Same, same but different: How preferential claims skew returns of venture capital investments

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Abstract

Venture capital often involves complex equity contracts, which affect the allocation of cash flows among shareholdings at an exit liquidation. To facilitate economic impact analysis, we structure exit relevant preferential rights by their economic impact in a two-dimensional framework. Based hereon, we provide a model that allows to assess ex-ante value of such shares. We apply our model to a selected sample of ventures and find an average overvaluation on a share class basis of 22.1% (median 23.9%), where overvaluation is particularly severe for common and early-on investments.

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1. Introduction

As commonly known, venture capital ('VC') investments involve high uncertainty. An insight underlined by a study of Korteweg and Sorensen (2011) reporting that only 10% of VC-backed firms go public and only 23% are acquired while the vast majority of the remaining firms has been either liquidated or has become 'living zombies' with no profitable path to exit. High returns on successful exits follow high risks of no or negative return investments. Translating this relationship into numbers, Cochrane (2005) presents lognormal average returns for VC investments of 15% p.a. with a standard deviation of 89% p.a. implying 37% of investments end up in negative returns on an annual base.

To hedge themselves at least partially against adverse outcomes, VCs regularly require various rights specified in VC financial contracts, such as information rights, control rights, exit rights and cash flow rights, see e.g., Sahlman (1990). The latter are generally intended to allocate cash flows to shareholders of the venture in case of an 'exit'. Especially in case of mediocre or poor performance, cash flow rights result in an allocation of 'exit proceeds' skewed away from the usual 'pro-rata' allocation which has significant economic implications as pointed out by Broughman and Fried (2010):[1] In 84% of the ventures within their sample the investors exited as preferred shareholders, i.e., exit proceed distribution was determined by cash flow rights rather than pro-rata.

According to Broughman and Fried (2010), a thorough understanding of the mechanisms of cash flow rights is a basic prerequisite for reasonable pricing in VC transactions. A claim recently substantiated by a study of Gornall and Strebulaev (2017) who estimate an overvaluation of 37% for so-called 'unicorns'[2] when reflecting those rights correctly. Although there is some empirical research regarding the existence of cash flow rights, literature regarding the specific design and structure of such is scarce, as noted by Arcot (2014).[3] Cash flow rights relevant for exit proceed allocation are liquidation preferences, cumulative dividends, participation rights as well as conversion rights.[4]

In order to assess economic implications of those cash flow rights on investments in valuation terms, a respective modelling is required. Due to the peculiarity of capital structures induced by cash

1 Pro-rata allocation refers to an allocation based on the respective relative share in nominal capital. Exit proceeds refer to the total proceeds received for the stakes sold in the event of an exit.
2 The term 'unicorns' refers to ventures earmarked by valuations of at least USD 1 billion.
3 For an overview on the empirical research regarding the application of cash flow rights see Zambelli (2014).
4 See also Zambelli (2014) or Bengtsson and Sensoy (2015).

flow rights, the valuation of venture investments or 'shareholdings' is relatively complex.[5] This is resembled by the respective strands of literature: While there is some literature regarding the valuation of the entire venture, see Keeley et al. (1996), Schwartz and Moon (2001) or Hsu (2010), there is rather few literature concerning the valuation of the ventures' capital structures, see Cossin et al. (2002), Leisen (2012) and Gornall and Strebulaev (2017).

The purpose of our paper is twofold: First, we are going to present a structured evaluation framework for exit relevant rights. Thereby, we highlight the need for a more detailed debate on the specifications of such instruments. Second, we develop a modular valuation model, that allows to assess various designs of the respective rights in terms of their economic impact. This model extends existing literature by presenting a more general investment setting, where the number of investors and share classes is not limited. Third, we illustrate the economic implications of reflecting relevant cash flow rights on a share class level, based on a sample of venture capital investments. We thereby investigate the impact of different sets of preferential rights and respective valuation assumptions. Hereby, economic impact will be measured by the difference between the model-based (implied) value and the (imposed) post-money value.[6]

The remainder of the paper is structured as follows: In section two, we give a brief overview on the related literature. In section three, we introduce the elements of exit relevant cash flow rights and present our modelling framework as well as the economic concepts behind. Thereafter, we develop the model by separately valuing preferential claims and the remainder. Within the fifth section, we introduce our sample and the assumptions with regard to the implementation of the model. Subsequently, we summarize our results and provide comparative statics with respect to our exogenous parameters. We conclude the paper in section seven discussing the main results and suggesting areas for further research.

2. Literature

This paper lies at the crossroad of financial contract design and option valuation research, given a venture capital context. We identified and address two relevant strands of research that we contribute

[5] We define shareholding as owning shares of a specific share class by a single investor.

[6] We refer to the imposed post-money valuation as the number of shares outstanding times the price paid in the most recent financing round, implicitly assuming pro-rata rights, see also Gornall and Strebulaev (2017).

to.[7] The first strand of literature relates to VC and financial contract design, which largely deals with the choice of security and their respective design. Sahlman (1990) is one of the first who describes general deal terms and provisions used in venture capital contracts and depicts that VC investments usually involve preferred convertible securities. Theoretical research in this area often motivates use of preferred convertible securities by agency problems such as moral hazard (see Aghion and Bolton (1992), Berglöf (1994), Hellmann (1998), Bascha and Walz (2001), Hellmann (2006) and Arcot (2014)). The pre-dominant role of preferred convertible equity in VC finance is supported by empirical research for the US (see Gompers et al. (1997), Kaplan and Strömberg (2001) or Bengtsson and Sensoy (2015)). However, findings on an international level are mixed or even conflicting, see Cumming (2005) or Schwienbacher (2008), who state that common or 'straight' equity prevails. Other research suggests that this might change over time or is simply due to legal differences in design.[8] As such, convertible preferred shares are not a single share class by themselves, they are rather 'shell securities' that allow for multiple design to suit the individual investment objectives resulting in different legal and economic consequences, as pointed out by Burchardt et al. (2016). Counterintuitively, evidence provided by Bengtsson and Bernhardt (2014) suggests that applied security design is rather investor specific rather than tailored to the respective venture. According to Bengtsson and Bernhardt (2014), venture capitalists want to avoid costs with unanticipated impacts on pricing and incentives. Here, our structured framework will allow for a more comprehensive understanding, debate and assessment of such rights.

The second strand of literature integrates the perspectives of VC, contract design and option valuation: Among these are Cossin et al. (2002), Leisen (2012) and Gornall and Strebulaev (2017). Cossin et al. (2002) claim to be among the first who systematically analyze general equity contracts. Due to a rather simple investment setup of one investor and one class of preferred equity, they are able to consider several rights, such as liquidation preferences, convertibility, and anti-dilution. Their option-based model is based on considerations of the dynamic programming approach of Dixit and Pindyck (1994). Leisen (2012) applies a similar option approach, in a slightly different setting: He considers staging with antidilution and liquidation rights where two investors are involved. Thereby, he also

[7] For a broad and extensive literature review on venture capital context in general, see Tykvová (2018).

[8] Research provided by Hartmann-Wendels et al. (2011) suggests that these differences might be due to the legal setting. Alternative securities are used, which resemble the payoff-scheme of convertible preferred equity.

recognizes the seniority feature of liquidation preferences and explicitly refers to changes in the liquidation multiple. Leisen (2012) highlights the interaction of liquidation preferences and antidilution features. Based on his model, he shows that increasing the liquidation multiple helps to evade share price dilution and the need to waive ratchets.[9] Similar to Cossin et al. (2002), Leisen (2012) is not directly interested in the economic impact of cash flow rights, that is, the value of shareholdings or conceivable misvaluation due to the non-reflection of contractual provisions in valuation, as raised by Bengtsson and Bernhardt (2014). This issue is first addressed by Gornall and Strebulaev (2017), who explicitly cast doubt on the valuations of investments of venture capitalists and mutual funds who simply mark up the value of their investments to the price of the most recent funding round.[10] As a central result of their analysis of 64 ventures valued at least at USD 1 billion, Gornall and Strebulaev (2017) report an overall 'overvaluation' of 37%.[11] They explicitly lay out the basic mechanics of a simple liquidation preference, the dilutive effects of option pools, seniority, participation and IPO ratchets as well as automatic conversion exemptions. They also report having considered several other contractual rights as mentioned in the respective agreements and contracts of the venture, however, they do not provide explicit financial modelling. Due to the high modelling complexity the valuation approach of Gornall and Strebulaev (2017) is based on a simulation where the equity value of the venture is based on a geometric Brownian motion, which is consistent with the basic modelling approaches of Cossin et al. (2002) and Leisen (2012).[12] In contrast to Gornall and Strebulaev (2017), we provide an explicit model for most relevant cash flow rights at exit. Moreover, we extend their analysis by focusing on the economic impact of VC equity contracts on a shareholding level rather than on the venture-level or common shares as a selected category of shareholdings.

Compared to existing literature, we explicitly consider a more general investment setting, where the number of investors and share classes is not limited. In addition, to the best of our knowledge, we

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9 This could also be seen as some kind of 'hidden dilution', see Leisen (2012), p. 21.

10 They support their statement by findings of Chakraborty and Ewens (2017), who present empirical evidence for window dressing such as net asset value inflation by strategic delay of write-offs or additional investments. Somewhat differently, the presentations of Bengtsson and Bernhardt (2014) suggest that VC investors are not always aware of the difference between nominal valuation and effective pricing.

11 Overvaluation is reported as the difference between the imposed post-money valuation and the implied value calculated by Gornall and Strebulaev (2017).

12 Interestingly, consideration of contractual provisions of equity is rather common in US-american accounting practices, see for example the recent issue of the working draft of the AICPA Accounting and Valuation Guide 'Valuation of Portfolio Company Investments of Venture Capital and Private Equity Funds and Other Investment Companies', see also the practice-oriented simulation based research of Chamberlain (2007).

are the first who provide empirical results regarding the economic impact on a share class level. This is necessary for a general analysis in a VC context, since venture capitalists tend to specialize with regard to their investment focus and the venture's development stage and are often not able to invest in subsequent rounds.

3. General Framework

3.1. Exit and investment scenario

As pointed out earlier, exit relevant cash flow rights allocate the venture's value in case of an exit among the investors, entrepreneurs and management, deviating from pro-rata allocation.[13] The allocation of such value will be referred to as the allocation of exit-proceeds, where we use the term exit-proceeds and venture value interchangeably, assuming full sale or recapitalization of the venture.[14] The specification of such a set of rights is determined by the valuation perspective, characterized by the valuation date t, the time to exit and the type of exit event ('exit route'). First, we assume the exit to occur in T, where $T > t$. Thus, the time to exit amounts to $T - t$ in years, where there is no further financing or change of financing terms until exit. Second, we consider two stylized exit routes, which account for the most common exit choices in the VC context - a recapitalization via an IPO and a sale of the entire venture to another investor (referred to as 'M&A'-transaction). Differentiation is necessary since in case of an IPO generally all preferential rights are waived, while the allocation of exit proceeds in case of an M&A-transaction will be based on full application of preferential rights. Next, we determine the investment scenario, which defines the shareholding of the venture by each investor as per share class as well as the respective pricing. The individual shareholding $s_{i,j,T}$ in the venture at date T can be displayed via matrix $\mathbf{S_T}$, where i, $i = 1, ..., m$, refers to the share class index

13 For the sake of simplicity, we will refer to all such entities that represent shareholders of the venture as 'investors'.

14 We will assume the means of distribution, cash or shares, to be irrelevant.

of share class SC_i and j, $j = 1, ..., n$, refers to the respective investor Inv_j:

$$\mathbf{S_T} = \begin{array}{c} \\ SC_1 \\ SC_2 \\ \dots \\ SC_i \end{array} \begin{array}{c} \begin{array}{cccc} Inv_1 & Inv_2 & \dots & Inv_j \end{array} \\ \begin{pmatrix} s_{1,1,T} & s_{1,2,T} & \dots & s_{1,j,T} \\ s_{2,1,T} & s_{2,2,T} & \dots & s_{2,j,T} \\ \dots & \dots & \dots & \dots \\ s_{i,1,T} & s_{i,2,T} & \dots & s_{i,j,T} \end{pmatrix} \end{array} \tag{3.1}$$

Usually, $SC_{i=1}$ refers to common shares, which often do not have any preferential rights. Note, however, that the models' generality would also allow to include only preferred shares. The corresponding share prices per shareholding are referred to as $p_{i,j,\theta}$, and θ refers to the time of investment, where $\theta_{i,j} \leq t < T$. In aggregation, all prices of shareholdings are referred to as $\mathbf{P}$. Altogether, we refer to the set of shareholdings $\mathbf{S_T}$ and its prices $\mathbf{P}$ as the *investment scenario* of the venture.

3.2. Set of preferential rights

In order to evaluate the economic implications of exit relevant cash flow rights, we split the mechanisms of the exit proceed's allocation into two consecutive phases and provide the basic structure of our framework. The first phase corresponds to the allocation of exit proceeds due to the *explicit* preferential claims, i.e. liquidation preferences or preferential return rates, thus called *preferential claim allocation*. The second phase regards the allocation of the remaining exit proceeds after all preferential claims have been served. Here, the allocation generally follows pro-rata, however, it is also characterized by *implicit* claims, which arise due to the conversion feature, setoff of or caps on preferential claims. We refer to this phase as *remainder allocation*.

Our framework for structuring the elements of preferential claims is characterized by two dimensions, the *amount* and the *allocation* of preferential claims. The amount of preferential claims is determined by the *preference basis* and can be scaled by a *preference multiple* or *return* or can be restricted via a *preference cap*. The allocation of the preferential claim and the remainder is determined by *preference seniority* and *remainder allocation basis* and also depends on *preference conversion* into common and *participation* (or analogous *set-off* for non-convertible securities). We will introduce each of the elements in the subsequent paragraphs. With regard to exit routes, we will assume automatic conversion in case of an IPO, where all preferential rights will be waived and allocation takes place on a pro-rata basis. As suggested by Arcot (2014), even if there is no explicit or mandatory conversion in case of an IPO, factual conversion is a reasonable assumption.[15] In order to consider automatic conversion, we will assume IPO-probability denoted by π_{IPO}, whereas probability of the M&A exit equals $\pi_{M\&A} = 1 - \pi_{IPO}$.

Preference basis: The basis is generally linked to initial investment amount per share $s_{i,j,T}$:

$$p_{i,j,\theta} \tag{3.2}$$

Preference multiple $m_{i,j}$: Usually referred to as 'liquidation preference multiple' or 'multiple', the preference multiple determines the general height of the preferential claim:

$$m_{i,j}p_{i,j,\theta} \tag{3.3}$$

Empirical research provides evidence that the predominant multiple amounts to one. In this case, the respective preferential claim is often referred to as a 'simple' liquidation preference.[16]

Preference return $rr_{i,j,u}$: The preference return captures any cumulative dividends, preferential dividends or other rates applied to the preference amount such as inflation adjustments. In addition to the applicable rate $rr_{i,j}$, a period u, starting at θ has to be specified for the respective calculations:

$$m_{i,j}p_{i,j}(1 + rr_{i,j,u}) \tag{3.4}$$

Oftentimes u is not agreed on explicitly, but rather depends on pre-defined events such as the next financing round or subsequent exit. For sake of simplicity, we assume $u \leq T - \theta$. We will refer to the expression in equation 3.4 as $pc_{i,j,T}$. Referring to any other (implicit) claims regarding the remainder allocation of $s_{i,j,T}$ as $ra_{i,j,T}$, the total (uncapped) claim per share amounts to:

$$pt_{i,j,T} = pc_{i,j,T} + ra_{i,j,T} \tag{3.5}$$

Preference cap $cap_{i,j}$: A preference cap limits the amount of exit proceeds allocated to the respective investor with regard to his respective shareholding and resulting preferential claims. Consequently, the cap is applied with regard to allocated preferential claim amounts and any subsequent

[15] E.g., the conversion is a costly signal for venture capitalists, which, if placed, will facilitate the public offering in terms of higher valuation, i.e., the venture capital will be able to receive a higher payoff at exit. In addition, keeping a complex capital structure in case of an IPO would severely affect due diligence for potential investors, whereas the costs will be born via lower valuations at exit.

[16] For empirical research on the preference multiple, e.g., Bengtsson and Sensoy (2015).

remainder allocation:[17]

$$min\{pt_{i,j,T}; cap_{i,j}\} \tag{3.6}$$

Within the study of Bengtsson and Sensoy (2015), the cap was examined in combination with subsequent participation in the remainder allocation. According to their results, a cap was present in 23% of all investments under consideration.

Preference seniority: The central element of preferential claims and payments is the structuring of claims according to an agreed-on hierarchy of claims. Here, various structures are possible, which are generally based on two distinctive schemes: pari-passu treatment of preferential payments i.e., all preferential payments are served (pro-rata) at once but before any common shares are served, or, (strict) seniority, where share classes and respective preference claims are served in a specified order, also called 'stacking'.[18] For modelling purposes, we will set up an index $h_{i,j} = h$ with $h = 1, \ldots, v$ for each shareholding and the respective level of seniority, whereas $h = v$ denotes the lowest level of seniority and $h = 1$ ranks highest with regard to seniority.[19]

Remainder allocation basis: After preferential claims have been served, remaining exit-proceeds, if existing, will have to be distributed. Generally, we observe two different mechanisms, which apply to different legal settings and result in three different remainder allocation models. First, the remainder can either be allocated on a share basis or on a shareholder basis, where respective preferential claims are pooled accordingly. Depending on jurisdiction and legal form, companies may not issue preferred shares. However, respective provisions have evolved, which resemble the conversion feature of preferred shares. Instead of converting preferred shares, the preferential claims are 'credited' or rather 'set off' against any remainder allocation. Set-off takes place on a share class or share holder based level, where conversion only applies in a share based setting. Thus, second, we will consider remainder allocation based on (1) conversion and (non-)participation ('CPR') as well as remainder allocation based on (2) set-off with regard to share class ('SCB') and (3) set-off with regard to share-

[17] We will assume the cap $cap_{i,j}$ to be at least as large as any preferential claim, i.e., $\forall cap_{i,j} : cap_{i,j} \geq pc_{i,j,T}$.

[18] See also Woronoff and Rosen (2005), p. 110. In addition, Bengtsson and Sensoy (2015) found 42% of there sample investments featuring senior preferential claims, while 57% had pari-passu rights. In only 0.4% of their sample, junior claims were observed.

[19] The number of seniority levels is limited by the number of shareholdings but often corresponds to the number of share classes (strict seniority) or applies pari-passu among preferred share classes and shareholdings.

holder ('SHB').

Preference participation and conversion, CPR: Preferential claims can affect the subsequent distribution in different ways: On the one hand, shares might be eligible to receive pro-rata share of remaining exit proceeds without any consideration of previous claims, thus called 'participating convertible preferred shares'. On the other hand, they might be restricted to their preferential claim only. In this case, shareholders usually have the right to convert to common shares, thereby waiving all their rights, but participate in the allocation on an as-converted (to common shares) basis, thus called '(non-participating) convertible preferred shares'.[20] Participation is denoted by $y_{i,j,T}$ for each shareholding, where $y_{i,j,T} = 1$ if the shareholding is participating and $y_{i,j,T} = 0$ if not. The conversion feature usually also applies whenever a cap is agreed on the shares' participation in the exit proceeds. Whenever the cap is hit, the respective shareholding stops participating. However, once the as-converted shares have 'catched-up', that is, common shares are allocated as much as the capped participating convertible preferred shares, the investor will eventually convert her shares.

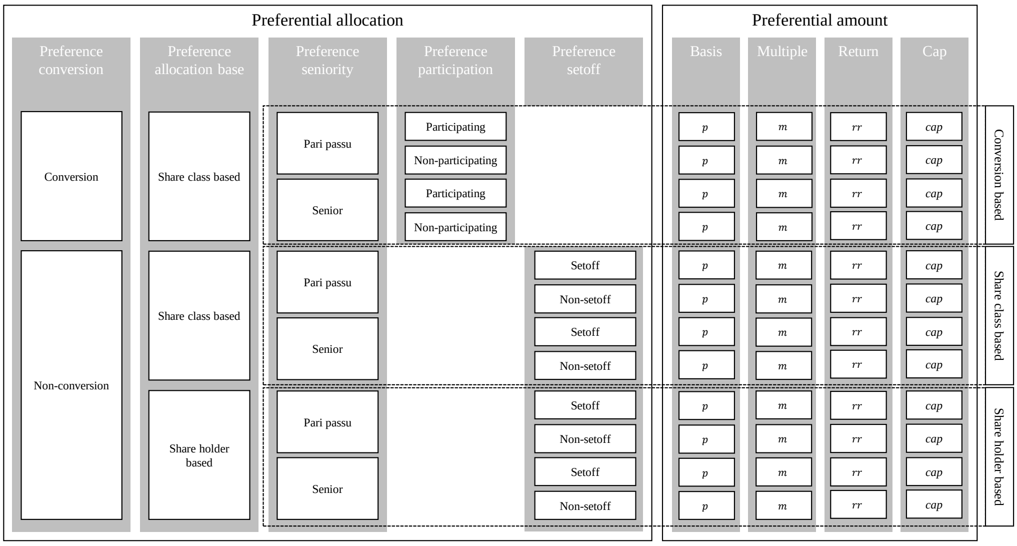
Preference participation and setoff, SCB and SHB: Similar to conversion, setoff allows other (more junior) shareholdings to 'catch up'.[21] Other than the conversion feature, set-off applies to shareholdings regarding a specific share class or to the entire shareholdings of a specific shareholder itself. Setoff will be denoted by $x_{i,j,T}$ for each shareholding, where $x_{i,j,T} = 0$ if the respective preferential claims of the shareholding are to be set-off and $x_{i,j,T} = 1$ if not. The participation in the remainder allocation might be capped, however, the contract usually allows for further ratable participation, once all other common shares have been allocated an amount up to the cap.

The respective rights can be structured as shown in figure 1. Practically, specific elements of preferential claims and remainder allocation have to be aligned for the entire venture: First, seniority is a relative measure and is set in relation to all other share classes and will generally not deviate within a share class. Second, the remainder allocation basis is also set for the entire investment scenario, without deviations across or within shareholdings and share classes. We refer to the entire set of preferential rights for the investment scenario as the *set of preferential rights*.

20 This conversion feature distinguishes from automatic conversion by the fact that exercise is up to the investor of the respective shareholding and therefore depends on his individual perspective, i.e. his benefit.

21 See Woronoff and Rosen (2005), p. 115; this applies especially for those companies, where the legal form prohibits the issuance of dedicated convertible or preferred equity shares.

Figure 1: Modelling framework based on structured preferential claims



4. Model

4.1. Venture value

Assessing the economic impact of the aforementioned claims and implied allocations on a share level requires both, the determination of the value of the venture as well as of each share. Starting with a basic model of the venture value itself, focus will be on the determination of the share value, which itself consists of the value of different explicit and implicit claims the respective share participates in. We assume the venture value V_t to follow a diffusion process with constant annual volatility σ and constant annual drift rate of return r, where t denotes the *valuation date* and $t < T$. Following the idea of Leisen (2012), we assume a lognormal distribution of the venture value under the risk-neutral probability measure:[22]

$$V_T = V_t e^{(r-\frac{\sigma^2}{2})(T-t)+\sigma\sqrt{T-t}Z} \tag{4.1}$$

V_T denotes the venture value at exit and Z is a standard normal distributed random variable. The stochastic process is presumed to remain unaffected by the equity capital structure. In order to determine the value of each share based on the venture value, we have to determine the value of each claim the respective share participates in. The explicit and implicit (stacked) claims represent conditional payments with respect to the eventual amount of the venture value at exit. As proposed by existing lit-

[22] For a more detailed discussion on the general assumptions see also Hull and White (1988) or Trigeorgis (1996).

erature such payments are most suitable for an option-based approach. Given our set of assumptions and following Leisen (2012), we apply European call option pricing for all of the subsequent claims:

$$C_t(V_t, K_T, r, \sigma, T - t) = V_t N(d_1) - K_T e^{-r(T-t)} N(d_2) \tag{4.2}$$

$$\text{where} \quad d_1 = \frac{ln(\frac{V_t}{K_T}) + (r + \frac{\sigma^2}{2})(T - t)}{\sigma\sqrt{T - t}} \quad \text{and} \quad d_2 = \frac{ln(\frac{V_t}{K_T}) + (r - \frac{\sigma^2}{2})(T - t)}{\sigma\sqrt{T - t}} \tag{4.3}$$

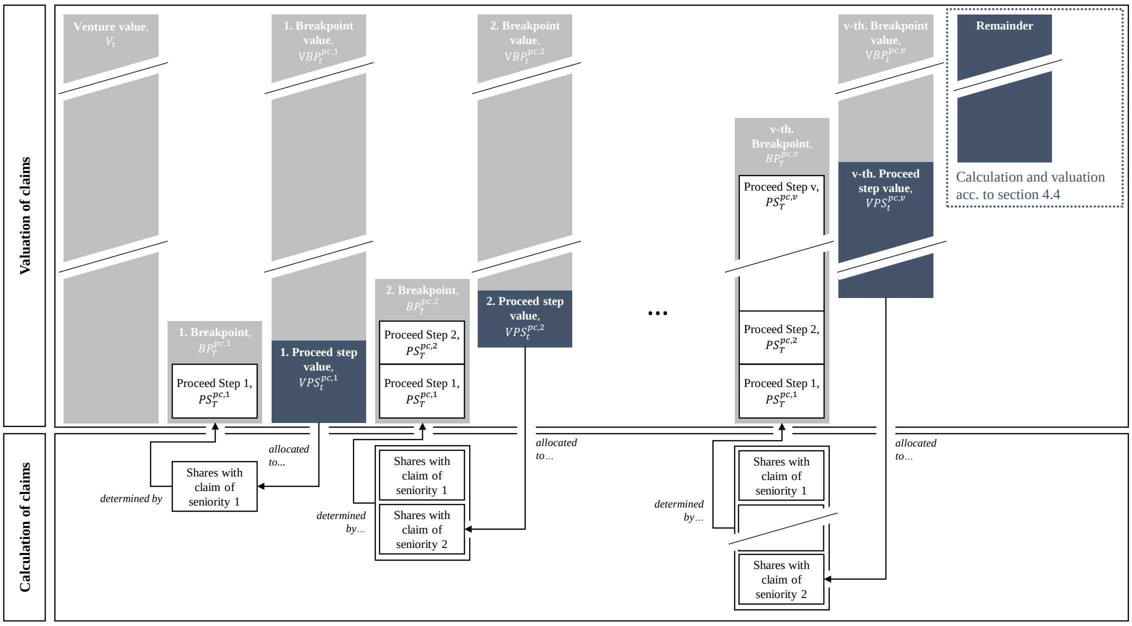
C_t represents the value of a call on V_t at a strike price K_T, $T - t$ represents the time to exercise. σ corresponds to the standard deviation in equation 4.1, r denotes the risk free rate. Central to our analysis is the appropriate specification of K_T and the integration of these claims into a model.

Valuation of preferential claims and remainder allocation will be based on a stepwise approach, as depicted in figure 2: Each of the stacked explicit and implicit claims is referred to as a *proceed step* PS_T.[23] The ordered proceed steps constitute successive breakpoints BP which are eventually used in the claim valuation model in order to assess the value of each breakpoint, VBP, and in turn the value of each proceed step VPS. For example, the first proceed step, i.e. the first breakpoint, represents a claim superior to any other claim regarding the exit proceeds of the venture. In other words, all other claims have a call on the venture at an exercise price (K_T) corresponding to the first breakpoint. The value of such call can then be evaluated via equation 4.2, and is referred to as 'breakpoint value'. Now, the claim value can be obtained by subtracting the breakpoint value from the venture value. Likewise all other breakpoint and proceed step values can be determined and used to evaluate claim values. Next, we determine the relative participation of each shareholding in each proceed step, to evaluate the value of each shareholding and share. The latter is fully determined by aggregating the relative participation per shareholding in each proceed step. This general approach will be followed in the preferential claim allocation as well as in each of the remainder allocation models.[24]

[23] Each proceed step is characterized by the nominal claim per share, the number of participating shares and its respective order. The latter adheres either to the seniority within the preferential claim allocation or is driven by the height of the per share amount in case of the remainder allocation.

[24] Note, that the last proceed steps' value in the remainder allocation will correspond to the last breakpoints' value, since it represents the ultimate residual call value on the venture after all preferential claims and subsequent implied allocations have been served.

Figure 2: Contingent claim based valuation approach



Notes: The valuation of the calculated preferential claims is shown for a case of $1, 2, \ldots, N$ preferential claim with strict seniority, where index pc denotes the respective PS and BP of the preferential claim allocation. The proceed steps $PS_T^{pc,h}$ are calculated based on the sum of preferential claims $pc_{i,j,T}$ of each seniority rank h. Thereupon, the breakpoints $BP_T^{pc,h}$ can be calculated as the sum of respective proceed steps in order to determine the breakpoint values $VBP_T^{pc,h}$ which are used to determine the value of each proceed step $PS_T^{pc,h}$ as a difference of consecutive breakpoint values. To determine the value of the first proceed step, the difference is taken with respect to the entire value of the venture and the first breakpoint value. Thereafter, the proceed step values are allocated on the respective shares to determine the value of each shareholdings preferential claim per share.

4.2. *Basic pro-rata allocation*

A naive approach of per-share valuation is to assume a ratable allocation of exit proceeds as per nominal shareholding without any preferential rights: That is, the exit proceeds are divided by the total amount of shares outstanding (pro-rata allocation) and where the resulting value per share is applied to each shareholding in order to derive the value of such shareholding, i.e., at time t the pro-rata value corresponds to $V_t / \sum_{i=1,j=1}^{m,n} s_{i,j,T}$.

4.3. *Preferential claim allocation*

For preferential claims, the nominal claim per share is given by $pc_{i,j,T}$. Considering the respective shares $s_{i,j,T}$ as well as pooling and ordering those amounts by seniority $h = 1, \ldots, v$, the proceed steps are fully determined by

$$PS_T^{pc,h} = \sum_{i=1}^{m}\sum_{j=1}^{n} \mathbf{1_{H_T=h} S_T} \circ \mathbf{PC_T} \tag{4.4}$$

where $PS_T^{pc,h}$ denotes the cumulative amount of preferential claims on the h-th seniority level, therefore called the h-th proceed step.[25] Thereby, $\mathbf{1_{H_T=h}}$ represents an indicator function for the respective seniority level h. Additionally, we define $ps_{i,j,T}^{pc,h,\%}$ to be the percentage share in proceeds of shareholding $s_{i,j,T}$ regarding $PS_T^{pc,h}$, where we describe the percentage share for all shareholdings regarding $PS_T^{pc,h}$ by matrices $\mathbf{S_T^{pc,h,\%}}$. Ordered proceed steps will be stacked consecutively to determine breakpoints $BP_T^{pc,h}$, where $h = 1, \ldots, v$ indicates the ordering of breakpoints:

$$BP_T^{pc,h} = \sum_{h=1}^{v} PS_T^{pc,h} \tag{4.5}$$

That is, the first breakpoint $BP_T^{pc,1}$ entails the first proceed step $PS_T^{pc,1}$, which in turn represents the cumulative preferential claims with highest seniority, the second breakpoint $BP_T^{pc,2}$ amounts to the sum of the first and the second proceed step $PS_T^{pc,1}$ and $PS_T^{pc,2}$, see also figure 2. The value of each breakpoint $VBP_T^{pc,h}$ can be determined according to the approach in equation 4.2:

$$VBP_t^{pc,h} = C_t(V_t, BP_T^{pc,h}, r, \sigma, T - t) \tag{4.6}$$

where $h = 1, \ldots, v$. Ceteris paribus, an increasing amount of preferential claims reduces the value of the residual claim $VBP_t^{pc,h}$. As mentioned above, the value of the first proceed step $PS_T^{pc,1}$ is determined by the value of the venture less the value of the residual claim on the venture, i.e., the first proceed step being fully served $VBP_t^{pc,1}$. The next proceed step values are determined similarly, by calculating the difference between the value of the residual claim $VBP_t^{pc,h}$ and the subsequent value of the residual claim $VBP_t^{pc,h+1}$, where $h = 1, \ldots, v$:

$$VPS_t^{pc,h} = \begin{cases} V_t - VBP_t^{pc,h} & h = 1 \\ VBP_t^{pc,h-1} - VBP_t^{pc,h} & 1 < h \leq v \end{cases} \tag{4.7}$$

25 pc denotes that $PS_T^{pc,h}$ is a proceed step of the preferential claim allocation.

Note, that $VBP_t^{pc,h}$, where $h = v$, will usually be equal to zero since it describes the lowest seniority level, which does not feature any preferential claims. Also, we can see that the values of each claim represented by each proceed step $VPS_t^{pc,h}$ are restricted, resembling a so-called, 'call spread option'.[26] Knowing the value of each proceed step $VPS_t^{pc,h}$ as well as the relative share of each shareholding according to $\mathbf{S_T^{pc,h,\%}}$, we can allocate the amounts accordingly:

$$\mathbf{VPC_t} = \sum_{h=1}^{v} (\mathbf{S_T^{pc,h,\%}} \circ \mathbf{VPS_t^{pc,h}}) \oslash \mathbf{S_T} \tag{4.8}$$

where $\mathbf{VPC_t}$ denotes the matrix of values per share for the shareholdings denoted by $\mathbf{S_T}$, each referred to as the referential claim value per share $vpc_{i,j,t}$.

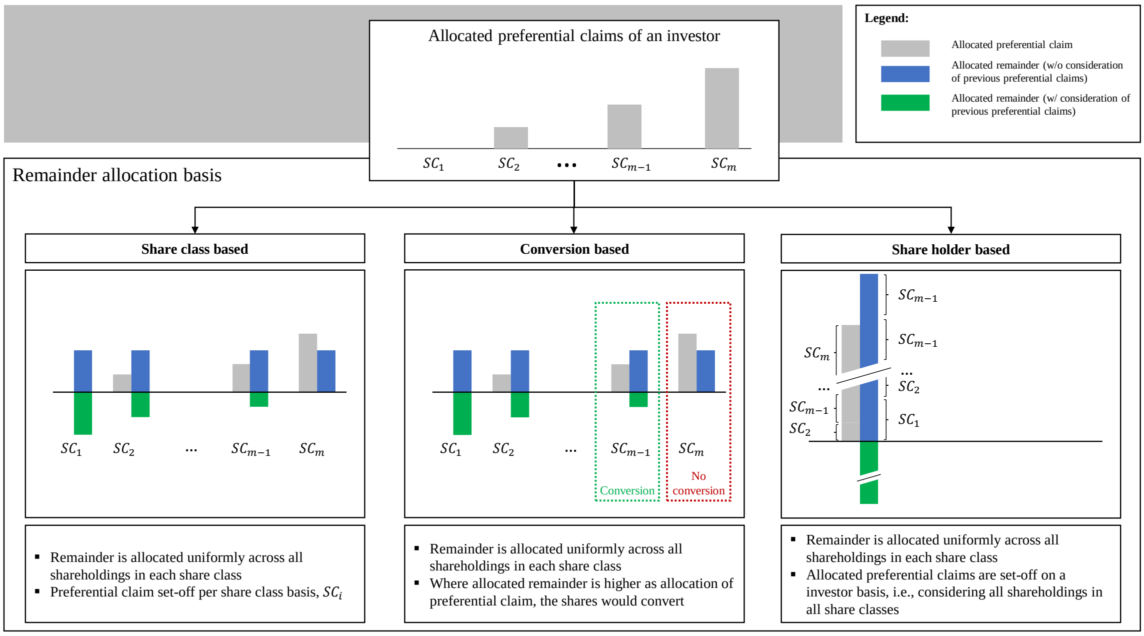
4.4. Remainder allocation

After the valuation and allocation of preferential claims $\mathbf{VPC_t}$, we have to determine the allocation and value of the remaining exit proceeds. As already noted in section 3.2 , the remainder allocation basis and the mode of the consideration of previously allocated preferential claims can differ. The latter stems from different jurisdictions, where the conversion feature of convertible preferred shares can be mimicked by an equivalent set-off of preferential claims for non-convertible shares in order to ensure subsequent catch-up. Remainder allocation basis differs with respect to the level of consideration of the previously allocated preferential claims: A conversion based approach generally applies on a share basis only, while set-off can either be pursued on a share or a shareholder level. This gives reason for three different models. In accordance with the basic differences, we refer to them as 'conversion-', 'share class based-' or 'shareholder based remainder allocation'. The key difference raises from different levels of preferential claim consideration and technically results in different (implicit) claims. However, apart from the determination of proceed steps, the structure and valuation approach remains the same across all models. Thus, we will develop one model in full (conversion

[26] See Hull (2014). The short call option has a higher strike price than the one of the long call option. Since the value of the respective proceed step h is actually determined as the sum of claims being long a call option on the venture $VBP_t^{pc,h-1}$ at an exercise price $BP_t^{pc,h-1}$ and being short a call option $VBP_t^{pc,h}$ at an exercise price $BP_t^{pc,h}$. Thus, any upside potential due to a higher venture value is transfered to the next proceed step. Also, variations in volatility do have ambigiuous effects on proceed step values: Following option-pricing theory regarding a european call option on a non-dividend paying asset, an increase in annual volatility should generally lead to an increase of the value of such an option, which is the basis of each of the breakpoint values. Thus, a 'call spread option', will generally decrease in value, given an increase in annual volatility.

based) and elaborate on the determination of proceed steps for the other models (share class and share holder based).

Figure 3: Remainder allocation base



Notes: The remainder allocation depends on the given legal framework: For some jurisdictions, the issuance of preferred shares is not possible given specific legal forms such as private limited companies. Whereas the share class based mechanism mimics the allocation under a conversion based regime, the share holder based mechanism considers preferential rights and remainder allocation a share holder level. The plots above characterize the mechanisms based on shareholdings in different share classes of a single investor.

4.4.1. Conversion based allocation

Conversion based allocation mechanism gives the investor the right to decide on whether to take the preferential claim or to convert into common shares. Rationally, she would choose the maximum thereof. The critical amounts at which a shareholder would convert her preferential shares rather than retain her preferential claim depend on the actual amount of preferential claims per share as well as whether it is participating or capped. At the same time, preferential claims impose implied claims for the more junior and all participating shares. Hence, we first evaluate which shareholdings will participate without being converted and which do not:

$$s_{i,j,T}^{cc,y=1} = y_{i,j,T}\, s_{i,j,T} \quad \text{and} \quad s_{i,j,T}^{cc,y=0} = (1 - y_{i,j,T}\, s_{i,j,T}) \tag{4.9}$$

$s^{cc,y=1}_{i,j,T}$ denotes the number of shares of each shareholding that participates and $s^{cc,y=0}_{i,j,T}$ denotes those which do not. Next, the implied claims for conversion will be determined: Apparently, there will be no conversion of any preferred shares, unless the amount of remaining exit proceeds allocated to all common and participating preferred shares per share exceeds the preferential claim amount of the lowest preferential claim amount per share. Whenever the remaining exit-proceeds exceed such an amount, the respective shares will convert and participate ratably (on an as-converted basis). The critical amounts of remaining exit proceeds at which conversion takes place determine implicit claims due to preferential claims; for shareholdings of share class i we denote such implicit claims by $ps^{cc,pc}_{i,j,T}$, where $ps^{cc,pc}_{i,j,T} = pc_{i,j,T} s^{cc,y=0}_{i,j,T}$, when $pc_{i,j,T} > 0$. Caps can be easily implemented into this approach by considering them as critical amounts, where respective capped convertible (participating) preferred shares will not participate. However, as mentioned in section 3.2, the capped (participating) shares will be converted to common at a certain level. That is, when all common, other participating or converted shares will receive at least as much as the amount of the respective cap. Thereafter, capped convertible (participating) preferred shares will participate ratably on an as-converted basis. Thus, the nominal cap per respective share $cap_{i,j,T}$ technically translates into two values. First, capped shareholdings of share class i will stop participating at an amount per share of $cap^{adj}_{i,j,T}$ per share, where $cap^{adj}_{i,j,T} = cap_{i,j} - pc_{i,j,T} y_{i,j,T}$. Second, they participate ratably on an as-converted basis, if all common and all as-converted common shares have been allocated an amount per share equalling the nominal cap $cap_{i,j,T}$. We denote the implied claims due to the cap by $ps^{cap}_{i,j,T}$ and $ps^{cap,adj}_{i,j,T}$ which are determined as follows:

$$ps^{cc,cap}_{i,j,T} = \begin{cases} cap_{i,j,T} s^{cc,y=1}_{i,j,T}, \text{ when } cap_{i,j,T} > 0 \\ 0, \text{ else} \end{cases} \tag{4.10}$$

$$ps^{cc,cap,adj}_{i,j,T} = \begin{cases} cap^{adj}_{i,j,T} s^{cc,y=1}_{i,j,T}, \text{ when } cap_{i,j,T} > 0 \\ 0, \text{ else} \end{cases} \tag{4.11}$$

Thus, proceed steps in remainder allocation are determined by preferential claims as well as caps. In a next step, to fully determine proceed steps, we order related claims per share on a per share amount basis in ascending order. We refer to the ordered proceed step claims as $ps^{cc,k}_{T}$, where $ps^{cc,k}_{T} \in$

$\{ps^{cc,pc}_{i,j,T}, ps^{cc,cap}_{i,j,T}, ps^{cc,cap,adj}_{i,j,T}\}$. Where $k = 1, \ldots, w$ denotes the index of ascending order. That is, $ps^{cc,1}_{T}$ denotes the preferential claim of the lowest level, i.e. $min\{pc_{i,j,T}\}$, which usually corresponds to common shares without any preferential claim.[27] w depends on the different levels of preferential claims and (adjusted) caps. Since subsequent modelling also applies for the other remainder allocation models, we index any model specific terms of the remainder allocation by ra.[28]

As a further step in the determination of proceed steps, the cumulative amounts of shares as per each implied claim $ps^{cc,k}_{T}$ will be calculated as follows:[29]

$$S^{ra,k}_{T} = \begin{cases} \sum_{i=1}^{m}\sum_{j=1}^{n}(s^{ra,y=1}_{i,j,T} + \mathbf{1}_{ps^{ra,k}_{T} \geq pc_{i,j,T}} s^{ra,y=0}_{i,j,T} - \mathbf{1}_{ps^{ra,k}_{T} > cap^{adj}_{i,j,T}} s_{i,j,T} + \mathbf{1}_{ps^{ra,k}_{T} > cap_{i,j,T}} s_{i,j,T}) & 0 \leq k < w \\ \sum_{i=1}^{m}\sum_{j=1}^{n}(s^{ra,y=1}_{i,j,T} + \mathbf{1}_{ps^{ra,k}_{T} \geq pc_{i,j,T}} s^{ra,y=0}_{i,j,T} - \mathbf{1}_{ps^{ra,k}_{T} \geq cap^{adj}_{i,j,T}} s_{i,j,T} + \mathbf{1}_{ps^{ra,k}_{T} \geq cap_{i,j,T}} s_{i,j,T}) & k = w \end{cases} \tag{4.12}$$

where $\mathbf{1}$ is an indicator function with respect to the indicated claims, e.g. whenever $ps^{ra,k}_{T} \geq pc_{i,j,T}$, $\mathbf{1}_{ps^{ra,k}_{T} \geq pc_{i,j,T}}$ is equal to one and zero otherwise. Apparently, participating shares $s^{ra,y=1}_{i,j,T}$ participate in any proceed step, whereas non-participating shares will only participate, when $ps^{ra,k}_{T} \geq pc_{i,j,T}$. Also, capped shares are subtracted whenever the implicit claim of the proceed step $ps^{ra,k}_{T}$ is higher than $cap^{adj}_{i,j,T}$. The subtraction is reversed via the fourth term in equation 4.12, whenever $ps^{ra,k}_{T}$ is higher than $cap_{i,j,T}$, i.e. when all other shares have "catched-up". Based on $S^{ra,k}_{T}$, the percentage share of each shareholding $s^{ra,k,\%}_{i,j,T}$ per level k can be derived for each level of k, where we refer to the percentage of all shareholdings per level k via matrices $\mathbf{S^{ra,k,\%}_{T}}$. Lastly, we will derive the total claim amount as per each proceed steps for the conversion based remainder allocation $PS^{ra,k}_{T}$ as an amount of the shares per proceed step $S^{ra,k}_{T}$ times the price differential of the current and the previous implied claim per share for all $k = 0, \ldots, w$:

$$PS^{ra,k}_{T} = \begin{cases} (ps^{ra,k}_{T} - 0)S^{ra,k}_{T} & k = 1 \\ (ps^{ra,k}_{T} - ps^{ra,k-1}_{T})S^{ra,k}_{T} & 1 < k \leq w \end{cases} \tag{4.13}$$

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27 Note, that $min\{cap_{i,j,T}, cap^{adj}_{i,j,T}\} >> min\{pc_{i,j,T}\}$.

28 Where $ra = cc$ refers to the conversion based, $ra = sc$ refers to the share class based and $ra = sh$ refers to the share holder based approach.

29 Note that the implied claim by the last proceed step $k = w$ marks also the last step of any allocation based on explicit and implicit claims. Thereafter, pro rata distribution applies. In order to include shares that are capped to the last proceed step, we had to determine $S^{ra,k}_{T}$ by case.

Ordered proceed steps provide the basis for the determination of respective breakpoints $BP_T^{ra,k}$, where $k = 1, \ldots, w$, by consecutively adding proceed steps as follows:

$$BP_T^{ra,k} = \begin{cases} PS_T^{ra,k} + BP_T^{pc,v} & k = 1 \\ PS_T^{ra,k} + BP_T^{ra,k-1} & 1 < k \leq w \end{cases} \tag{4.14}$$

Next, we will determine the corresponding values analogous to the idea described in section 4.3, where we determine the value of breakpoints as follows:

$$VBP_t^{ra,k} = C_t(V_t, BP_T^{ra,k}, r, \sigma, T - t) \tag{4.15}$$

The value of each proceed step is subsequently determined considering the sequence of breakpoint values. Thereby, the value allocation of preferential claims is considered via $VBP_t^{pc,v}$:

$$VPS_t^{ra,k} = \begin{cases} VBP_t^{pc,v} - VBP_t^{ra,k} & k = 1 \\ VBP_t^{ra,k-1} - VBP_t^{ra,k} & 1 < k < w \\ VBP_t^{ra,w} & k = w \end{cases} \tag{4.16}$$

where $VBP_t^{ra,w}$ represents the final residual claim and is allocated among all investors pro-rata, since there are no subsequent explicit or implicit claims anymore. Note that all proceed steps $VPS_t^{ra,k}$, $k < w$ are actually restricted and even decrease with increasing volatility.[30] That is, an increase in V_t results in a limited increase in $VPS_t^{ra,k}$ with $k < w$, since $VPS_t^{ra,k}$ equals $BP_t^{ra,k-1} - BP_t^{ra,k}\}$. Knowing the value of each proceed step, allows to calculate for the value of remainder allocation for each shareholding, by applying $\mathbf{S_T^{ra,k,\%}}$ to the respective proceed level value $VPS_t^{ra,k}$ and sum up the amounts as per each shareholding $s_{i,j,T}$ denoted by $vpa_{i,j,t}^{ra}$ altogether denoted as $\mathbf{VPA_t^{ra}}$, where

$$\mathbf{VPA_t^{ra}} = \sum_{k=1}^{w} (\mathbf{S_T^{ra,k,\%}} VPS_t^{ra,k}) \oslash \mathbf{S_T} \tag{4.17}$$

Adding the value of preferential claim allocation as per each shareholding $\mathbf{VPC_t}$ gives the total value per shareholding $\mathbf{VPT_t^{ra}}$ which is the matrix of all shareholding values per share reflecting preferential claims and conversion based remainder allocation.

30 For a more detailed explanation see footnote 26.

4.4.2. Share class based allocation

Share class based allocation mimics the convertible based allocation mechanism. Instead of converting, the remaining exit proceeds are allocated among all shares pro-rata, but any previously allocated preferential claim $pc_{i,j,T}$ will be credited ('set-off') against such allocation - depending on whether to be set off, i.e., $y_{i,j,T} = 0$, or not, $y_{i,j,T} = 1$. Similar to the option of conversion, the set-off per share up to the amount of the preferential claim, allows common (and other more junior) shares to catch-up in the remaining exit proceeds, which represents an implied claim. Analogous to section 4.4.1, we first evaluate which shareholdings will participate without being setoff and those which do not:

$$s^{sc,x=1}_{i,j,T} = x_{i,j,T} s_{i,j,T} \quad \text{and} \quad s^{sc,x=0}_{i,j,T} = (1 - x_{i,j,T} s_{i,j,T}) \tag{4.18}$$

$s^{sc,x=1}_{i,j,T}$ denotes the number of shares for each shareholding where preferential claims are not to be setoff and $s^{sc,x=0}_{i,j,T}$ where they are to be setoff. Subsequently, the determination of implied claims per proceed step due to the set-off of preferential claims is straightforward: $ps^{sc,pc}_{i,j,T} = pc_{i,j,T} s^{sc,x=0}_{i,j,T}$ when $pc_{i,j,T} > 0$. Where $ps^{sc,pc}_{i,j,T}$ denotes the implied claims due to the preferential claim $pc_{i,j,T}$. As already noted in section 4.4.1, the nominal cap per respective share $cap_{i,j,T}$ translates into two values: $cap_{i,j,T}$ and $cap^{adj}_{i,j,T}$. We denote the implied claims due to the cap by $ps^{sc,cap}_{i,j,T}$ and $ps^{sc,cap,adj}_{i,j,T}$ and determine them analogously to section 4.4.1, equation 4.11. Again, amount-based ordering of proceed steps is required, considering unique values of $ps^{sc,pc}_{i,j,T}$, $ps^{sc,cap}_{i,j,T}$ and $ps^{sc,cap,adj}_{i,j,T}$. Here, $ps^{sc,k}_{T}$ denotes the claim per share related to the k-th proceed step, where $k = 1, \ldots, w$ depicts the index in ascending order. Based on the different levels and order of claims per proceed step, we follow the modelling approach depicted in section 4.4.1, equation 4.12-4.17, to determine per share values.

4.4.3. Shareholder based allocation

The share holder based mechanism is similar to the share class based mechanism by featuring a setoff of preferential claims rather than conversion of share classes, however, it differs with regard to the set-off mechanism itself. Instead of crediting the allocated preferential claims as per share, the preferential claims are set off based on a shareholder level. All preferential claims that are to be set-off for each shareholder are pooled and will be credited against the ratable allocation of remaining exit proceeds corresponding to the total shareholding of the shareholder, regardless the specific share class of the shareholdings. First of all, we will determine the shares which are and are not to be set off with regard to their preferential claim:

$$s_{i,j,T}^{sh,x=1} = x_{i,j,T} s_{i,j,T} \quad \text{and} \quad s_{i,j,T}^{sh,x=0} = (1 - x_{i,j,T}) s_{i,j,T} \tag{4.19}$$

$s_{i,j,T}^{sh,x=1}$ denotes the number of shares for each shareholding where preferential claims are not to be set off and $s_{i,j,T}^{sh,x=0}$ where they are to be set off. In order to determine the implied claims as in the modelling approach in section 4.4.1 and 4.4.2, the mechanism has to reflect the preferential claim set-off and shares on a shareholder level rather then a share class level. Thus, the pooled amount of preferential claims for each shareholder which has to be set-off with regard to any participation in remaining exit proceeds has to be divided by the entire amount of shares per shareholder:[31]

$$\overline{pc}_{j,T} = \frac{\sum_{i=1}^{m} s_{i,j,T}^{sh,x=0} pc_{i,j,T}}{\sum_{i=1}^{m} s_{i,j,T}} \tag{4.20}$$

The result reflects the amount which is to be set-off per share - on average - for the respective shareholder regarding any allocated amounts of the remaining exit proceeds. That is, the critical amounts after which the shares of the respective share holder will participate in the remaining exit proceeds and thus determines the implied claims per proceed step due to the setoff of preferential claims:

$$ps_{i,j,T}^{sh,pc} = \overline{pc}_{j,T} \tag{4.21}$$

Obviously, $ps_{i,j,T}^{sh,pc}$ depends on the shareholding structure of investors due to the direct relation towards $\overline{pc}_{j,T}$ and the averaging of preferential claims, which represents the primary difference compared to the other remainder allocation models.[32] Just as described in section 4.4.1 and 4.4.2, the existence of caps with regard to the exit proceed allocation results in implied claims of other shares, since caps are assumed not to be pooled but rather refer to the respective shareholding or share class. Thus, we define the implied claims per share due to the cap $ps_{i,j,T}^{sh,cap}$ and $ps_{i,j,T}^{sh,cap,adj}$ analogously to section 4.4.1,

[31] That is, any amounts of preferential claims due to shares that do not require any setoff will not be included.

[32] However, the impact of such difference among models would decrease by increasing the concentration of shareholdings of different shareholders. That is, if each shareholder would be invested in just one class of shares, there would be no difference with regard to the share class based approach.

equation 4.11. Again, amount-based ordering of proceed steps is required, considering unique values of $ps_{i,j,T}^{sh,pc}$, $ps_{i,j,T}^{sh,cap}$ and $ps_{i,j,T}^{sh,cap,adj}$. Here, $ps_{T}^{sh,k}$ denotes the per share claim related to the k-th proceed step, where $k = 1, \ldots, w$ depicts the index in ascending order. Based on the different levels and order of claims per proceed step, we follow the modelling approach depicted in section 4.4.1, equation 4.12-4.17, to determine per share values.

5. Application of the model

The proposed model is able to reflect various preferential rights of different investors holding different shares of different share classes, i.e. shareholdings. Within this section, we report the results on a share class basis of an implementation of the model based on a sample of selected ventures.

5.1. Description of the sample

We retrieved data from various venture capitalists for a total sample of 49 ventures, where financing took place between 2009 and 2017.[33] Implementation of the model and its variants requires a rather detailed level of data, e.g., shareholdings per each share class for each investor, which, to the best of our knowledge, is not systematically provided for by any commercial database.[34] We provide some descriptives on our sample in table 1. As can be seen in panel A of table 1, the number of investors and share classes varies strongly. The median count of investors per venture is 20 (average approx. 29) and the median count of share classes per venture amounts to 5 (average approx. 6). Interestingly, the elements of preferential claims per venture vary a lot with regard to allocation mechanism and seniority, but there are just two ventures participating or non-set-off rights. Also, there is just very few variation within the preferential claim amount. On average, the preference multiple amounts to one and there are just a few financing including a preference return rate and for all

[33] Initially, we were provided with data on 56 ventures. However, we dropped five ventures which were actual duplicates we already received data for and we also exclude two other ventures due to lack of sufficient data.

[34] For the participating funds, we were obliged to sign non-disclosure agreements, which also covered non-disclosure of data, prohibiting the dissemination of data or publication of results on a funds or venture level. We transcribed the relevant information from contracts and capitalization tables to anonymized data frames for each venture. Hereby, we refer to a 'share class' as a distinct class of equity issued by the venture. We indexed share classes by order of issuance and indexed investors by order of the provided capitalization table. We supplemented and cross-checked the data with basic information from federal registers as well as from commercial VC data sets such as CrunchBase.

the ventures within our sample no cap was agreed for any share class.

Table 1: Sample descriptives

PANEL A: INVESTMENT SCENARIO			
	Number of investors	Number of share classes	
Maximum	356.0	21.0	
Average	28.8	5.5	
Median	20.0	5.0	
Minimum	5.0	2.0	
PANEL B: PREFERENTIAL AND REMAINDER ALLOCATION			
Allocation mechanism	Convertible preferred	Share class based	Share holder based
	22	16	11
Seniority	Pari-passu	Senior	Other
	15	10	24
Participation/setoff	Participating or non-setoff	Non-participating or setoff	
	2	47	
PANEL C: PREFERENTIAL CLAIM AMOUNT			
Multiple	Minimum	Average	Maximum
	1.0	1.0	3.0
Return rate	Minimum	Average	Maximum
	0.0%	0.0%	12.0%
Cap	Minimum	Average	Maximum
	n/a	n/a	n/a

Notes: Descriptive statistics regarding the preferential rights within our sample of 49 ventures. Fundings were pursued from 2009 to 2017. Panel A enlists statistics regarding the investment scenarios of the ventures in our sample. Note that we recorded the investors on a most detailed level. E.g., some ventures issued equity to employee/management directly, some bundled those holdings into a trust. Panel B shows the specifications regarding the elements of the *allocation* mechanisms of the preferential rights, denoted as the count of ventures within this simple, where financial contracts indicate the respective feature. For example, 47 ventures of the sample do feature solely preferential claims that are to be set off or non-participating. Preference seniority is often a mix of pari-passu and strict seniority, where some share classes are pari-passu, but senior towards other share classes. Panel C shows descriptive statistics on the specification of the elements regarding the *amount* of the preferential rights. For example, the average multiple of preferential claims across all ventures is about 1.0, whereas the maximum multiple observed for at least one venture amounts to 3.0.

5.2. Exit scenario, annual volatility and risk free rate

When implementing the model with respect to the sample, we have to make assumptions regarding the exit scenario, namely, the IPO-probability and the time to exit. We explicitly refrain from modelling those assumptions, in order to show the impact of the variation in such assumptions later on and to allow for a closed-form solution. We applied fixed values for both parameters: For $T - t$

we assume a period of four years, which is in line with Gornall and Strebulaev (2017), who derived an average time to exit of approximately four years.[35] Similarly, we set the IPO-probability at a fixed rate of 25%, which is in line with the results of a recent study of Gompers et al. (2016), which indicates that about 75% of the venture capitalists exited their investment via an M&A-transaction rather than an IPO.[36] This rate is higher compared to the findings of Cumming and Johan (2008), where an IPO was carried out as an exit route in approximately 14% of the sample, and Espenlaub et al. (2015), where the rate of IPOs within the sample varied by region, ranging from 8% up to 19%, but still lower compared to the IPO probability range stated by Giot and Schwienbacher (2007) of about 26.3% to 35.1%.[37] In addition to the assumptions regarding the exit scenario, we also have to specify the assumptions regarding expectations of the annual volatility and the risk free rate. With regard to annual volatility, we follow Leisen (2012) and Gornall and Strebulaev (2017) by applying 90% annual volatility based on the results provided by Cochrane (2005). Other researchers such as Ewens (2009) and Korteweg and Sorensen (2011), estimated annual volatility ranging from 88% to 130%. Lastly, for the risk free rate, we apply a rate of 2.50%, thereby following Gornall and Strebulaev (2017).[38] Note that, when implementing our model, we prescind from any other terms and provisions having an impact on the economic value of the venture or any share thereof. Further, all ventures are assumed to be free of debt, which we checked for in capitalization tables and available contracts.[39]

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35 Note, that similar to IPO-probability, the time to exit may vary significantly as reported for example by Giot and Schwienbacher (2007) or Félix et al. (2014).

36 In contrast to our fixed rate approach, Gornall and Strebulaev (2017) modelled the IPO-probability based on actual exits observed in Dow Jones VentureSource, whereas the applied IPO-probability for each venture of their sample depends on the future value. However, the results shown for the model seem to be ambiguous, i.e., the 95% confidence interval for their estimates covers an interval reaching from as low as 0% IPO-probability to as high as 100% IPO-probability. In addition, extant research reveals, that IPO probability critically depends on the legal environment, the origin and experience of investors as well as the level of information asymmetry (e.g., Giot and Schwienbacher (2007), Félix et al. (2014), Espenlaub et al. (2015)).

37 According to Giot and Schwienbacher (2007), the pursued exit route as well as the time to exit, differ significantly across stages, industries and investor characteristics.

38 Basically, Gornall and Strebulaev (2017) point out that besides being rather at the higher end of a reasonable range in the '...era of very low interest rates...', an increase in the interest rate will yield monotonically higher implied equity values. Other researchers such as Leisen (2012) refer to Cochrane (2005) and apply a rate of 5.0%.

39 Still, there are other limitations, too: For example, a common feature of venture capital finance is the provision of so-called option pools. We did not get access to the contracts of such programs systematically, so that we assumed those shares to be fully equivalent to common shares. For our analysis, we also refrain from the existence of any deferred or forfeited shares, that is, we would assume the amount of deferred shares at exit to be zero. Also, the vesting of the shares of founders is often an issue in venture capital financial contracts. We abstract from this feature, since we would assume the shareholding to be fully vested at exit.

6. Empirical results

In determining the implied venture values by calibration to the last funding, we assume the most recent share class to be fairly priced.[40] Thereupon, we backsolved the model for the *implied venture value* V_t numerically. At the same time, we implicitly solved for all other shares' implied values. Comparison of the implied share value and the price of the most recent share class reveals whether there is an over- or undervaluation, when using the post-money valuation as an estimate for the shares' fair values. We will refer to the extent of over- or undervaluation in terms of the imposed post-money valuation as 'implied valuation discount'. The discount may be positive (undervaluation) or negative (overvaluation).[41] For reporting purposes, we derived the implied valuation discounts as per share class.[42] We report our results of the implied valuation discounts regarding our sample in figure 4. Results are plotted with respect to the relative share class index ('RSCI') of the respective share class for all ventures, which is calculated on the highest share class index. In order to provide a more detailed look at the difference with regard to RSCI, we subdivided the implied valuation discounts into two groups by RSCI:[43] RSCI up to 0.5 and RSCI higher than 0.5 but lower than 1.0.

We also indicate whether respective share classes feature preferential claims or not. Overall, implied valuation discounts range from −56.7% to +36.6%, whereas the average amounts to −22.1% (median −23.9%), indicating general overvaluation in terms of the most recent share price. Generally, share classes of the lower RSCI group tend to have higher (negative) implied valuation discounts on average (−31.2%, median −28.6%) than share classes of higher RSCI (average −20.7%, median −22.8%), however, as indicated by plots in figure 4, implied valuation discounts do not solely depend on the share class level or on the existence or absence of preferential claims for a given share class. As we will see in subsequent exploratory analysis, implied valuation discounts are due to the interplay of all three modelling aspects, i.e., the investment scenario, the set of preferential rights and the assumptions regarding the exit scenario, annual volatility and the risk free rate.

The investment scenario includes the allocation of shares among share classes and investors as

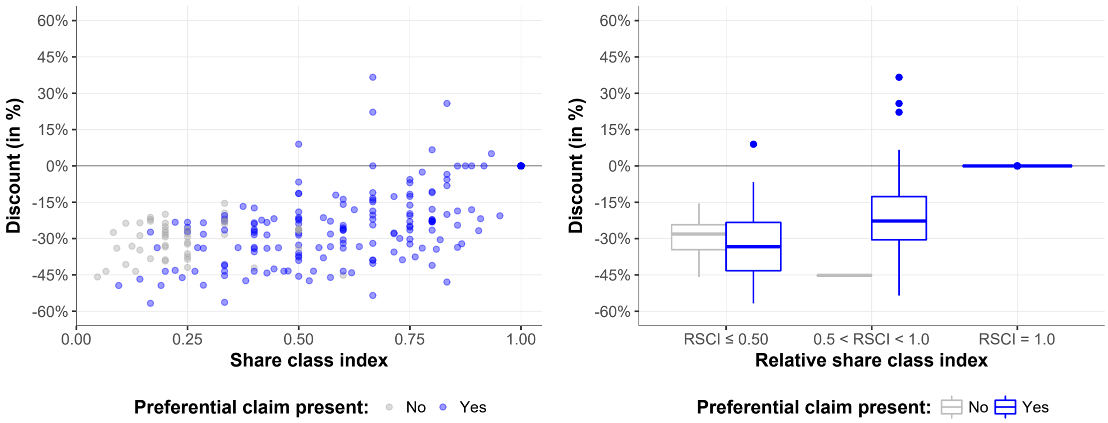
[40] We therefore assume the valuation date of each venture to coincide with the closing date of the transaction represented by the last financing round.

[41] The approach is analogous to the one applied by Gornall and Strebulaev (2017).

[42] That is, we present the mean of the implied valuation discounts per share class, across shareholders of one share class per each venture.

[43] Restriction to two groups reflects that some of the ventures within our sample just have two share classes.

Figure 4: Implied valuation discounts on share class level



Implied valuation discounts by relative share class index (RSCI), in %												
	$RSCI \leq 0.5$						$0.5 < RSCI < 1.0$					
	Min	25%-Q	Mean	50%-Q	75%-Q	Max	Min	25%-Q	Mean	50%-Q	75%-Q	Max
No pref. claim	−45.9%	−34.6%	−30.0%	−28.1%	−24.3%	−15.5%	−45.2%	−45.2%	−45.2%	−45.2%	−45.2%	−45.2%
Pref. claim	−56.8%	−43.2%	−31.9%	−33.3%	−23.3%	+9.0%	−53.5%	−30.5%	−20.4%	−22.7%	−12.7%	+36.6%
Total	−56.8%	−38.6%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%

Notes: The plots depict the implied valuation discounts with respect to their relative share class index ('RSCI'). Relative scaling is determined by the highest share class and highest seniority level. Within each plot, we indicate existence of any preferential claim right of each share class. For the box plot, we grouped implied valuation discounts by their RSCI into two groups: From 0 to 0.5 and greater 0.5 up to but not including 1.0, since each venture of our sample had at least two share classes. The line within the box plot indicates the median for the distribution within the respective bin. The lower and upper hinges of the box plot correspond to the first and third quartiles (the 25th and 75th percentiles), the distance in-between defining the interquartile range ("IQR"). The upper whisker extends from the upper hinge to the largest value no further than $1.5 \cdot$ IQR. The lower whisker extends from the lower hinge to the smallest value at most $1.5 \cdot$ IQR. Data beyond the end of the whiskers are plotted individually.

well as respective pricing. Pricing is one of the most popular issues of venture capital financing, since it is supposed to reflect economic performance, whereas poor performance is reflected via lower prices, resulting in so-called 'downrounds'.[44] Downrounds are present in 34.7% of the ventures of our sample.[45] Although adjustments of investment terms are rarely adjusted across financing rounds, the likelihood increases for situations such as downrounds, as is reported by Bengtsson and Sensoy (2015), especially when it comes to a restructuring in terms of the seniority of claims or antidilution.[46] In figure 5, we indicate share classes of ventures, where a downround took place at least once in the funding history. Apparently, any share class featuring a positive implied valuation discount, i.e. share classes which are undervalued by the most recent share price, are part of venture capital

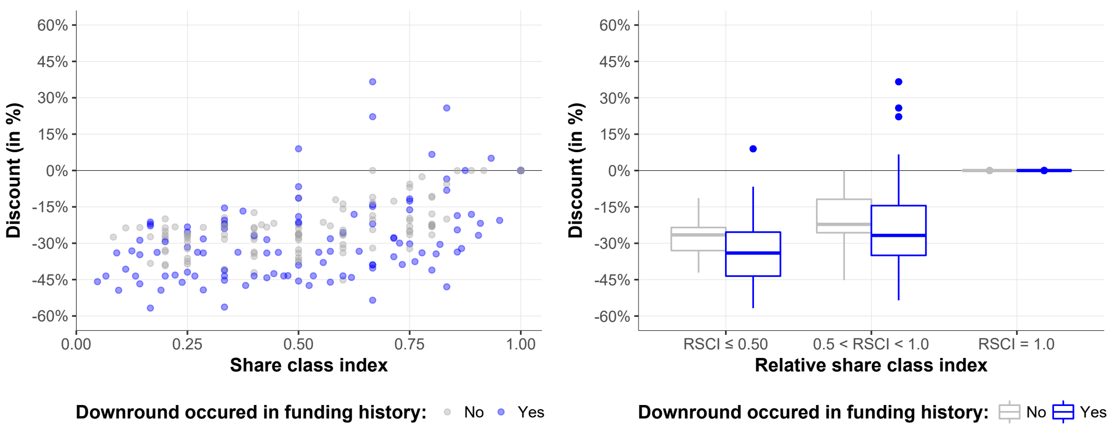
44 See also Bengtsson and Sensoy (2015).

45 We refer to a downround as stated by Bartlett (2003), that is, '...the issuance of securities [...] at a price that is below the price previously paid by the company's investors...', see Bartlett (2003), p. 23. Flatrounds refer to a stagnating but stable pricing level, see also Bengtsson and Sensoy (2015). We evaluated downrounds by comparing the (average) price paid for a given share class to the (average) price paid for the previous share class. Whenever the pricing differential was negative, we assumed the given share class to be a downround.

46 Bengtsson and Sensoy (2015) suggest that such adjustments are less frequent in cases where the set of investors does not change much. However, we did not systematically tracked the change in investment terms across rounds.

funding, where a downround occurred in funding history. Their preferential claims offer protection against deterioration of prices per share, in contrast, we observe no undervaluation for any of the share classes, where there was no downround within the funding history of the respective venture. Besides any undervaluation, we also observe that share classes of the highest (negative) implied valuation discounts are all affected by downrounds, providing for a high range of implied valuation discounts from −56.8% to +36.6%, compared to −42.1% to 0%. Still, the mean and median (negative) implied valuation discount is higher for those shares where no downround took place in funding history, no matter the respective share class index. Interestingly, in any case the variation in implied valuation discounts seems to be larger for share classes of relatively high RSCI. Those observations already indicate the importance of considering the investment scenario in determination of shares' fair value.

Figure 5: Implied valuation discounts on share class level considering downrounds



Implied valuation discounts by relative share class index (RSCI), in %												
	RSCI ≤ 0.5						0.5 < RSCI < 1.0					
	Min	25%-Q	Mean	50%-Q	75%-Q	Max	Min	25%-Q	Mean	50%-Q	75%-Q	Max
Downround	−56.8%	−43.5%	−34.4%	−34.0%	−25.4%	+9.0%	−53.5%	−35.0%	−22.2%	−26.8%	−14.5%	+36.6%
No downround	−42.1%	−33.0%	−27.9%	−26.6%	−23.5%	−11.4%	−45.2%	−25.7%	−19.1%	−22.2%	−11.9%	0.0%
Total	−56.8%	−38.6%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%

Notes: The plots depict the implied valuation discounts with respect to their relative share class index ('RSCI'). Relative scaling is determined by the highest share class and highest seniority level. Within each plot, we indicate whether a downround occurred in the funding history of the respective venture or not. For the box plot, we grouped implied valuation discounts by their RSCI into two groups: From 0 to 0.5 and greater 0.5 up to but not including 1.0, since each venture of our sample had at least two share classes. The line within the box plot indicates the median for the distribution within the respective bin. The lower and upper hinges of the box plot correspond to the first and third quartiles (the 25th and 75th percentiles), the distance in-between defining the interquartile range ("IQR"). The upper whisker extends from the upper hinge to the largest value no further than 1.5 · IQR. The lower whisker extends from the lower hinge to the smallest value at most 1.5 · IQR. Data beyond the end of the whiskers are plotted individually.

With regard to the set of preferential rights, we observe considerable variation in preference seniority and preferential and remainder allocation. In figure 6, we indicated respective variation. Considering preference seniority, we observe lower (negative) implied valuation discounts for pari-passu regimes, whereas the difference between share classes of lower and higher RSCI seems to be most pronounced, see the first row of plots. This relates to the fact that there are only two explicit steps in the allocation of preferential claims, partly mitigating differences among share classes featuring preferential claims. The ranges for implied valuation discounts of strict and mixed seniority are strongly overlapping, whereas the ranges of implied valuation discounts seem to be lowest for share classes of strict seniority and remain at or below zero for any level of RSCI. In contrast, ranges of implied valuation discounts for mixed seniority seem to be largest. Also, we can observe the highest (negative) implied valuation discounts for this group. Both could be affected by the comparably high counts of downrounds within the group of share classes featuring mixed seniority (approx. 70.6% versus 34.7% for the entire sample). This is in line with previous findings of Bengtsson and Sensoy (2015), whereby downrounds are a frequent trigger for changes in seniority.

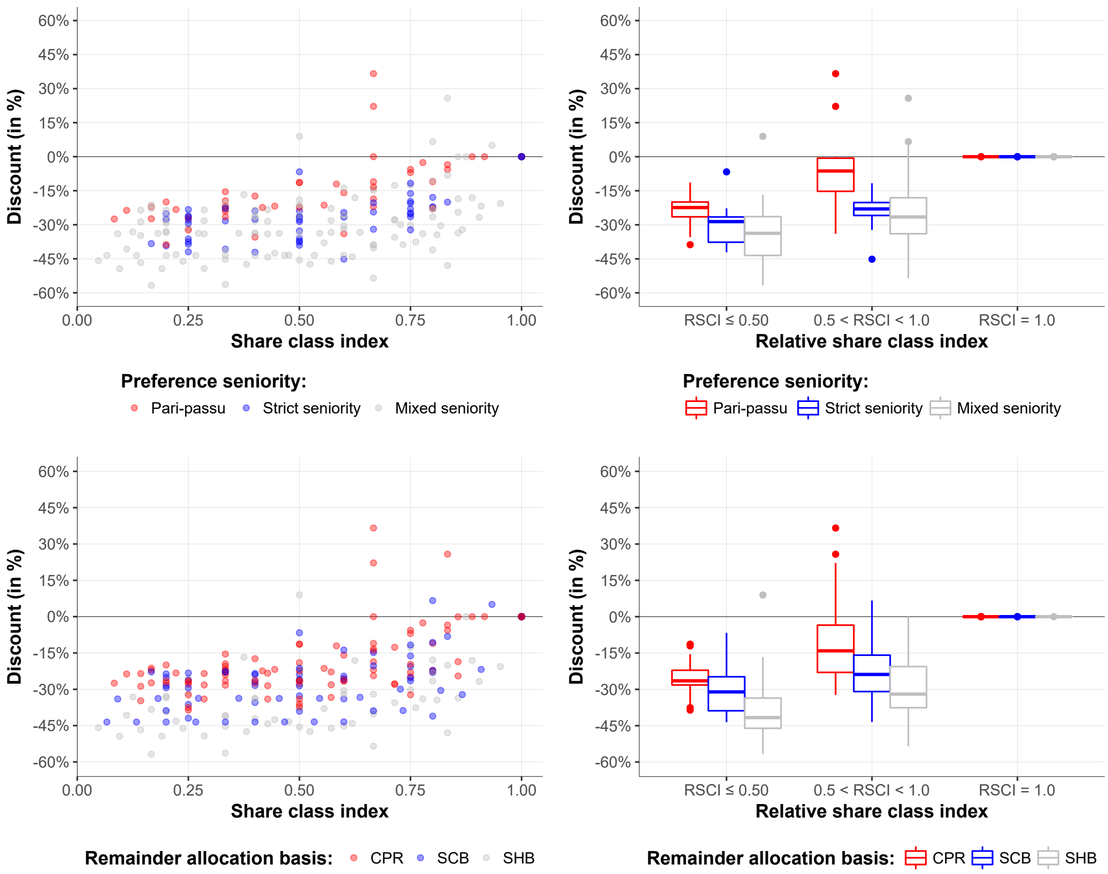
We also observe differences in implied valuation discounts with regard to the remainder allocation basis: For CPR, the (negative) implied valuation discounts are lowest, but the variation is comparably high, especially for shares of high RSCI. For SCB, we see strong overlap of ranges with CPR, however, the implied valuation discounts are lower. This difference might be also due to the pricing-performance or individual background of the respective venture: CPR is often applied for American or UK-based ventures, whereas SCB or SHB often applies for European ventures.

Table 2: Implied valuation discounts on share class level considering variation in the assumptions regarding the exit scenario, annual volatility and the risk free rate

Implied valuation discounts by relative share class index (RSCI), in %												
	$RSCI \leq 0.5$						$0.5 < \text{RSCI} < 1.0$					
	Min	25%-Q	Mean	50%-Q	75%-Q	Max	Min	25%-Q	Mean	50%-Q	75%-Q	Max
IPO-probability π, in %												
π : 5%	−67.8%	−48.7%	−39.2%	−36.2%	−29.7%	+10.0%	−64.1%	−38.5%	−26.2%	−28.4%	−16.4%	+45.9%
π : 25%	−56.8%	−38.8%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%
π : 75%	−21.7%	−13.0%	−10.5%	−9.5%	−7.9%	+3.9%	−20.3%	−10.3%	−6.9%	−7.5%	−4.3%	+12.4%
Time to Exit $T-t$, in years												
$T-t$: 2.0	−75.7%	−48.7%	−39.8%	−36.8%	−31.4%	+20.9%	−72.2%	−37.0%	−24.7%	−28.6%	−24.7%	+52.8%
$T-t$: 4.0	−56.8%	−38.8%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%
$T-t$: 12.0	−19.9%	−14.8%	−11.2%	−10.2%	−7.9%	+0.8%	−18.2%	−11.0%	−7.9%	−8.3%	−4.5%	+11.2%
Annual volatility σ, in %												
σ : 60%	−77.0%	−46.5%	−37.8%	−34.7%	−30.0%	−26.0%	−73.5%	−33.1%	−22.9%	−26.9%	−14.5%	+52.4%
σ : 90%	−56.8%	−38.8%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%
σ : 120%	−37.7%	−28.7%	−22.3%	−20.4%	−16.2%	+2.8%	−35.5%	−22.0%	−15.4%	−16.6%	−9.3%	+23.7%
Risk free rate r, in %												
r : 0.0%	−59.0%	−42.4%	−34.1%	−31.5%	−25.8%	+7.3%	−55.8%	−33.6%	−22.8%	−24.8%	−14.5%	+39.5%
r : 2.5%	−56.8%	−38.8%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%
r : 5.0%	−54.5%	−35.3%	−28.4%	−25.8%	−21.4%	+10.3%	−51.2%	−27.9%	−18.7%	−20.4%	−11.7%	+33.8%

Notes: The table above contains summary statistics of implied valuation discounts with regard to variation in the valuation assumptions of the model, i.e. the exit scenario (IPO-probability, time to exit), annual volatility and the risk free rate, supplementing plots in figure 7.

Figure 6: Implied valuation discounts on share class level considering difference in preference seniority and remainder allocation basis

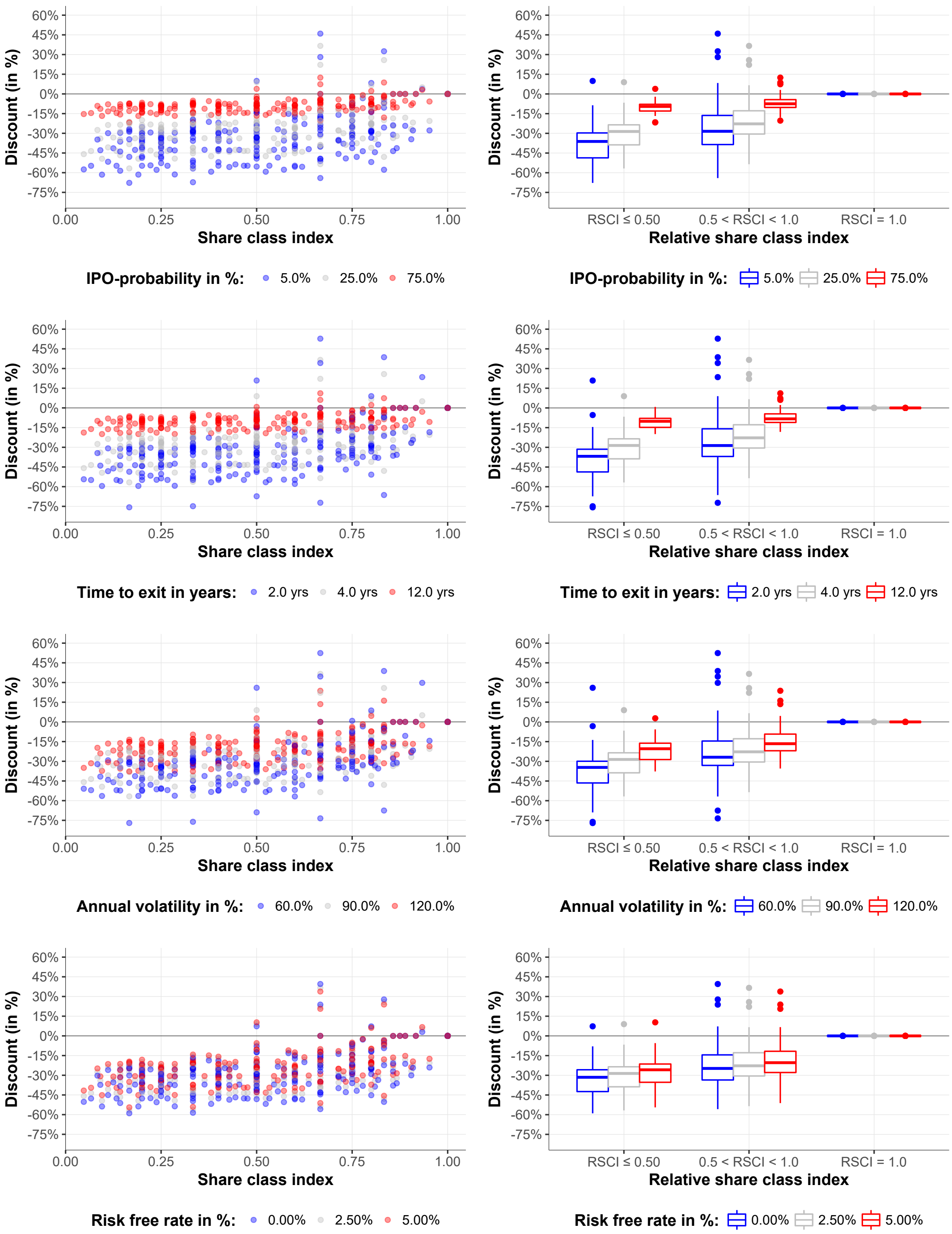


Implied valuation discounts by relative share class index (RSCI), in %												
	$RSCI \leq 0.5$						0.5 < RSCI < 1.0					
	Min	25%-Q	Mean	50%-Q	75%-Q	Max	Min	25%-Q	Mean	50%-Q	75%-Q	Max
Pari-passu	−38.8%	−26.5%	−22.8%	−22.4%	−20.0%	−11.4%	−34.0%	−15.2%	−6.3%	−6.3%	−0.6%	+36.6%
Strict seniority	−42.1%	−37.7%	−31.0%	−28.6%	−26.5%	−6.7%	−45.2%	−25.9%	−24.0%	−23.0%	−20.2%	−11.7%
Mixed seniority	−56.7%	−43.5%	−34.0%	−33.7%	−26.4%	+9.0%	−53.5%	−34.0%	−24.7%	−26.6%	−18.1%	+25.8%
CPR	−38.6%	−28.2%	−25.6%	−26.5%	−22.1%	−11.4%	−32.3%	−23.0%	−11.5%	−14.1%	−3.5%	+36.6%
SCB	−43.5%	−38.8%	−31.6%	−31.1%	−24.8%	−6.7%	−43.5%	−30.9%	−23.0%	−23.8%	−15.9%	+6.6%
SHB	−56.7%	−46.1%	−39.0%	−41.7%	−33.6%	+9.0%	−53.5%	−37.6%	−30.1%	−32.0%	−20.6%	0.0%
Total	−56.8%	−38.6%	−31.2%	−28.6%	−23.5%	+9.0%	−53.5%	−30.5%	−20.7%	−22.8%	−12.8%	+36.6%

Notes: The plots depict the implied valuation discounts with respect to their relative share class index ('RSCI'). Relative scaling is determined by the highest share class and highest seniority level. Within the first row of plots, we indicate the respective preference seniority. In the second row of plots, we indicate the respective remainder allocation model: CPR refers to the conversion based approach, SCB refers to the share class based approach and SHB refers to the share holder based approach of remainder allocation. For the box plot, we grouped implied valuation discounts by their RSCI into two groups: From 0 to 0.5 and greater 0.5 up to but not including 1.0, since each venture of our sample had at least two share classes. The line within the boxplot indicates the median for the distribution within the respective bin. The lower and upper hinges of the box plot correspond to the first and third quartiles (the 25th and 75th percentiles), the distance in-between defining the interquartile range ("IQR"). The upper whisker extends from the upper hinge to the largest value no further than $1.5 \cdot$ IQR. The lower whisker extends from the lower hinge to the smallest value at most $1.5 \cdot$ IQR. Data beyond the end of the whiskers are plotted individually.

Lastly, we considered variations in the specification of the assumptions of the exit scenario, annual volatility and the risk free rate. We report results in figure 7 and table 2. The plots in the first row of figure 7 depict implied valuation discounts for an increase (decrease) of IPO-probability, 5% and 75%, respectively. Where the variation lead to shrinking (widening) positive or negative implied valuation

Figure 7: Implied valuation discounts on share class level considering variation in the assumptions regarding the exit scenario, annual volatility and the risk free rate



Notes: The plots depict the implied valuation discounts with respect to their relative share class index ('RSCI'). Relative scaling is determined by the highest share class and highest seniority level. For the box plot, we grouped implied valuation discounts by their RSCI into two groups: From 0 to 0.5 and greater 0.5 up to but not including 1.0, since each venture of our sample had at least two share classes. The line within the box plot indicates the median for the distribution within the respective bin. The lower and upper hinges of the box plot correspond to the first and third quartiles (the 25th and 75th percentiles), the distance in-between defining the interquartile range ("IQR"). The upper whisker extends from the upper hinge to the largest value no further than $1.5 \cdot IQR$. The lower whisker extends from the lower hinge to the smallest value at most $1.5 \cdot IQR$. Data beyond the end of the whiskers are plotted individually.

discounts. This is due to the higher prevalence of pro-rata allocation which applies in case of an IPO. The respective box plot and summary statistics (table 2) indicate a more pronounced effect for share classes of lower RSCI. In addition, the change in IPO-probability also has an effect on the variation of implied valuation discounts: An increase in IPO-probability seems to reduce the interquartile range as well as the range marked by the whiskers, where the effect is more pronounced for share classes of higher RSCI. Interestingly, differences between implied valuation discounts of higher and lower RSCI decreases at an increased IPO-probability.footnoteStill, the general effect of lower (negative) implied valuation discounts at a higher IPO-probability does not hold for each specific case: As explained in section A.1, higher IPO-probability can be detrimental for those investors of shareholdings that have (uncapped) participating/non-set-off preferences or preference multiples larger than one, which leads to a higher (negative) implied valuation discount. Similarly, higher IPO-probability also results in lower (positive) implied valuation discounts, i.e. there is less undervaluation of respective share classes. Considering the time to exit, we see similar effects for an increase (12 years) or decrease (2 years) of the parameter, as is depicted in the plots in the second row of figure 7. Generally, the longer the time to exit period, the lower the (negative) implied valuation discount. That is, the values of the underlying explicit and implicit claims of each share class increase. Again, the adjacent box plot indicates that the effect is generally larger for share classes of lower RSCI. Also, the reduction in variation of implied valuation discounts is more pronounced for the more senior share classes. Compared to the variation in IPO-probability, we observe much more variation and outliers, compared to the basic case, especially for shorter time to exit periods, i.e. 2 years. The variation in the assumptions regarding annual volatility has different effects as already discussed in section 4.4.1. This is reflected by the respective results in the plots in the third row of figure 7, via high variation for share classes of low and high RSCI. Interestingly, variation in and median of implied valuation discounts is higher for lower estimates of annual volatility. Also, there is strong overlap of interquartile ranges for annual volatility estimates of the implied valuation discounts especially for share classes of high RSCI. That is, median implied valuation discounts for share classes of higher (relative) share class level does not change considerably for the given range of annual volatility estimates. Overall, compared to variations in IPO-probability, time to exit and the risk free rate, even rather high estimates of annual volatility do not result in implied valuation discounts close to zero for the median and also on average (see table 2). Lastly, we consider variation in the risk free rate, assuming values of 0.00% and 5.00%. As can be observed in the plots of the last row of figure 7, the negative (positive) implied valuation discount decreases in absolute terms, when increasing the value of the underlying risk free rate parameter. Compared to the variation of the other parameters, the variation in the risk free rate seems to only have moderate effects on the median implied valuation discounts and their variation, given the respective range and our sample. This holds in particular for share classes of lower RSCI, as is indicated in the respective box plot.

7. Discussion

Based on our framework of preferential claims in venture capital finance, we present a modular approach along two dimensions (amount of preferences and allocation of preferences and remainder) for different sets of preferential rights, which allows to assess the impact of different investment and exit scenarios as well as assumptions regarding annual volatility and the risk free rate on a shareholding level. The model offers closed-end solutions and lends itself to in-depth analysis of different assumptions for individual shareholdings. Thus, the model provides a useful tool in venture capital financing which is characterized by explicitly designed equity securities. Aside from an analysis of overall overvaluation of common shares as provided by Gornall and Strebulaev (2017), our model also allows to evaluate the economic implications regarding any share class and even any shareholding of a given venture. Relevance of such analysis is stressed by its broad range of application: On the one hand, appropriate fair value estimates are important for strategical considerations such as investment and exit decisions, especially in follow-up rounds, restructuring, downrounds or secondaries. On the other hand there are several regulatory reporting requirements, which invoke determination of appropriate fair value estimation, such as share-based payments or net asset value reporting to a fund's limited partners.[47]

We illustrated the model's implications by applying it to a sample of actual ventures. In line with evidence presented by Gornall and Strebulaev (2017) of general 'overvaluation', we are able to show the impact of preferential rights due to individual investment scenarios, sets of preferential rights and

[47] International valuation guidelines such as International Private Equity Valuation (IPEV) guidelines 2018 and the International Valuation Standards (IVS) 2017 explicitly require consideration of security-immanent rights which affect the value of such securities.

assumptions regarding exit scenario, annual volatility and risk free rate on a share class base-level. We base our analysis on the comparison of most recent share price (imposed post-money valuation) and implied model-based fair values. According to our results, implied valuation discounts ranges from 'overvaluation' of −56.8% to 'undervaluation' of +36.6%, averaging an implied valuation discount across all share classes and ventures of −22.0% (median −23.9%). Additional exploratory analysis indicates that results differs considerably across different investment scenarios, sets of preferential rights and assumptions regarding exit scenario, annual volatility and risk-free rate. For example, our model reveals that for ventures, where a downround occurred, implied valuation discounts can even get positive, implying that respective share classes and shares are overvalued at the most recent share price. With regard to the set of preferential rights, we observe substantial variation in the preference and remainder allocation, which also affects results regarding implied valuation discounts. For example, strict seniority of preferential claims generally results in higher implied discounts than pari-passu. Also, the remainder allocation basis plays an important role, where investors have to consider their entire shareholdings, when evaluating exit outcomes, since it also affects investment strategy: Shareholdings of a single shareholder compensate set-off of preferential claims of each other in case of a share holder based remainder allocation. In general, investors participating in multiple financing rounds face a basic trade-off: Higher claims of a recent shareholding may secure recent investment, but harms previous ones. Here, our model enables to identify such problems. In addition, since terms are generally not often changed across financing rounds, as indicated by findings of Bengtsson and Sensoy (2015), our model can be used by early stage investors and founders to evaluate and assess the impact of subsequent financing. According to our model, those investors should prefer a simple, non-participating (or set-off) preferential claim with pari-passu seniority. The extent of the economic impact is also affected by the underlying assumptions regarding the exit scenario: For example, high IPO-probability generally results in lower (negative) implied valuation discounts having lower variation. Similarly, (negative) implied valuation discounts are lower for longer time to exit, annual volatility and higher risk free rates, at a decreasing level of variation. We also infer that the effect is larger for shares of earlier share classes (of lower relative share class index, 'RSCI'), whereas the variation is higher for shares of later share classes (of higher RSCI), when considering the interquartile ranges of the distribution of implied valuation discounts. In general our findings suggest, that a dedicated analysis of each shareholding is necessary. Of course, our results are bound by certain limitations that also provide avenues for further research. For example, we assumed all option shares to be equivalent to common shares. Also, we prescind from integrating other rights such as antidilution or redemption provisions. Additionally, the model could be extended technically by integrating uncertainty of the time to exit or modelling IPO probability as a stochastic process. Apart from the extension of the model, further empirical research is needed, since extant research is currently limited to large, US-american ventures and existing samples are rather small and applicability of multivariate analysis is limited. From a practical point of view, implementation of such models is rather complex, so that further empirical analysis is clearly helpful in order to provide benchmarking and insights from different tools and provisions, especially when dealing with pricing in the growing secondary market. Although such research is clearly restricted by available data, a broader scope in terms of size and geography would be inevitable to support academic research as well as venture capital investment profession at all levels.

A. Appendix: A

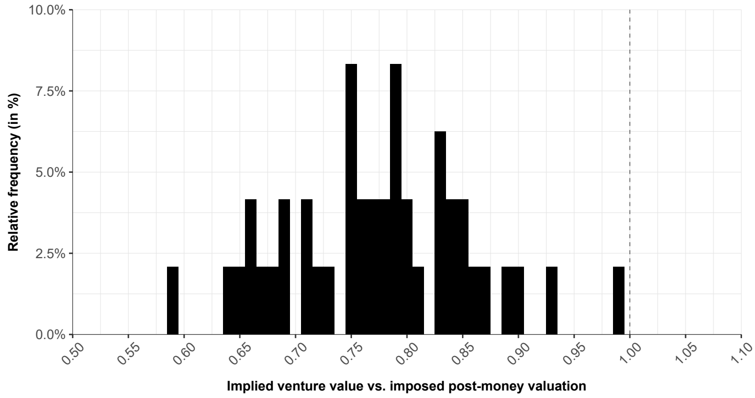
A.1. Venture level results

We calculated imposed post-money valuation based on pro-rata allocation, which shall serve as a benchmark. Although such an allocation is apparently not applicable, when preferential claims are involved, it is well-known and often used in press and publications. Comparison of the implied venture value and imposed post-money valuation reveals whether there is an over- or undervaluation, when using the post-money valuation as an estimate for the venture's fair value. We will refer to the extent of over- or undervaluation in terms of the imposed post-money valuation as 'implied valuation discount'. The discount may be positive (undervaluation) or negative (overvaluation).[48]

In figure 8 we plot the results regarding the comparison of the implied venture value and the imposed pro-rata value, ranging from 0.592 to 0.994 for the entire sample. In terms of Gornall and Strebulaev (2017), this corresponds to a range of 'overvaluation' of 0.6% to 40.8%, where the mean (median) overvaluation amounts to 22.0% (21.1%). The implied venture value also critically depends on the choice of assumptions such as IPO-probability, time to exit, annual volatility and the risk free rate. Thus, we also provide results which are based on alternative parameter specifications, as displayed in table 3. Regarding our sample, we can generally observe that the implied valuation discounts decrease (increase), when assuming a higher (lower) IPO-probability, a longer (shorter) time to exit, a higher (lower) risk free rate or when annual volatility is increased (decreased). For the IPO-probability, this is generally due to the higher weight put on the automatic conversion and imposed pro-rata allocation in case of an IPO. Thus, the relative share value of the last share class will be lower, resulting in a lower (negative) implied venture value. Note, however, that increased IPO-probability can potentially also result in increased (negative) implied valuation discounts. For example, in case of high preference multiples (larger than one) or uncapped participation, the higher probability of conversion in case of an IPO has an detrimental effect on respective shareholdings. This rather simple example highlights the need for a share level based consideration of effects. But also more complex analysis is possible on our claim based model, to consider the effects of different explicit and implicit claims which react differently with regard to parameter specification. For example, when evaluating changes in annual volatility and respective venture values for the most recent share class, we have to

[48] The same approach is applied by Gornall and Strebulaev (2017).

Figure 8: Histogram of implied venture values



Notes: Implied venture values are denoted in terms of the imposed post-money valuation.

assess at least two claims: The explicit preferential claim (which often is the most senior one) and the implicit claim regarding the pro-rata allocation once all other explicit and implicit claims have been served. As per definition, the latter claim is generally unrestricted in its participation in any upsides of the venture value and will increase in value, given an increase in volatility. At the same time, it represents the most junior claim, featuring the highest breakpoint of all claims. Thus, at any given venture value, the claim is most likely out of the money. In contrast, the explicit preferential claim is generally restricted with respect to the preferential claim amount, wherefore an increase in the venture value leads to a limited increase and an increase in annual volatility generally results in a decrease of the claim's value.[49] Simultaneously, being of highest seniority, the explicit claim features the lowest breakpoint of all claims, thus being the most likely one of all claims being at least at or in the money. The different claims represented by a single share result in the following effect: Given lower levels of annual volatility, the share's value is primarily determined by the value of the explicit claim. Thus, solving for the implied venture value will generally result in higher implied venture values. When increasing annual volatility, the share's value will (increasingly) be determined by the implicit claim, which results in a relatively lower implied venture value. However, at some level of annual volatility, the value of the explicit claim will decrease, thus implying higher venture values in order to equate the price paid and the implied value per share. This already quite complex example illustrates that an appropriate evaluation of preferential claims always necessitates a shareholding view of the analysis.

[49] See also section 4.3, footnote 26.

Table 3: Sensitivities of implied valuation discounts of venture values

IPO-probability, in %	Implied valuation discount					
	Minimum	25%-Quantil	Average	Median	75%-Quantil	Maximum
5.00%	−51.28%	−34.31%	−27.82%	−26.75%	−22.02%	−0.74%
25.00%	**−40.8%**	**−27.52%**	**−22.09%**	**−21.17%**	**−17.31%**	**−0.58%**
75.00%	−13.82%	−9.16%	−7.41%	−7.07%	−5.74%	−0.19%
Time to exit, in years	**Implied valuation discount**					
	Minimum	25%-Quantil	Average	Median	75%-Quantil	Maximum
2	−49.28%	−33.57%	−27.96%	−27.24%	−22.69%	−0.51%
4	**−40.8%**	**−27.52%**	**−22.09%**	**−21.17%**	**−17.31%**	**−0.58%**
12	−16.98%	−9.53%	−7.94%	−7.38%	−5.91%	−0.24%
Annual volatility, in %	**Implied valuation discount**					
	Minimum	25%-Quantil	Average	Median	75%-Quantil	Maximum
60.00%	−50.13%	−31.15%	−26.46%	−25.99%	−21.7%	−0.34%
90.00%	**−40.8%**	**−27.52%**	**−22.09%**	**−21.17%**	**−17.31%**	**−0.58%**
120.00%	−31.48%	−19.09%	−15.79%	−14.93%	−12.15%	−0.47%
Risk free rate, in %	**Implied valuation discount**					
	Minimum	25%-Quantil	Average	Median	75%-Quantil	Maximum
0.00%	−44.8%	−29.68%	−24.21%	−23.28%	−19.28%	−0.69%
2.50%	**−40.8%**	**−27.52%**	**−22.09%**	**−21.17%**	**−17.31%**	**−0.58%**
5.00%	−36.98%	−25.03%	−20.08%	−19.19%	−15.59%	−0.49%

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