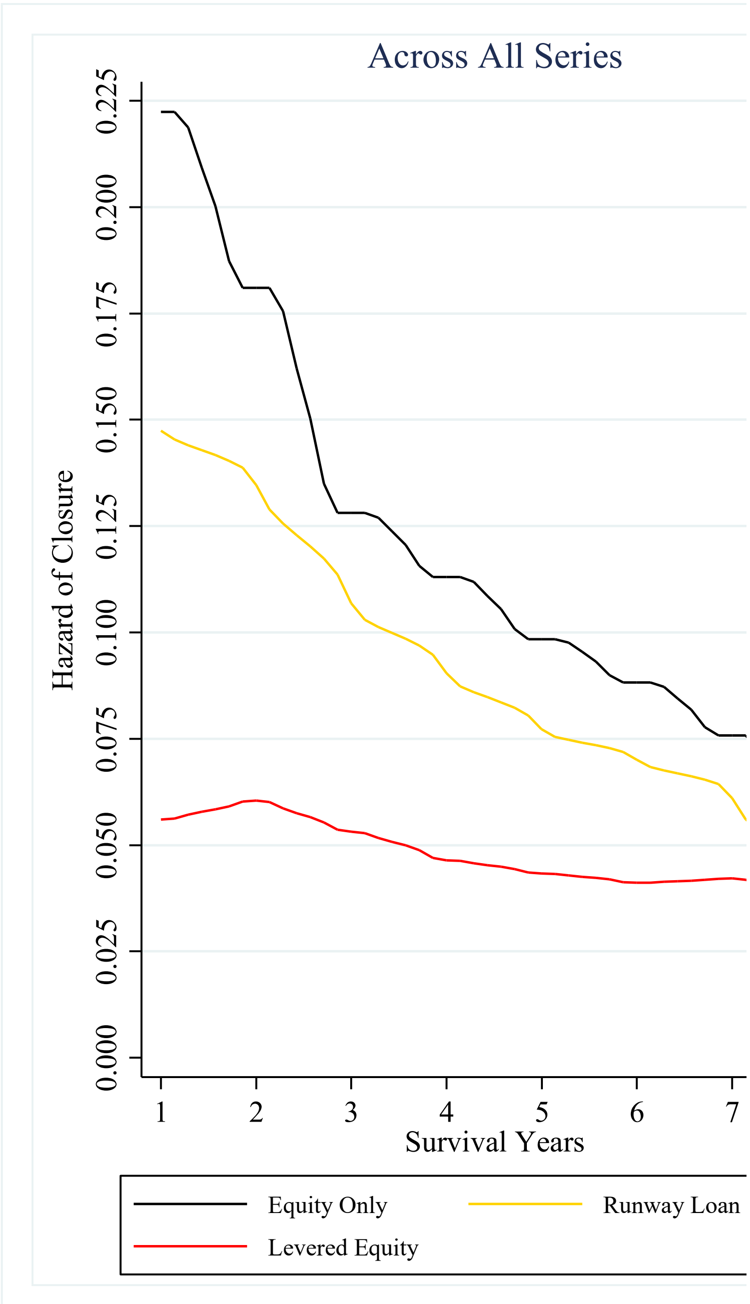
Figure 3: Predicted Hazard of Closure by Series



This figure shows the hazard functions of closure by stage, corresponding to the estimation in Table 3, columns (1)-(4).

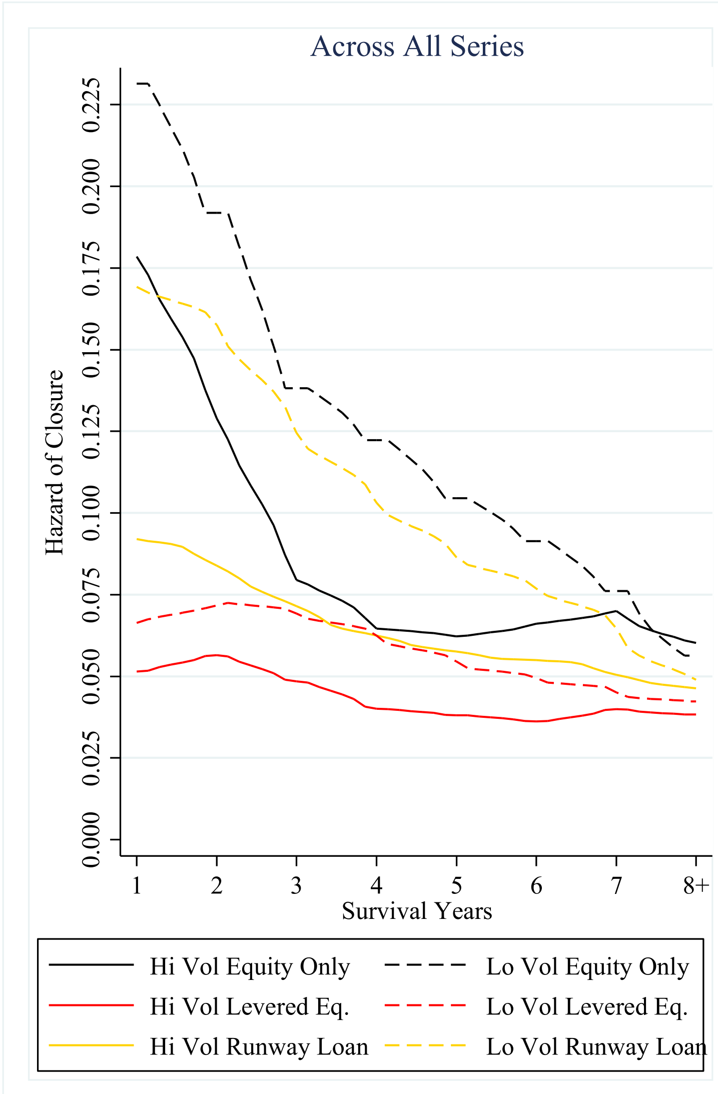
Figure 4: Predict Hazard of Closure across All Series



	Predicted hazard		
Survi-val Time	Equity Only	Levered Equity	Runway Loan
1	0.222	0.056	0.148
2	0.181	0.061	0.135
3	0.128	0.053	0.106
4	0.113	0.046	0.090
5	0.098	0.043	0.077
6	0.088	0.041	0.070
7	0.076	0.042	0.062
8+	0.057	0.040	0.047
Total	0.152	0.051	0.108

This figure shows the hazard functions of closure pooled across all series, constructed as the weighted average of the predicted hazard from Table 3, columns (1)-(4). The weights are the number of round-year observations from each series.

Figure 5: Predict Hazard of Closure across All Series, by high/low volume (reputation) investors



High Volume Investors: Predicted hazard

Survival Time	Equity Only	Levered Equity	Runway Loan
1	0.179	0.052	0.096
2	0.129	0.057	0.084
3	0.080	0.048	0.067
4	0.065	0.040	0.061
5	0.062	0.038	0.056
6	0.066	0.036	0.054
7	0.070	0.040	0.054
8+	0.060	0.038	0.044
Total	0.112	0.047	0.072

Low Volume Investors: Predicted hazard

Survival Time	Equity Only	Levered Equity	Runway Loan
1	0.231	0.065	0.170
2	0.192	0.074	0.158
3	0.138	0.069	0.123
4	0.122	0.062	0.103
5	0.104	0.054	0.086
6	0.091	0.049	0.077
7	0.076	0.046	0.065
8+	0.056	0.042	0.049
Total	0.160	0.061	0.123

This figure shows the hazards functions of closure pooled across all series and split by high and low volume financiers. We pool the predicted hazard by taking the weighted average of all series where the weights are the number of round-year observations from each series.

Table 1: Summary Statistics

This table reports summary statistics for the sample used in our analysis. Observations are rounds of financing. The sample period is 1999-2016. Panel A presents the distribution of observations across series, conveying how many rounds, rounds per firm, and how many yearly observations this translates into for the survival analysis. We also display the counts and percentage of levered equity, runway loans, and equity financing by series. Panel B reports the industry distribution by series. Panel C reports the number of employees across series, as reported in quintiles to Crunchbase.

Panel A: Capital Structure Deal Prevalence

	Seed	Series A	Series B	Series C	Total
Observations					
Overall Rounds:	46,480	24,481	14,481	6,794	92,236
Representing # of Firms:	36,360	22,104	12,988	6,110	54,000
Representing # Rounds/Firm:	1.3	1.1	1.1	1.1	1.7
# of Round-Years in Lifespan:	202,744	131,422	77,984	36,984	449,134

	Seed Counts	Seed %	Series A Counts	Series A %	Series B Counts	Series B %	Series C Counts	Series C %	Total Counts	Total %
Equity Only	36,503	78.5%	14,788	60.4%	7,267	50.2%	2,842	41.8%	61,400	66.6%
Levered Equity	5,015	10.8%	5,594	22.9%	4,519	31.2%	2,541	37.4%	17,669	19.2%
Runway Loan	4,962	10.7%	4,099	16.7%	2,695	18.6%	1,411	20.8%	13,167	14.3%

Distribution of Funding Year	Seed	Series A	Series B	Series C	Total
25%ile	2012	2009	2008	2009	2008
50%ile	2014	2013	2012	2012	2011
75%ile	2015	2015	2015	2014	2013

Panel B: Industry Distribution

	Seed		Series A		Series B		Series C		Total	
	Counts	%	Counts	%	Counts	%	Counts	%	Counts	%
Biotech / Health	6,705	14.4%	5,521	22.6%	3,660	25.3%	1,929	28.4%	17,815	19.3%
Energy	506	1.1%	539	2.2%	434	3.0%	211	3.1%	1,690	1.8%
Finance	1,779	3.8%	791	3.2%	456	3.1%	150	2.2%	3,176	3.4%
Other	6,907	14.9%	2,876	11.7%	1,557	10.8%	625	9.2%	11,965	13.0%
Software / AI	29,221	62.9%	14,216	58.1%	8,112	56.0%	3,796	55.9%	55,345	60.0%
Unknown	1,362	2.9%	538	2.2%	262	1.8%	83	1.2%	2,245	2.4%

Panel C: Size Distribution

	Seed		Series A		Series B		Series C		Total	
	Counts	%	Counts	%	Counts	%	Counts	%	Counts	%
Employees 1 to 10	20,388	43.9%	4,228	17.3%	1,589	11.0%	583	8.6%	26,788	29.0%
11 to 50	18,675	40.2%	10,755	43.9%	5,248	36.2%	2,217	32.6%	36,895	40.0%
51 to 100	2,180	4.7%	3,409	13.9%	2,724	18.8%	1,512	22.3%	9,825	10.7%
101 to 250	981	2.1%	1,786	7.3%	1,554	10.7%	851	12.5%	5,172	5.6%
251 to 500	325	0.7%	734	3.0%	775	5.4%	483	7.1%	2,317	2.5%
501 to 1000	206	0.4%	542	2.2%	593	4.1%	350	5.2%	1,691	1.8%
1001 to 5000	94	0.2%	234	1.0%	250	1.7%	146	2.1%	724	0.8%
5001+	40	0.1%	92	0.4%	108	0.7%	60	0.9%	300	0.3%
Unknown	3,591	7.7%	2,701	11.0%	1,640	11.3%	592	8.7%	8,524	9.2%

Table 1, continued

Panel D presents the summary statistics for the control covariates in our sample. We report statistics by series and by capital structure. Current investment is amount of capital raised in the current financing round. Prior investments is the sum of all prior capital raised by the startup. The pre-money valuation is the valuation accruing to founders and prior investors as implied by the valuation of the current investment. This is an estimate, as we use observed numbers when available and apply Pitchbook year-industry averages for missing values. High volume investor are those who have financed an above-median number of deals in the prior year.

Panel D: Firm and Investment Characteristics	Equity Only					Levered Equity					Runway Loans				
	Mean	St Dev	P 25	P 50	P 75	Mean	St Dev	P 25	P 50	P 75	Mean	St Dev	P 25	P 50	P 75
						Seed									
Observations	36,503					5,015					4,962				
Current Investment ($ 1,000)	700	1,037	125	383	1,000	1,497	1,967	525	1,200	2,000	620	1,474	100	250	750
Prior Investments ($ 1,000)	233	1,500	0	0	0	376	2,009	0	0	100	452	3,474	0	0	0
PreMoney Valuation ($ 1,000)	2,893	4,933	541	1,591	3,885	5,964	7,958	2,147	4,669	7,894	2,481	5,868	461	1,051	3,000
High Volume Investor (0-1)	0.11	0.32	0	0	0	0.58	0.49	0	1	1	0.17	0.38	0	0	0
						Series A									
Observations	14,788					5,594					4,099				
Current Investment ($ 1,000)	4,380	5,932	1,400	3,000	5,000	8,004	8,714	3,000	5,600	9,600	5,048	6,349	1,200	3,358	6,500
Prior Investments ($ 1,000)	1,044	3,778	0	0	750	1,803	5,700	0	0	1,735	1,663	5,965	0	0	1,000
PreMoney Valuation ($ 1,000)	12,375	25,523	3,750	7,800	14,365	21,707	24,198	8,389	14,933	25,636	13,614	19,742	3,241	8,836	16,777
High Volume Investor (0-1)	0.21	0.41	0	0	0	0.68	0.47	0	1	1	0.33	0.47	0	0	1
						Series B									
Observations	7,267					4,519					2,695				
Current Investment ($ 1,000)	10,220	12,541	2,000	5,998	13,000	15,876	13,079	7,200	12,000	20,000	11,247	13,047	2,000	7,500	15,000
Prior Investments ($ 1,000)	5,071	9,396	0	2,300	5,923	8,790	12,035	1,800	5,500	10,800	6,607	10,681	310	3,490	8,000
PreMoney Valuation ($ 1,000)	34,572	44,506	6,977	18,808	43,669	52,987	54,256	22,687	38,284	65,224	40,084	92,620	6,977	22,953	48,493
High Volume Investor (0-1)	0.25	0.43	0	0	0	0.76	0.43	1	1	1	0.38	0.49	0	0	1
						Series C									
Observations	2,842					2,541					1,411				
Current Investment ($ 1,000)	10,133	13,182	2,000	5,000	12,092	20,712	15,806	10,000	16,000	27,500	10,775	13,553	1,585	5,567	15,000
Prior Investments ($ 1,000)	15,686	18,562	4,340	10,000	20,000	22,212	19,702	10,000	17,305	28,400	18,851	20,249	6,073	13,000	24,150
PreMoney Valuation ($ 1,000)	46,923	95,284	8,493	22,518	51,600	89,567	87,346	34,885	65,783	115,779	48,361	71,511	6,957	22,548	60,174
High Volume Investor (0-1)	0.22	0.41	0	0	0	0.85	0.36	1	1	1	0.37	0.48	0	0	1

Table 2: Survival and Exit

This table reports the univariate statistics for closure and exits by capital structure and series. Observations are rounds of financing. The sample period is 1999-2016. When explicit closure is not available in the data, we classify any firm that goes without a funding round or news update for two years as closed. Survival is defined as ongoing, undisclosed-price acquisition, price-disclosed acquisition, and IPO.

	All Rounds				
	Seed Percent	Series A Percent	Series B Percent	Series C Percent	Total Percent
Closed	45%	33%	27%	21%	37%
Survival	55%	67%	73%	79%	63%
Resolution Condition on Survival					
Ongoing	85.0%	69.6%	61.3%	56.3%	74%
Acquistion without Price	12.1%	19.8%	21.9%	22.7%	17%
Acquistion with Price	1.9%	6.5%	10.0%	11.9%	6%
IPO	1.0%	4.1%	6.8%	9.2%	4%

	Equity				
	Seed Percent	Series A Percent	Series B Percent	Series C Percent	Total Percent
Closed	48%	37%	33%	28%	43%
Survival	52%	63%	67%	72%	57%
Resolution Condition on Survival					
Ongoing	86.7%	74.2%	67.1%	62.7%	79.3%
Acquistion without Price	10.5%	17.1%	19.0%	19.8%	14.0%
Acquistion with Price	1.7%	4.8%	7.6%	9.1%	3.8%
IPO	1.1%	3.9%	6.4%	8.4%	3.0%

	Levered Equity				
	Seed Percent	Series A Percent	Series B Percent	Series C Percent	Total Percent
Closed	23%	19%	18%	14%	19%
Survival	77%	81%	82%	86%	81%
Resolution Condition on Survival					
Ongoing	78.7%	65.3%	56.0%	51.0%	64.3%
Acquistion without Price	18.2%	22.1%	24.0%	24.3%	21.9%
Acquistion with Price	2.8%	8.5%	12.8%	15.1%	9.1%
IPO	0.3%	4.2%	7.3%	9.6%	4.8%

	Runway Loans				
	Seed Percent	Series A Percent	Series B Percent	Series C Percent	Total Percent
Closed	46%	34%	28%	21%	36%
Survival	54%	66%	72%	79%	64%
Resolution Condition on Survival					
Ongoing	82.0%	61.1%	57.0%	54.7%	65.9%
Acquistion without Price	14.3%	25.0%	25.4%	24.6%	21.7%
Acquistion with Price	2.2%	9.2%	10.9%	11.0%	7.6%
IPO	1.5%	4.7%	6.7%	9.7%	4.8%

Table 3: Survival Results

This table reports the loglogistic estimates for the effect of capital structure on survival. Observations are at the round-year level. The sample period is 1999 - 2018. We follow firms from the financing round year until positive exit (M&A or IPO), closure, or 2018, whichever comes first. The dependent variable is an indicator variable equal to one if a firm is still ongoing in that year. Columns (1) to (4) divide the estimation by series. Standard errors in brackets are clustered at the firm level. Columns (5) to (8) are pooled across series, including a series fixed effects, and implemented via a loglogistic frailty survival function, where frailty is estimated at the firm level in columns (5) to (7) and at the firm-capital structure level in column (8). All specifications control for the natural logarithm of the amount of capital raised, the natural logarithm of prior investment, the natural logarithm of the pre-money valuation, and an indicator variable for whether the investor is a high volume investor. We also include employee quintiles at the time of fundraising, industry fixed effects and year fixed effects. The gamma statistic is the shape parameter of the loglogistic estimation, with a gamma less than one indicating that the hazard of closure increases then decreases. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model:	Loglogistic Survival Model				Loglogistic-Frailty Survival Model			
Sample:	Seed	Series A	Series B	Series C	All Series Pooled			
Display:	Log Odds				Log Odds			
Levered Equity	0.452***	0.500***	0.384***	0.421***	0.240***		0.197***	0.3083***
	[0.0216]	[0.029]	[0.0383]	[0.0625]	[0.0161]		[0.0153]	[0.0175]
Runway Loans	0.118***	0.185***	0.147***	0.217***		0.0635***	0.0556***	0.1077***
	[0.0168]	[0.026]	[0.0359]	[0.0542]		[0.0128]	[0.0127]	[0.0158]
Log Current Investment	0.208***	0.490***	0.748***	0.977***	0.113***	0.105***	0.108***	0.1275***
	[0.0137]	[0.0503]	[0.0938]	[0.173]	[0.0149]	[0.014]	[0.0136]	[0.0144]
Log Prior Investments	0.0427***	0.0488***	0.0708***	0.0280**	-0.129***	-0.134***	-0.126***	-0.1160***
	[0.00414]	[0.00437]	[0.00523]	[0.0112]	[0.002]	[0.002]	[0.002]	[0.002]
Log Premoney Value	-0.125***	-0.395***	-0.681***	-0.887***	-0.0712***	-0.0640***	-0.0743***	-0.0786***
	[0.0147]	[0.0524]	[0.0957]	[0.175]	[0.016]	[0.015]	[0.015]	[0.015]
High Volume Investor	-0.0368**	0.037	0.00504	0.0183	-0.0505***	-0.0492***	-0.0401***	-0.0359***
	[0.0154]	[0.0235]	[0.032]	[0.0542]	[0.0134]	[0.0136]	[0.0121]	[0.0127]
Other Variables Included	Calendar Year Effects, Employee Count Buckets, Industry Fixed Effects				Series Fixed Effects, Calendar Year Effects, Employee Count Buckets, Industry Fixed Effects			
Frailty					Firm	Firm	Firm	Firm-Capital Structure
Observations	156,264	106,941	63,503	29,740	227,363	202,319	272,174	272,174
Gamma	0.472	0.609	0.616	0.599	0.279	0.272	0.280	0.285
Funding Rounds	46,480	24,481	14,481	6,794	50,276	45,631	59,806	59,806
Number of Frailty Groups					20,712	19,708	21,570	29,222
Mean Round-Years per Frailty Group					10.98	10.27	12.62	9.31
LR chi2					11,323	11,732	12,888	16,361

Table 4: Exit Results, Conditional on Survival

This table reports the effect of capital structure on exits. Observations are rounds of financing. The sample period is 1999-2016. We restrict the sample by dropping all firms that eventually close. Columns (1) to (4) reports the estimates from an ordered logistic specification. The dependent variable is exits in the following descending order: IPO, priced M&A, M&A with undisclosed price, and ongoing. Columns (5) to (9) report the estimates from a logistic specification. The dependent variable is an indicator variable equal to one if a startup eventually achieves a M&A or IPO. Columns (1) to (8) subsample the rounds by series. Column (9) is a mixed logit (random effects) model, with pooled series and series fixed effects to absorb static firm heterogeneity. All specifications control for the natural logarithm of the amount of capital raised, the natural logarithm of prior investment, the natural logarithm of the pre-money valuation, and an indicator variable for whether the investor is a high volume investor. We also include employee quintiles at the time of fundraising, industry fixed effects and year fixed effects. Standard errors in brackets are clustered at the firm level in columns (1) to (8). *** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Model:	Ordered Logit of Resolution				Logit (Exit)				Logit (Exit) Random Effects
Sample:	Seed	Series A	Series B	Series C	Seed	Series A	Series B	Series C	Pooled
Display:	Log Odds				Marginal Effects				Marginal Effects
Levered Equity	0.437***	0.278***	0.0632	0.0146	0.0504***	0.0536***	0.0193	0.0136	0.0071***
	[0.0562]	[0.0485]	[0.0547]	[0.0828]	[0.0091]	[0.0117]	[0.0156]	[0.0238]	[0.0021]
Runway Loans	0.194***	0.266***	0.135**	0.162**	0.0211**	0.0553***	0.0396**	0.0368	0.0088***
	[0.0650]	[0.0521]	[0.0618]	[0.0821]	[0.0088]	[0.0130]	[0.0177]	[0.0231]	[0.0021]
Log Current Investment	0.336***	0.249*	0.168	0.597***	0.0331***	0.0655*	-0.0108	0.137**	0.0102*
	[0.0804]	[0.138]	[0.188]	[0.203]	[0.0101]	[0.0342]	[0.0472]	[0.0700]	[0.0062]
Log Prior Investments	0.0640***	0.0302***	0.0251***	0.0818***	0.0131***	0.0128***	0.0179***	0.0496***	0.0029***
	[0.0131]	[0.0081]	[0.0086]	[0.0182]	[0.0015]	[0.0017]	[0.0028]	[0.0088]	[0.0003]
Log Premoney Value	-0.213**	-0.115	-0.0143	-0.484**	-0.0270**	-0.0473	0.0269	-0.139**	-0.0053
	[0.0850]	[0.140]	[0.188]	[0.204]	[0.0107]	[0.0351]	[0.0475]	[0.0701]	[0.0063]
High Volume Investor	0.0879	-0.0155	0.104**	0.0265	0.00964	0.00622	0.0401***	0.0208	0.0028
	[0.0549]	[0.0442]	[0.0489]	[0.0722]	[0.0069]	[0.0102]	[0.0141]	[0.0212]	[0.0017]
Other Variables Included	Calendar Year Effects, Employee Quintiles , Industry Fixed Effects								+ Series Fixed Effects
Rounds Observations	25,454	16,458	10,542	5,342	15,974	12,805	9,240	5,145	43,165
Number of Firm Effects									15,052
Pseudo R-Squared	0.179	0.189	0.159	0.144	0.185	0.255	0.265	0.255	

Table 5: Dilution Mechanism Results

This table reports the mixed logit (random effect) estimates of the effect of dilution on the choice of capital structure. Observations are rounds of financing. The sample period is 1999-2016. The dependent variable in columns (1) to (4) is an indicator equal to one if the round is financed with levered equity and zero if financed with equity only, excluding runway loans from the sample. The dependent variable in columns (5) to (8) is an indicator equal to one if the round is financed with runway loan and zero if financed with equity only, excluding levered equity rounds. All specifications control for the natural logarithm of the amount of capital raised, the natural logarithm of prior investment, the natural logarithm of the pre-money valuation, and an indicator variable for whether the investor is a high volume investor. We also include employee quintiles at the time of fundraising, industry fixed effects and year fixed effects. Standard errors are in brackets. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model:	Logit (Choice of Levered Equity)				Logit (Choice of Runway Loan)			
Estimation:	Mixed Model with Random Effects				Mixed Model with Random Effects			
Sample:	Seed	Series A	Series B	Series C	Seed	Series A	Series B	Series C
Display:	Marginal Effects				Marginal Effects			
Log Dilution	0.177***	1.115***	1.200***	2.177***				
	[0.0461]	[0.177]	[0.296]	[0.554]				
Forward Log Dilution					0.200***	0.251	-0.307	2.446**
					[0.0712]	[0.225]	[0.313]	[1.090]
Log Prior Investments	0.000407	0.0154***	0.0279***	0.0126***	0.0112***	0.0171***	0.0209***	0.0259
	[0.000718]	[0.00128]	[0.00200]	[0.00443]	[0.00147]	[0.00193]	[0.00292]	[0.0188]
Log PreMoney Value	0.0441***	0.106***	0.119***	0.158***	-0.0246***	0.0029	-0.00427	-0.0443*
	[0.00125]	[0.00342]	[0.00626]	[0.00909]	[0.00271]	[0.00469]	[0.00616]	[0.0263]
High Volume Investor	0.169***	0.338***	0.418***	0.627***	0.0677***	0.134***	0.123***	0.126*
	[0.00337]	[0.00676]	[0.0151]	[0.0189]	[0.00817]	[0.0114]	[0.0160]	[0.0729]
Other Variables Included	Calendar Year Effects, Employee Quintiles, Industry Fixed Effects				Calendar Year Effects, Employee Quintiles, Industry Fixed Effects			
Observations	41,517	20,383	11,786	5,383	15,942	8,642	4,523	323
Number of Random Effects	32,980	18,741	10,749	4,942	11,932	7,671	4,014	294

Table 6: Duration-to-Next-Financing Mechanism Results

This table reports the mixed linear (random effects) estimates of the effect of duration on the choice of capital structure. Observations are rounds of financing. The sample period is 1999-2016. All specifications control for the natural logarithm of the amount of capital raised, the natural logarithm of prior investment, the natural logarithm of the pre-money valuation, and an indicator variable for whether the investor is a high volume investor. We also include employee quintiles at the time of fundraising, industry fixed effects and year fixed effects. The dependent variable is the natural logarithm of the number of days until the next round of financing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log Runway Forward: Duration until Next Round (in log days)							
Sample	Seed		Series A		Series B		Series C	
Model	LS Random Effects	AR1 Random Effects	LS Random Effects	AR1 Random Effects	LS Random Effects	AR1 Random Effects	LS Random Effects	AR1 Random Effects
AR1: Lag Log Runway		0.0720***		0.020		0.0677***		0.0666***
		[0.0145]		[0.0153]		[0.0159]		[0.0190]
Levered Equity	-0.0443**	-0.0115	-0.0607***	0.0064	0.0472*	0.0545*	-0.0797*	-0.0795*
	[0.0205]	[0.0393]	[0.0198]	[0.0327]	[0.0268]	[0.0292]	[0.0427]	[0.0440]
Runway Loan	-0.184***	-0.148***	-0.186***	-0.140***	-0.0874***	-0.0732**	-0.174***	-0.149***
	[0.0224]	[0.0432]	[0.0219]	[0.0358]	[0.0307]	[0.0335]	[0.0428]	[0.0433]
Log Current Investment	0.160***	0.118***	0.0929	0.166*	0.0435	0.16	0.11	0.0301
	[0.0233]	[0.0383]	[0.0703]	[0.0898]	[0.0839]	[0.110]	[0.111]	[0.116]
Log Prior Investments	-0.0472***	-0.0531***	-0.0324***	-0.0641***	-0.0293***	-0.123***	-0.0278***	-0.0679***
	[0.00384]	[0.0117]	[0.00340]	[0.0120]	[0.00462]	[0.0125]	[0.00910]	[0.0193]
Log PreMoney Value	-0.0578**	0.01	-0.00962	-0.0484	0.0523	-0.024	0.0104	0.104
	[0.0249]	[0.0398]	[0.0717]	[0.0920]	[0.0852]	[0.112]	[0.111]	[0.116]
High Volume Investor	0.0105	0.0640*	0.0955***	0.116***	0.105***	0.105***	0.130***	0.118***
	[0.0190]	[0.0355]	[0.0181]	[0.0304]	[0.0248]	[0.0274]	[0.0381]	[0.0390]
Constant	3.792***	3.166***	3.639***	3.696***	3.239***	3.952***	2.799***	2.675***
	[0.129]	[0.248]	[0.206]	[0.313]	[0.295]	[0.353]	[0.367]	[0.442]
Other Variables Included	Calendar Year Effects, Employee Quintiles, Industry Fixed Effects							
Observations	18,771	5,205	11,919	4,870	7,197	5,882	3,554	3,327
Number of Random Effects	13,725	3,625	10,294	4,282	6,127	5,023	3,077	2,926