Venture Capital Contracts

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This paper

Efficient allocation of start-up resources is first-order important.

High uncertainty, large information asymmetries, severe agency problems, limited liability ⇨ contracts matter.

Predominant theory: Contracts can provide optimal incentives and information sharing, improving start-up value.

- Typically, assume competitive VCs who do not participate in value creation.

Alternative view: VCs can skew the distribution of value in their favor, even if this reduces the overall start-up value.

- VCs have deal flow access, skill & participate in value creation ⇨ bargaining power. Limited liability & incomplete contracts misalign VC's and overall start-up's goals.

To date, ***little empirical evidence*** on this debate.

Contribution

Use ***new, large data set*** of VC contracts and dynamic ***search and matching model*** to estimate the impact of contract terms on:

- Start-up value;
- Split of value between VC and entrepreneur.

Main results:

VCs add value to startups:

- Higher quality VCs (who offer participating preferred and board seats) ⇨ higher start-up value and entrepreneur stake
- … but not as much as possible if they used different contract terms.

Major contract terms affect start-up value and its split:

- Optimal equity split between VC and entrepreneur.
- Participating preferred decreases value, shifts higher proportion to VCs.
- Board seat impact is nuanced and smaller.
- Pay-to-play increases value and shifts higher proportion to entrepreneur.

Identification challenge

In an ideal world, run regression of outcomes (e.g. IPOs) on contract terms.

BUT: *omitted variable bias.*

- VC and entrepreneur quality affects matches, contracts, and outcomes.
- Quality is (largely) unobserved.

We illustrate bias in the presence of search frictions in the VC market.

- Useful to understand our identification strategy.

Identification example: setup

Three VCs of quality $i = 1,2,3$.

Three entrepreneurs of quality $e = 1,2,3$.

Value of a match between entrepreneur and VC:

$$\pi = i \cdot e \cdot \exp\{-2.5 \cdot c\}, \text{ or } \log \pi = \log i + \log e - 2.5 \cdot c.$$

Assume common equity contracts, with VC receiving equity fraction c.

- For example, If $i = 1$ and $e = 2$ match with $c = 0.4$, then:
  - $\pi = 2 \cdot \exp\{-1\} = 0.74$.
  - VC receives 40% of π and entrepreneur retains 60%.

VCs and entrepreneurs search and randomly encounter counterparties. A match is made if

- VC quality is in entrepreneur's acceptable range.
- Entrepreneur quality is in VC's acceptable range.

Identification example: matches

Investor i

Entrepreneur e	1	2	3
3		π = 4.39 c^* = 0.13	π = 5.11 c^* = 0.23
2		π = 2.51 c^* = 0.19	π = 2.92 c^* = 0.29
1	π = 0.58 c^* = 0.21	π = 0.74 c^* = 0.40	

If i, e, c, and π are ***observed***, then the OLS regression

$$\log \pi = \beta_1 c + \beta_2 \log i + \beta_3 \log e + \varepsilon$$

is identified and yields the ***correct*** coefficients,

$$\beta_1 = -2.5, \beta_2 = 1, \beta_3 = 1.$$

Identification example: endogeneity

Investor i

Entrepreneur e	1	2	3
3		π = 4.39 c^* = 0.13	π = 5.11 c^* = 0.23
2		π = 2.51 c^* = 0.19	π = 2.92 c^* = 0.29
1	π = 0.58 c^* = 0.21	π = 0.74 c^* = 0.40	

In practice, i and e are <u>***unobserved***</u>, so running

$$\log \pi = \beta_1 c + \varepsilon$$

yields <u>***biased***</u> $\beta_1 = 2.04$.

Omitted variables i and e are in the residual, and correlated with c.

Bias generally ambiguous: Better (worse) VCs (entrepreneurs) get higher c.

Traditional solutions are limited

It is difficult to find instruments/experiments that vary contracts but not VC/entrepreneur matches.

VC and entrepreneur fixed effects could help, however:

- Need to estimate a parameter for each agent ⇨ less statistically efficient.
- Most entrepreneurs (and some investors) match once ⇨ cannot estimate f.e.

We use a ***model of selection*** to recover unobservable qualities:

- Matches and contract terms are chosen by agents in equilibrium ⇨ informative about qualities.
- Recovery of individual i and e is difficult: different (i, e) may sign same contract.
- A feasible approach:
  - Individual i and e combine into agent quality distributions.
  - ⇨ equilibrium distribution of matches, contract terms and exits in successful matches.
  - ⇨ recover quality distributions by fitting equilibrium to data.

Dynamic search and matching model

VCs randomly encounter entrepreneurs with Poisson intensity λ_i:

- Entrepreneur quality drawn i.i.d. from c.d.f. $F_e(e)$ on $[\underline{e}, \bar{e}]$.

Similarly, entrepreneurs randomly encounter VCs with intensity λ_e:

- Investor quality drawn i.i.d. from c.d.f. $F_i(i)$ on $[\underline{i}, \bar{\imath}]$.

If agents match, PV of future cash flows is $\pi(i, e, c)$.

VC optimally proposes a take-it-or-leave-it set of contract terms c:

- Formally, $c(i, e) = \underset{c \in C: \pi_e(i,e,c) \geq V_e(e)}{\arg\max} \pi_i(i, e, c)$.
- Limited liability + risky cash flows ⇨ fixed-amount cash transfers are infeasible.
- If accepted, VC receives $\pi_i = \alpha(c)\pi$, entrepreneur retains $\pi_e = \big(1 - \alpha(c)\big)\pi$.
- If not accepted, both agents resume their search.
  - Search is costly: agents discount future at rate r.
- ⇨ VCs and entrepreneurs have bargaining power: they can keep searching.
  - Model allows competitive VCs as a special case.

Implementation: value

Assume quality distributions $F_i \sim Beta(a_i, b_i)$ and $F_e \sim Beta(a_e, b_e)$:

- Discretize (i, e) on a 50x50 grid.

Reduced-form firm value:

$$\log \pi = \log Costant\ Elasticity\ of\ Substitution(i, e; \rho)$$
$$+\beta_1 c_1 + \beta_2 c_1^2 + \beta_{3:\#T+1} \cdot Terms + \beta_{\#T+2:\#T+\#I+1} \cdot Interactions.$$

- $\rho = -\infty$: qualities are perfect complements; $\rho = 1$: qualities are perfect substitutes.
- c_1: the VC share of equity upon conversion.
  - Quadratic specification allows for an internal optimal equity share.
- $Terms$: other contract terms interacted with VC equity:
  - The impact of other terms is the highest for intermediate values of VC equity.
  - It is zero when VC equity is either 0 or 100%: term is either irrelevant or VC already gets all the value.
- $Interactions$: all cross-interactions among other terms.

- ***Directly model impact of terms on values (and split)***, agnostic about mechanisms.

Implementation: split of value, outcome

Reduced-form split of value:

$$\log(1-\alpha(c)) = \log(1-c_1)$$
$$+\gamma_1(1-c_1) + \gamma_{2:\#T} \cdot Terms + \gamma_{\#T+1:\#T+\#I} \cdot Interactions.$$

- When $Terms = \emptyset$ (common equity contract), $\alpha(c) = c_1$.
- Other terms are mostly VC-friendly, pushing $\alpha(c) > c_1$.
- γ_1 captures the effect of other terms omitted from the contract space.
  - Some terms are always present in the data, or are considered unimportant.
  - The most important of these terms is liquidation preference.
  - It is zero when VC equity is 100% but strongest when VC equity is 0 ⇨ γ_1 is interacted with VC equity.

Since π is not observed directly, specify ***success probability***:

$$Prob(Success = 1 | i, e, c) = \Phi(\kappa_0 + \kappa_1 \pi(i, e, c)).$$

Estimate quality distributions, encounter frequencies, β, γ, and $Success(\pi)$ via method of moments.

Identification in GMM: contract terms

Model produces joint distribution of time between deals across VCs, contract terms, and success outcomes.

We use all first and second moments (including all covariances).

Parameters mainly shift specific moments, and can be identified from them:

- $\beta \cdot Terms$: higher impact of a contract term on value changes both the incidence of this term and the likelihood of success (via higher value):
  - Identified from Avg. (and Var., for equity) term and Cov. term and success rate.
- $\gamma \cdot Terms$: higher impact of a contract term on split of value only changes the incidence of this term:
  - Identified from the remaining information in Avg. term.
- $\beta \cdot Interactions, \gamma \cdot Interactions$: higher impact of term interactions on value and split changes the joint likelihood of these terms:
  - Identified from Cov. term1 and term2.

Identification in GMM: freq's, qualities

Parameters mainly shift specific moments, and can be identified from them:

- λ_i, λ_e: higher meet frequencies decrease average $E[\text{time}]$ between deals across VCs but have opposite effects on the dispersion of $E[\text{time}]$ between deals across VCs:
  - Identified from Avg. and Var. time since last VC financing.
- a_i, b_i, a_e, b_e, ρ: jointly impact time between VC deals and terms (by shifting bargaining power across and within VCs and entrepreneurs):
  - Identified from Cov. time since last VC financing and term.
- κ_0, κ_1: higher value changes the likelihood of success:
  - Identified from Avg. success rate and Cov. time since last VC financing and success rate.

Data

US start-ups with 2002–2015 first financing rounds.

- DowJones VentureSource, VentureEconomics, Pitchbook, and Correlation Ventures.

Contract data from Pitchbook and VC Experts.

- Collected from articles of incorporation (CA and DE).
- At least 86% of all VentureSource start-ups are incorporated in CA or DE.

First rounds only (seed or series A) with a lead VC investor.

- Follow-on rounds different due to existing contracts with prior investors.
- Non-VC leads may have objectives other than profit maximization.
- Restrict to rounds using an equity-type security.

Outcome variable: IPO or high-value acquisition within seven years of first financing round.

Main sample: ***1,695 contracts*** (robustness: >2,500 contracts).

Firm and exit statistics

Deals	Number	Mean	Median	St.Dev.
Firm Age at financing (years)	1,695	1.62	1.10	1.70
IT	1,695	0.47		
Healthcare	1,695	0.19		
Years since last round (VC)	1,695	0.69	0.28	1.13
Capital raised in round ($m)	1,695	7.26	5.20	8.37
Post-money valuation ($m)	1,695	21.20	13.01	39.38

Exits	Number	Mean
Went public	1,695	0.04
Acquired	1,695	0.39
IPO or Acquired > 2X capital	1,695	0.13
Out of business	1,695	0.13
Still private	1,695	0.43
Had follow-on within 2 years	1,695	0.73

VC Contracts 101

Convertible preferred equity:

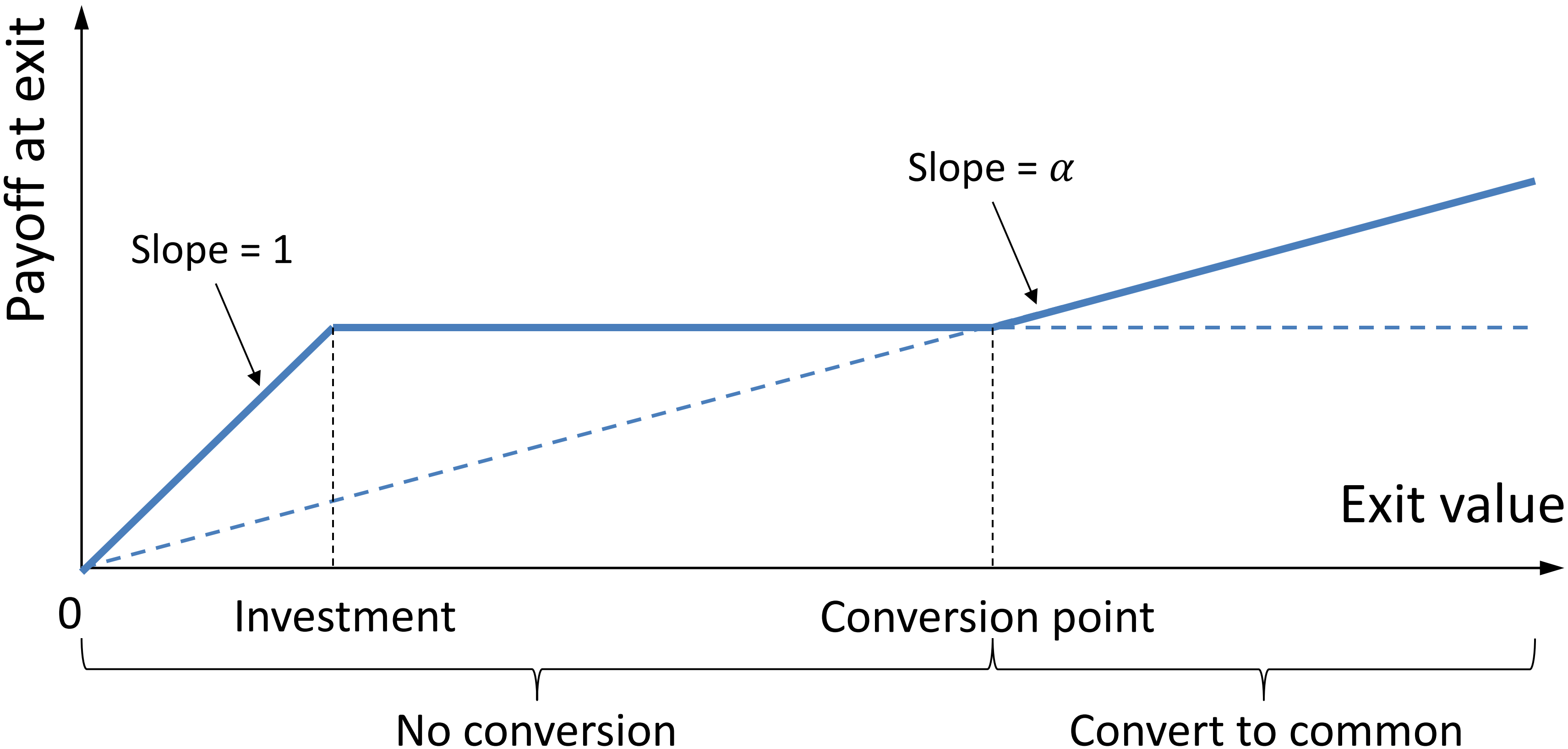
- The investor holds an option to convert into common stock.

Cash flow rights:

- Liquidation preference:
  - Debt-like feature that returns a multiple of invested capital to the preferred stockholder before common equity receives any payout.
- Participation.

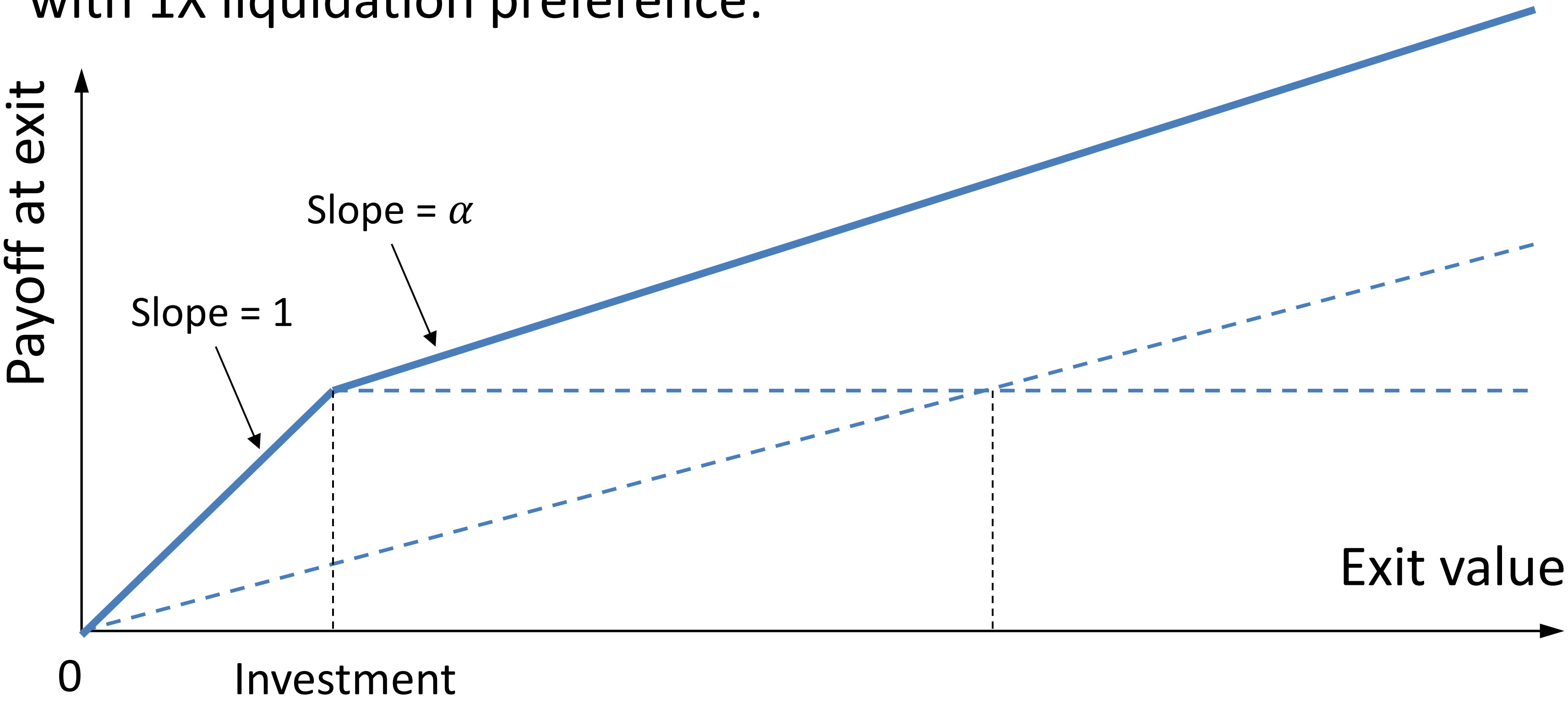
Convertible preferred equity

With a 1X liquidation preference the payoff figure looks as follows:



Participating convertible preferred

Payoff figure of participating convertible preferred (uncapped) with 1X liquidation preference:



VC Contracts 101

Convertible preferred ***<u>equity</u>***:

- The investor holds an option to convert into common stock.

Cash flow rights:

- Liquidation preference:
  - Debt-like feature that returns a multiple of invested capital to the preferred stockholder before common equity receives any payout.
- ***<u>Participation</u>***.
- Dividends.
- Redemption (put option).

Control rights:

- ***<u>VC board seat(s)</u>***.

Other: ***<u>Pay-to-play</u>***:

- Investor loses certain cash flow and voting rights if no pro-rata participation in next round (often conversion to common equity).

Contracts statistics

Contracts	Number	Mean	St.Dev.
Equity share sold to VC	1,695	0.40	0.17
Participating preferred	1,695	0.51	
Pay to play	1.695	0.12	
VC has board seat?	1,695	0.89	
Liquidation preference > 1X	1,689	0.03	
Cumulative dividends	1,694	0.21	
Redemption rights	1,675	0.39	
Full ratchet	1,013	0.02	
Common stock sold?	1,694	0.04	

Contract frequencies are similar to sample of 5,510 deals that does not require that key terms are known for every deal.

OLS estimates

$$Outcome = Const + \beta_1 \cdot Equity + \beta_2 \cdot Equity^2 + \beta_{3:5} \cdot Terms$$

Outcome		(1) IPO or 2X Acq.		(2) IPO only		(3) Log postmoney	
Parameter		Value	St.Err.	Value	St.Err.	Value	St.Err.
β_0	Intercept	-4.704***	0.655	-4.527***	0.611	2.638***	0.343
β_1	Total value, share of VC equity	-1.641**	0.964	-2.367	1.703	-5.004***	0.490
β_2	Total value, share of VC equity squared	2.546**	1.088	4.076***	1.547	5.252***	0.458
β_3	Total value, participation	-0.238***	0.065	-0.201**	0.091	-0.023	0.043
β_4	Total value, pay-to-play	0.115	0.133	0.376***	0.135	0.207**	0.077
β_5	Total value, VC board seat	0.136	0.198	0.280	0.219	0.241**	0.103
	Year FE	Y		Y		Y	
	Year founded FE	Y		Y		Y	
	State FE	Y		Y		Y	
	Industry FE	Y		Y		Y	
	R squared	6.2%		19.5%		12.9%	

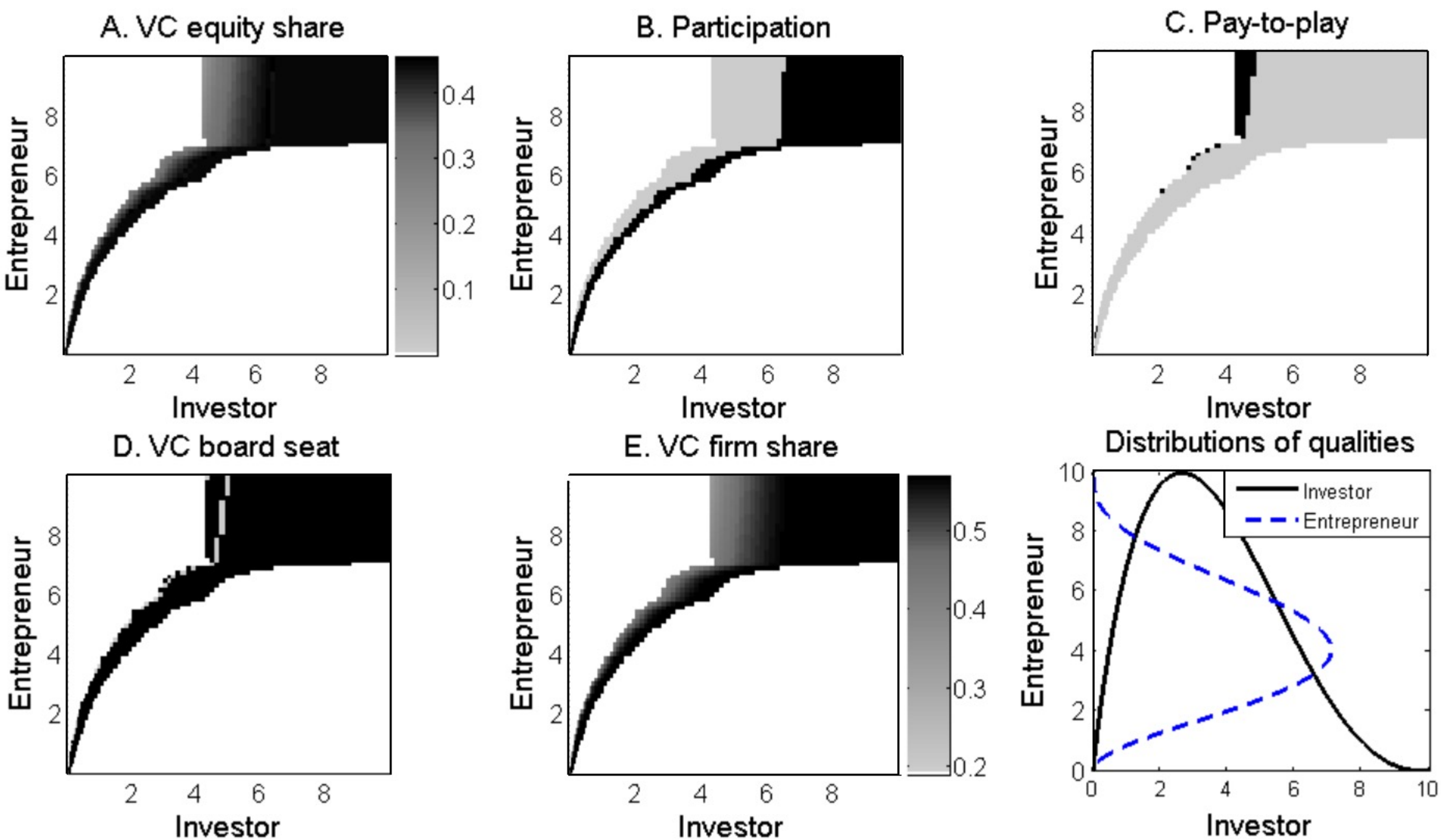
Counterintuitively, the OLS finds a ***U-shaped impact of equity***.

- Result is robust to controlling for raised capital, interactions among terms.

Model estimates

Parameter		Value	St.Err.
a^i	Distribution of investor qualities	1.927***	0.257
b^i	Distribution of investor qualities	3.602**	0.760
a^e	Distribution of entrepreneur qualities	3.142***	0.334
b^e	Distribution of entrepreneur qualities	4.152***	0.573
λ^i	Frequency of investor encounters	13.443**	6.096
λ^e	Frequency of entrepreneur encounters	10.393***	2.739
ρ	Substitutability of qualities	-1.370***	0.078
κ_0	Probability of IPO, intercept	-4.056**	2.066
κ_1	Probability of IPO, total value	0.104*	0.061
β_1	Total value, share of VC equity	0.679***	0.220
β_2	Total value, share of VC equity squared	-2.362***	0.233
β_3	Total value, participation	-0.163***	0.027
β_4	Total value, pay-to-play	0.024	0.048
β_5	Total value, VC board seat	-0.026***	0.006
β_6	Total value, participation x pay-to-play	0.016	0.102
β_7	Total value, participation x VC board seat	0.033^^	0.026
β_8	Total value, pay-to-play x VC board seat	0.019	0.064
γ_1	Split of value, intercept	-0.211***	0.076
γ_2	Split of value, participation	-0.174***	0.027
γ_3	Split of value, pay-to-play	0.055*	0.029
γ_4	Split of value, VC board seat	-0.040***	0.007
γ_5	Split of value, participation x pay-to-play,	0.015	0.113
γ_6	Split of value, participation x VC board seat	0.029^^	0.027
γ_7	Split of value, pay-to-play x VC board seat	0.012	0.107

Matches, contracts, and qualities



Equity and firm value

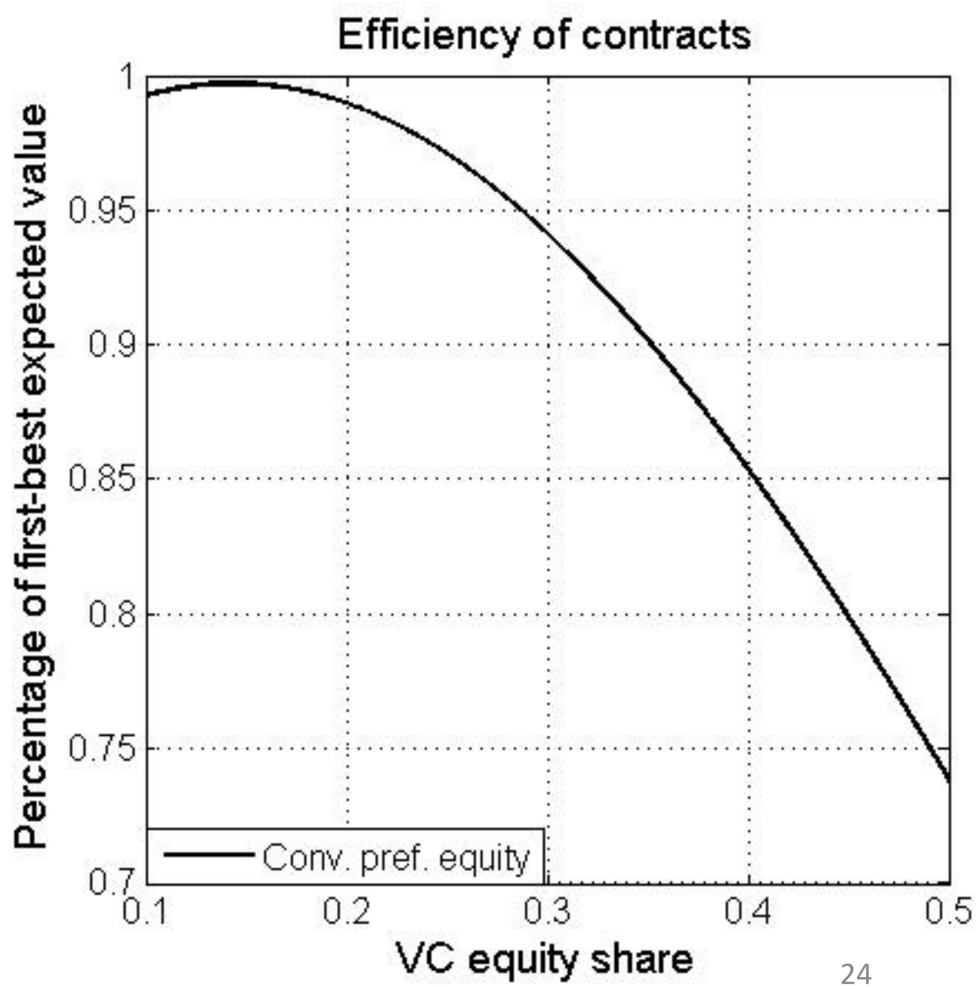
$$\log \pi = CES(i, e; \rho) + \beta_1 \cdot Equity + \beta_2 \cdot Equity^2 + \beta_{3:8} \cdot Terms \,\&\, Interactions$$

Fix VC and entrepreneur quality.

How does firm value compare to the maximal value across all possible contracts?

First, consider convertible pref.:

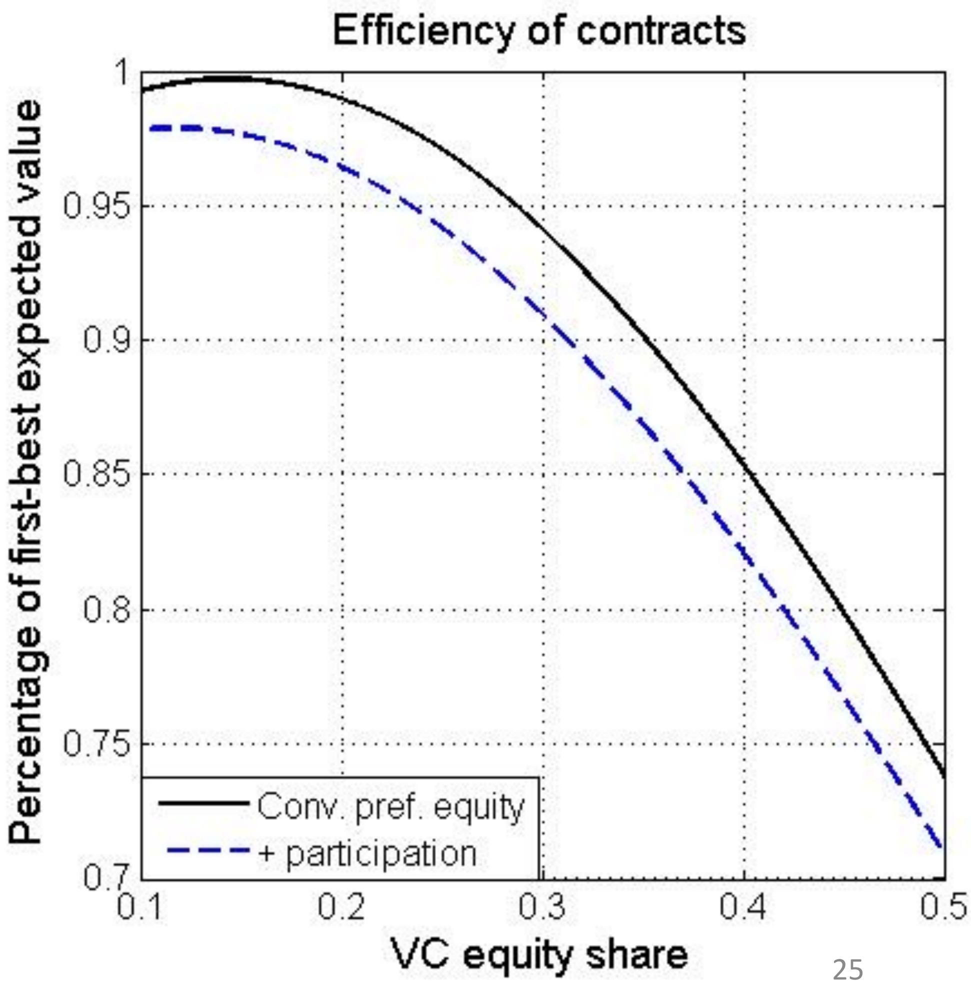
- Internal optimal equity share.
- Convertible pref. alone does not achieve maximal value.



Participating preferred and firm value

$$\log \pi = CES(i, e; \rho) + \beta_1 \cdot Equity + \beta_2 \cdot Equity^2 + \beta_{3:8} \cdot Terms\ \&\ Interactions$$

Introduction of participating preferred term lowers the achievable firm value:



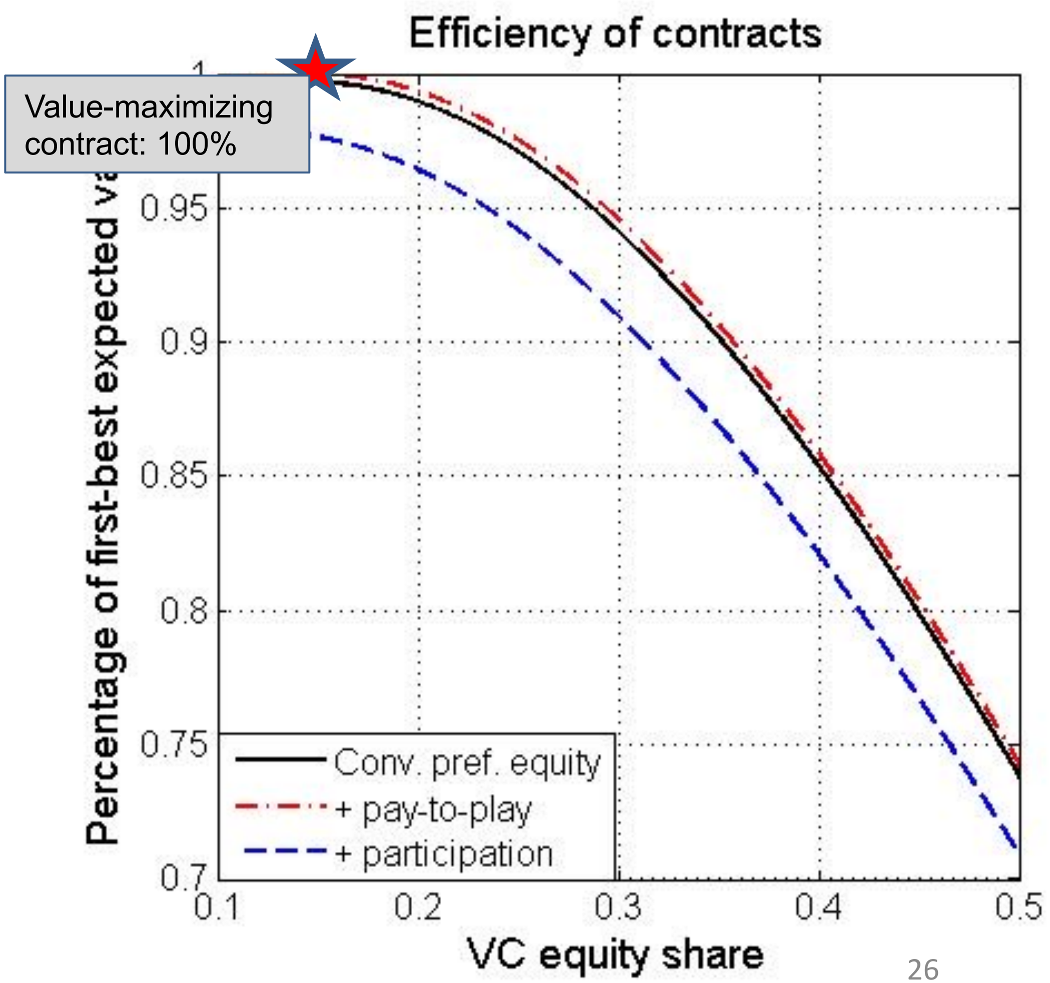
Pay-to-play and firm value

$$\log \pi = CES(i, e; \rho) + \beta_1 \cdot Equity + \beta_2 \cdot Equity^2 + \beta_{3:8} \cdot Terms\ \&\ Interactions$$

Pay-to-play term allows agents to achieve maximal firm value:

Value-maximizing contract:

- Convertible preferred.
- 1X liquidation.
- Pay-to-play.
- 14.7% VC equity share.



VC board seats and firm value

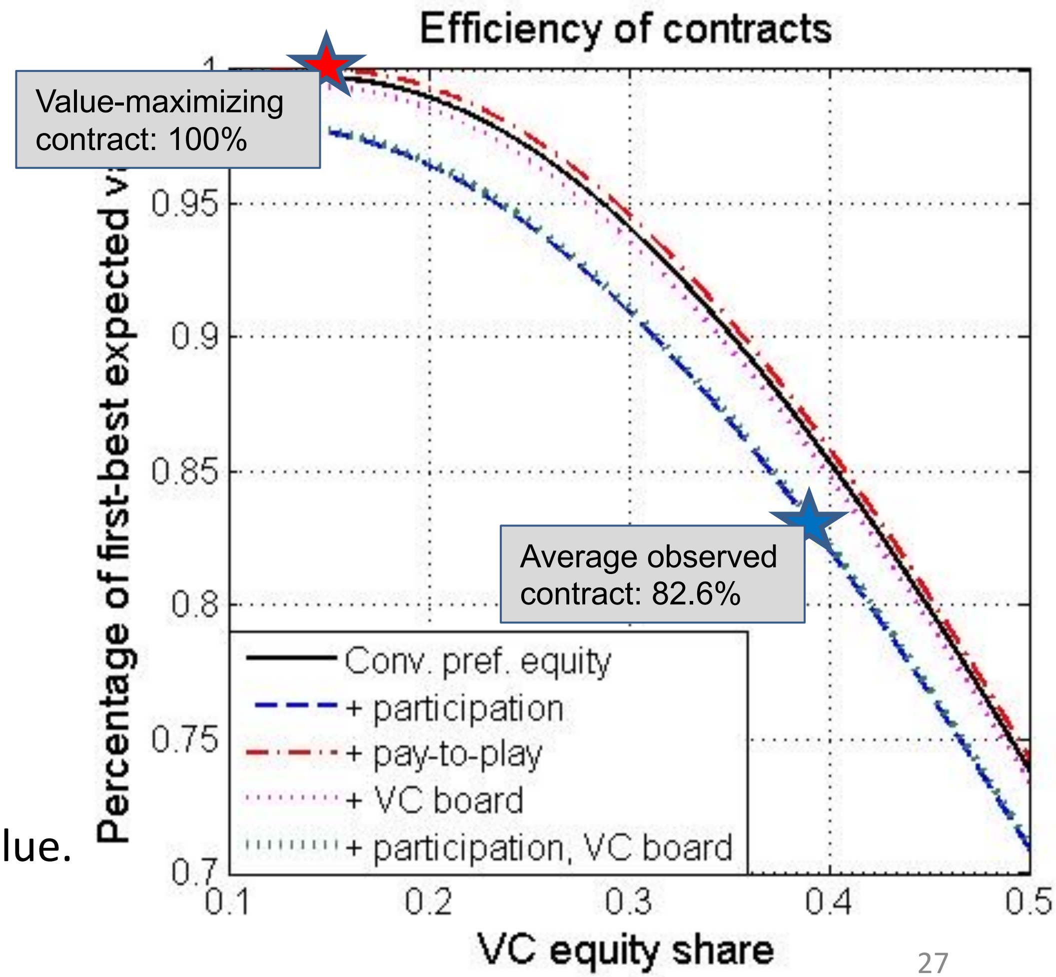
$$\log \pi = CES(i, e; \rho) + \beta_1 \cdot Equity + \beta_2 \cdot Equity^2 + \beta_{3:8} \cdot Terms \,\&\, Interactions$$

VC board seats is nuanced:

- Increase value relative to participating preferred (offered by high quality VCs).
- Decrease value otherwise.

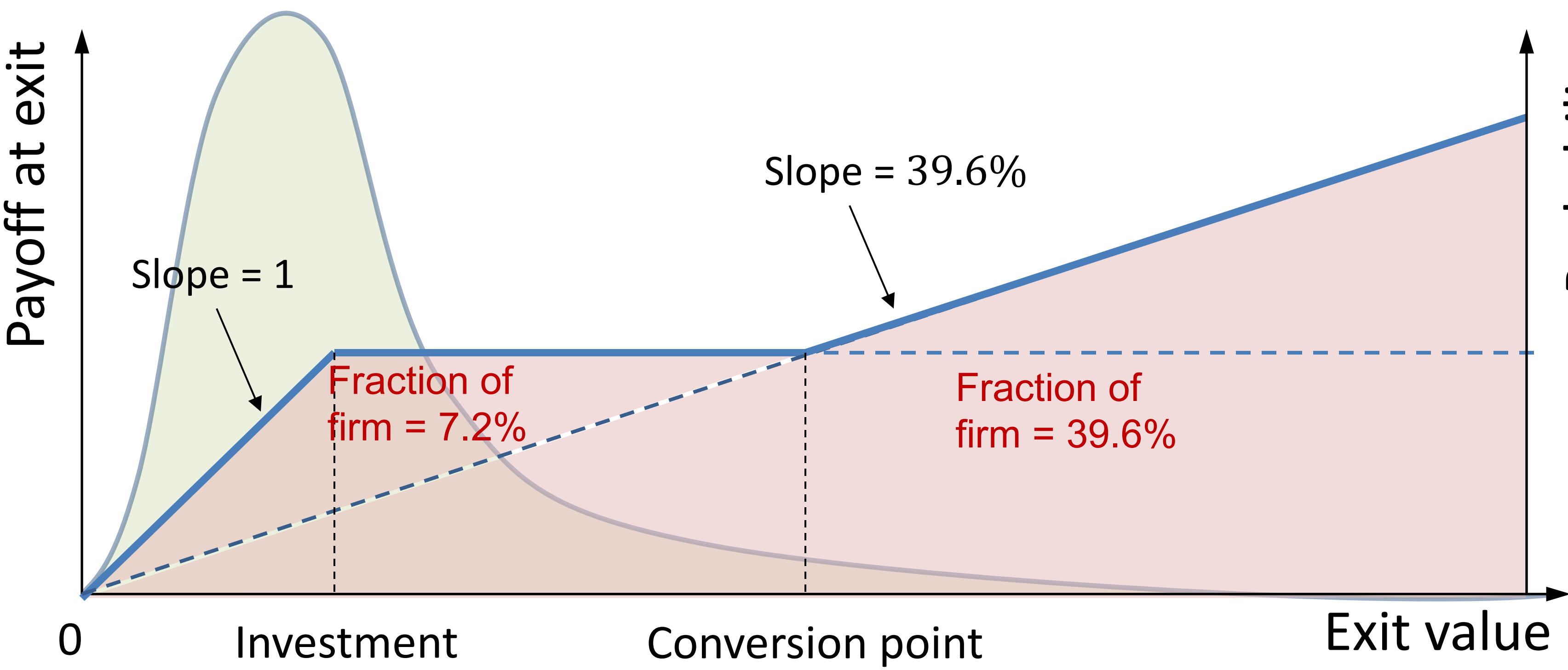
<u>Average observed contract:</u>

- Convertible preferred.
- 1X liquidation.
- Participating preferred.
- VC board seats.
- 39.6% VC equity share.
- Achieves 82.6% of maximal value.



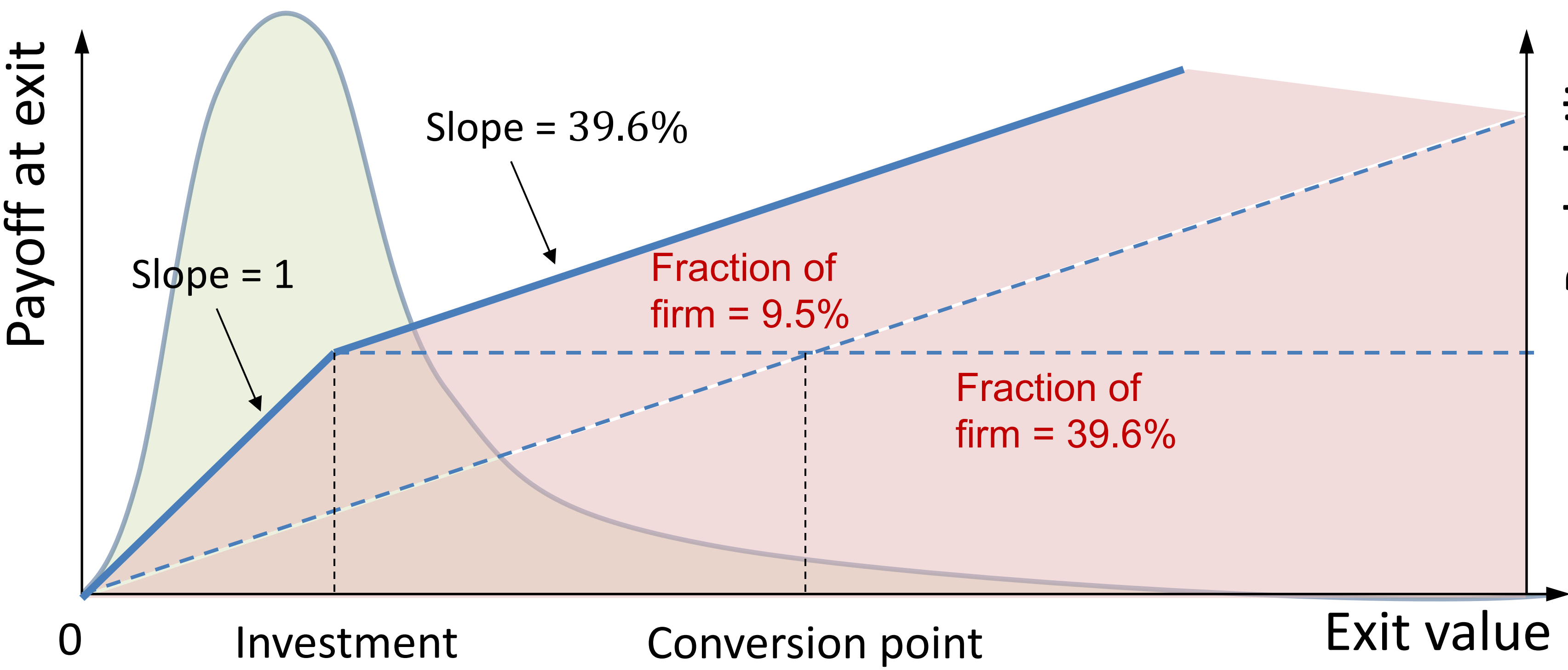
Split of value for average contract

39.6% of convertible preferred equity is 46.8% of the firm:



Split of value for average contract

39.6% of participating convertible preferred is 49.1% of the firm:



Split of value

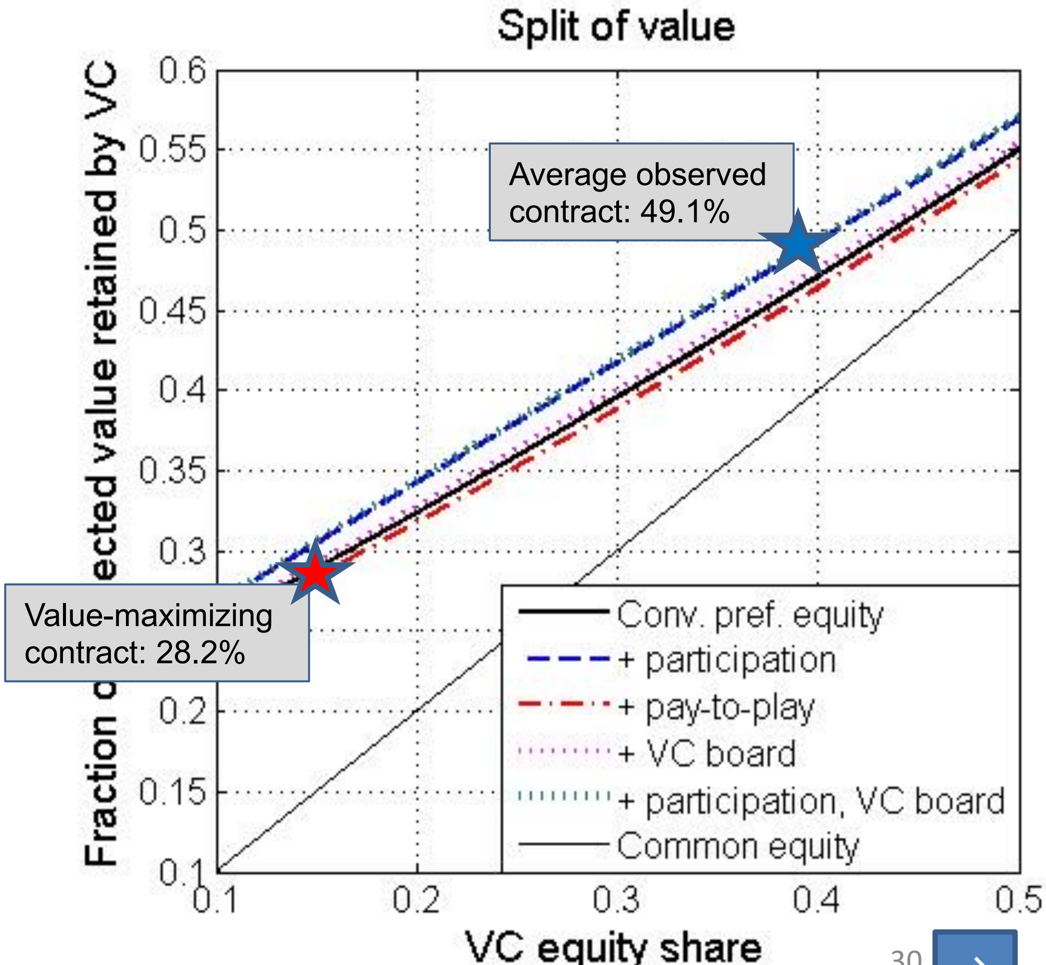
$$\log(1-\alpha) = \log(1-Equity) + \gamma_1(1-Equity) + \gamma_{2:7} \cdot Terms\ \&\ Interactions$$

Value-maximizing contract:

- 14.7% VC equity share.
- VC retains 28.2% of firm value.

Average observed contract:

- 39.6% VC equity share.
- VC retains 49.1% of firm value.



Average vs value-maximizing contract

Exits	Value-maximizing	Observed
Equity share	14.7%	39.6%
Participation	N	Y
Pay-to-play	Y	N
VC board seat	N	Y
Fraction of maximal value	**100%**	**82.6%**
VC share of firm	**28.2%**	**49.1%**

Why the difference between average and value-maximizing contract?

- Bargaining power.
- VC is better off under the observed contract:
  - Average VC prefers 49.1% of 82.6% (best achievable in equilibrium) to 28.2% of 100%.
- VC would like to have even more equity but is unwilling to lose entrepreneurs.

Implications for startup valuation

In practice, commonly cited measure of value is "post-money" valuation:

- Startup financed with $\$1m$ via, say, an average observable contract leaves the VC with 39.6% equity share and is "worth" $\frac{1}{0.396} = \$2.53m$.

This measure is incorrect, because it assumes $Terms = \emptyset$:

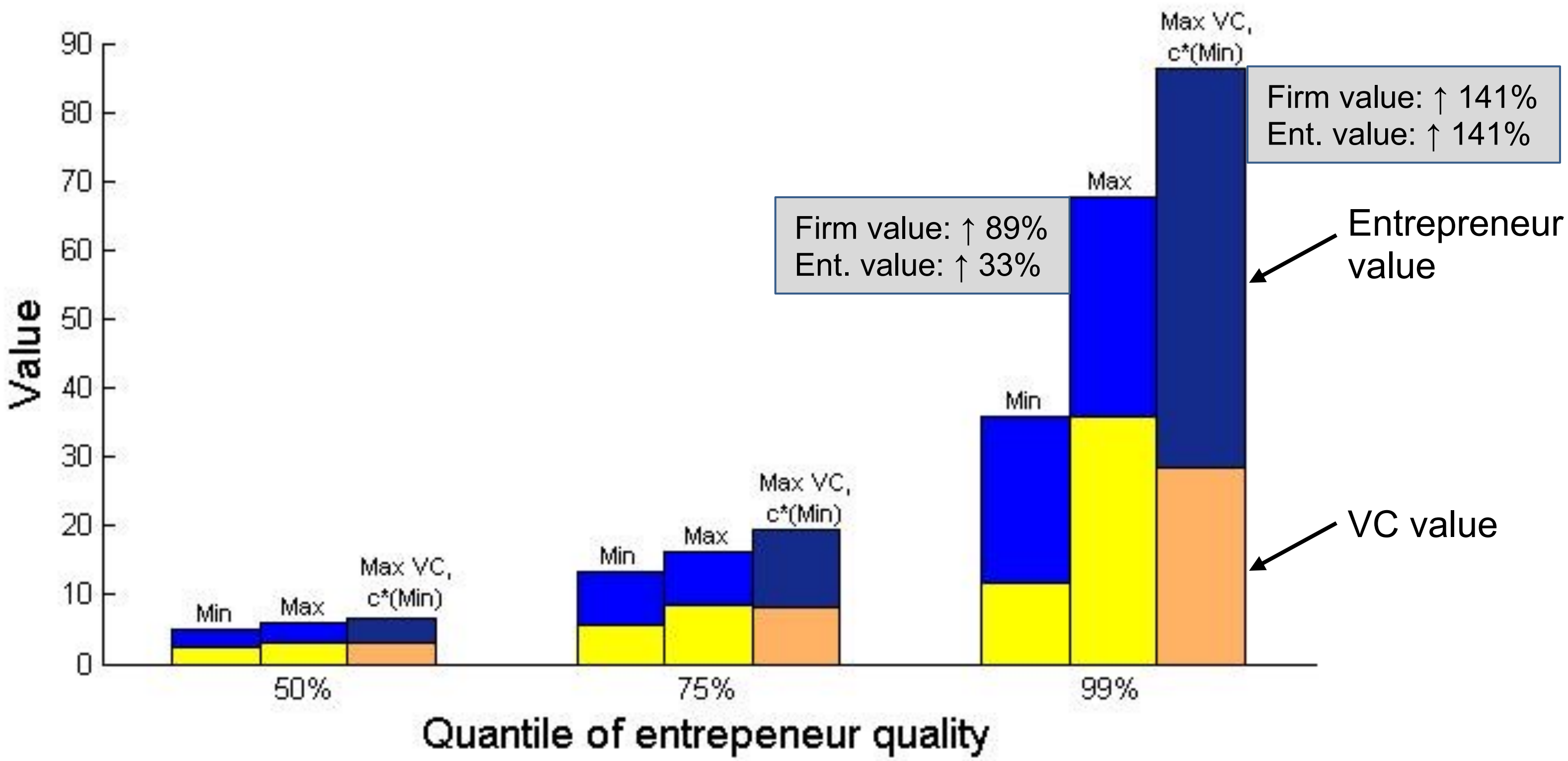
- As if VC holds common equity.

Our method can value startups in the presence of other terms:

- The startup is worth $\frac{1}{0.491} = \$2.04m$, or 19.3% lower than its post-money valuation, due to VC-friendly terms.
- Gornall and Strebulaev (2019) calibrate Black-Scholes valuations of unicorns in the absence of control terms and market effects.

Good VCs add firm/entrepreneur value

Although better VCs receive larger share of the firm value, ***entrepreneurs still prefer high-quality VCs*** – and their investor-friendly contracts:



However, firm and entrepreneur (but not VC) value could have been higher had VCs not been able to use their bargaining power.

Counterfactuals: contracts

Change in the present value across all deals if VC-friendly contract features (implemented by terms) are disallowed:

ΔPV of Deals (% of Estimated Mkt Size)	No Participation	No VC Board Seat
Overall	+1.70%	+1.66%
VC	-0.20%	-0.35%
Entrepreneur	+1.90%	+2.00%

Entrepreneurs become more selective, while investors become less selective.

- High-quality entrepreneurs drop their worst matches and match less often.
- Low-quality entrepreneurs match more often with low-quality investors.
- At estimated parameters, the second effect dominates and leads to more frequent deals but a lower average deal value.
- ***The present value of all deals modestly increases***:
  - Intuitively, the VCs can easily rebalance the remaining contract terms and achieve an almost identical outcome.

Counterfactuals: search frictions

Change in the present value of all deals if search frictions are relaxed:

- E.g., an online platform akin to AngelList is adopted:

ΔPV of Deals (% of Estimated Mkt Size)	2X Frequency of Encounters	5X Frequency of Encounters	10X Frequency of Encounters
Overall	+1.19%	-2.74%	-5.14%
VC	+2.43%	+5.42%	+7.25%
Entrepreneur	-1.24%	-8.16%	-12.38%

At estimated parameters, VCs become comparatively more selective when cost of waiting decreases.

- VCs offer more VC-friendly terms.
- The frequency of deals increases but the average firm value decreases.
- ***<u>The present value of all deals can decrease</u>*** if search frictions are very low.
  - This result is similar to the "Vegas effect" in Glode and Opp, 2018.
- Entrepreneurs lose out.

Caveats

Cannot speak about:

- The impact on value of contract terms that are always present:
  - They are absorbed in qualities of VC and entrepreneur.
- General equilibrium effects / extensive margin:
  - E.g., if disallow certain contractual features, would this reduce the availability of VC funding? How many VCs and entrepreneurs would enter or exit? Would VCs come up with new contractual features to substitute?
  - When participating preferred and VC board seats are disallowed, the relative present value loss to all VCs is less than 1% and gain to all entrepreneurs is approximately 4%:
    - Does entry of entrepreneurs overshadow exit of VCs?

Robustness / extensions

Results are robust to:

- Industries: IT vs healthcare.
- Deal types: seed vs Series A, syndicated vs non-syndicated.
- Time periods: before vs after Amazon Cloud, before vs after financial crisis.
- Locations: California vs Massachusetts.
- Capital intensity: low vs high.
- Outcome variables: IPO, IPO+2X M&A, follow-on financing.
- Contract filters: if two terms are present and the rest are missing, impute as zeros.
- Higher discount rate.
- Entrepreneur overconfidence.
- Higher entrepreneur bargaining power.
- Match-specific shocks (same pair of agents can sign different contracts).
- Directed search.
- Finer grid of entrepreneur and VC qualities.
- Non-optimal GMM weighting matrix.
- Endogenous investment (show via comparative statics).

Conclusions

VC quality has a positive impact on start-up and entrepreneur value:

- Although not as high as theoretically possible.

Contracts provide a mechanism for VCs of different types to match with better entrepreneurs.

- But VCs get a higher fraction of value than the first-best.

Contract terms have an impact on firm value and split of value:

- For average VCs, participation and VC board seats reduce success prob. and shift value to VC.
- For high-quality VCs, board seats actually help.
- Pay-to-play increases value and shifts more to entrepreneur.
- VCs get a much higher fraction of value than VC equity share alone suggests.

Related literature

Empirical literature on contracts in VC market:

- Gompers, Lerner (1996), Moskowitz, Vissing-Jorgensen (2002), Kaplan, Stromberg (2003, 2004), Hsu (2004), Cumming (2008), Bengtsson, Ravid (2009), Hall, Woodward (2010), Bengtsson, Sensoy (2011, 2013), Bengtsson, Bernhardt (2014).

Empirical models of selection in VC market:

- Sorensen (2007), Hochberg, Lindsey, Westerfield (2015), Fox, Hsu, Yang (2015).

Theoretical models of contracting between entrepreneur and investor:

- Too many to mention them all. Start with books by Bolton, Dewatripont (2005), Tirole (2006). Most relevant: Townsend (1979), Diamond (1984), Green (1984), Gale, Hellwig (1985), Berglof (1994), Kalay, Zender (1997), Biais, Casamatta (1999).
- In VC market: Schmidt (2003), Casamatta (2003), Cornelli, Yosha (2003), Inderst, Muller (2004), Repullo, Suarez (2004), Hellmann (2006), Cestone (2014), Gornall, Strebulaev (2019).

Theoretical models of dynamic search and matching, and matching with contracts:

- Shimer, Smith (2000), Adachi (2003, 2007), Hatfield, Milgrom (2005), Smith (2011).

Appendix: value functions

Three events can occur to VC in next time interval dt:

- With probability $\lambda_i dt \int_{e \in \mu_i(i)} dF_e(e)$, the VC encounters an entrepreneur in set $\mu_i(i)$ that is willing to negotiate a contract.
- With probability $\lambda_i dt \left(1 - \int_{e \in \mu_i(i)} dF_e(e)\right)$, the VC encounters an entrepreneur who is unwilling to negotiate.
- With probability $1 - \lambda_i dt$, the VC does not encounter anyone.

VC's continuation value then is

$$V_i(i) = \underbrace{\frac{\lambda_i}{\lambda_i + r}}_{\substack{Discount \\ rate}} \int_e \max[\underbrace{1_{e \in \mu_i(i)} \pi_i(i, e, c^*)}_{Negotiation}, \quad \underbrace{V_i(i)}_{\substack{No \\ negotiation}} \quad] dF_e(e)$$

- Modified discount rate captures expected time until the next encounter.

Similar events and continuation value for entrepreneurs.

Appendix: dynamic vs static model

Our dynamic model of search and matching approximates reality:

- Neither VCs nor entrepreneurs see all possible deals in the market.

Dynamic models generate exogenous variation in matches:

- Because delay is costly, each investor (entrepreneur) matches with a range of entrepreneurs (investors).

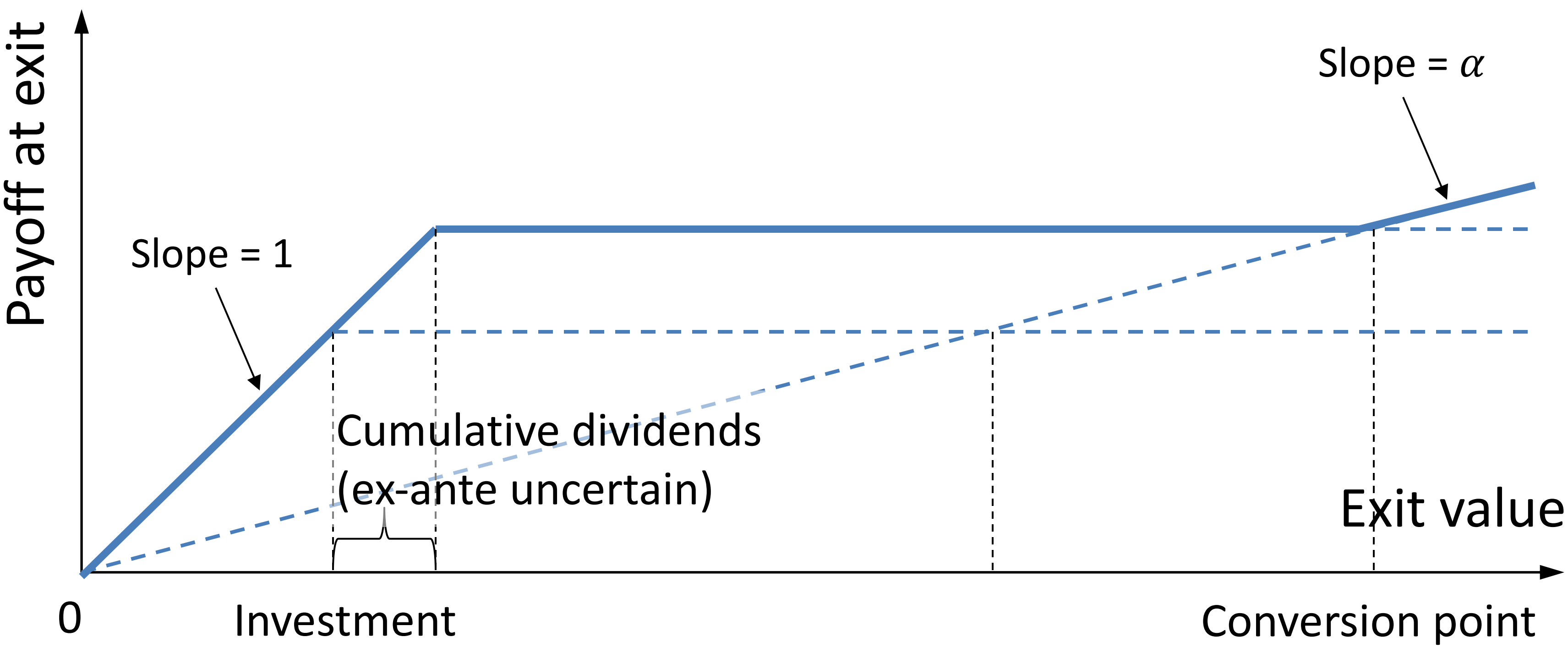
No need to artificially split the sample into "static" subsamples.

Dynamic models are easier to estimate:

- No need to compare observed matches and contracts to all counterfactual matches and contracts.
- Instead, compare value of the observed match to the expected value of the next encounter.

Appendix: cumulative dividends

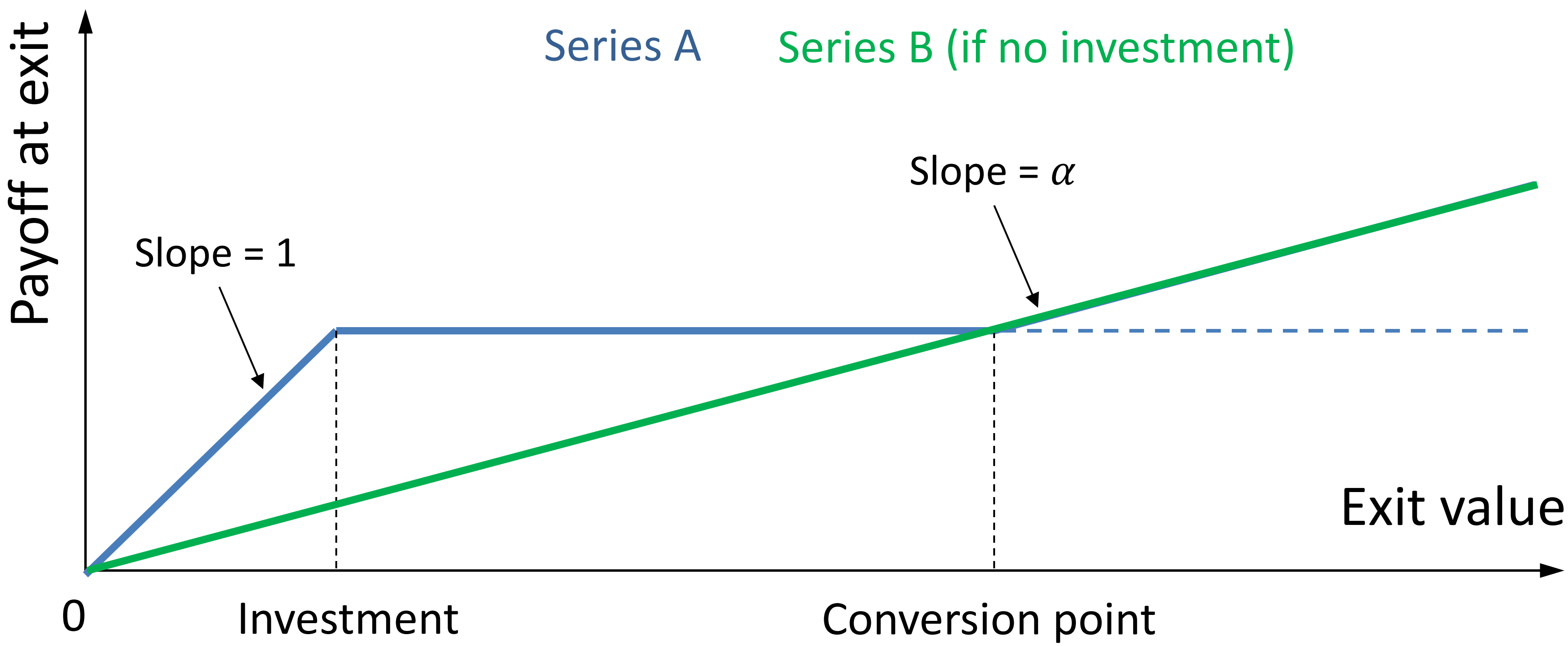
Cumulative dividends are supposed to increase liquidation preference by dividends × years before exit



In practice, cumulative dividends are rarely paid

Appendix: pay-to-play

With pay-to-play the payoff figure of convertible preferred equity can change between rounds:



Appendix: GMM moments

Moment	Data	Model
Avg. time since last VC financing	0.689	0.494
Var. time since last VC financing	1.276	0.420
Avg. VC share of equity	0.396	0.406
Var. VC share of equity	0.031	0.003
Skew. VC share of equity	0.002	-0.000
Cov. time since last VC financing and VC share of equity	0.003	0.001
Avg. participation	0.512	0.465
Cov. time since last VC financing and participation	0.055	0.002
Cov. VC share of equity and participation	0.015	0.018
Avg. pay-to-play	0.122	0.049
Cov. time since last VC financing and pay-to-play	-0.003	-0.001
Cov. VC share of equity and pay-to-play	0.012	-0.001

Moment	Data	Model
Cov. participation and pay-to-play	0.018	-0.023
Avg. VC board seat	0.893	0.970
Cov. time since last VC financing and VC board seat	-0.018	-0.001
Cov. VC share of equity and VC board seat	0.006	0.003
Cov. participation and VC board seat	0.004	0.014
Cov. pay-to-play and VC board seat	0.005	0.000
Avg. success rate	0.127	0.093
Cov. time since last VC financing and success rate	-0.014	0.024
Cov. VC share of equity and success rate	0.004	-0.001
Cov. participation and success rate	-0.012	-0.008
Cov. pay-to-play and success rate	0.005	0.005
Cov. VC board seat and success rate	0.002	-0.000

Appendix: alternative outcomes, filters

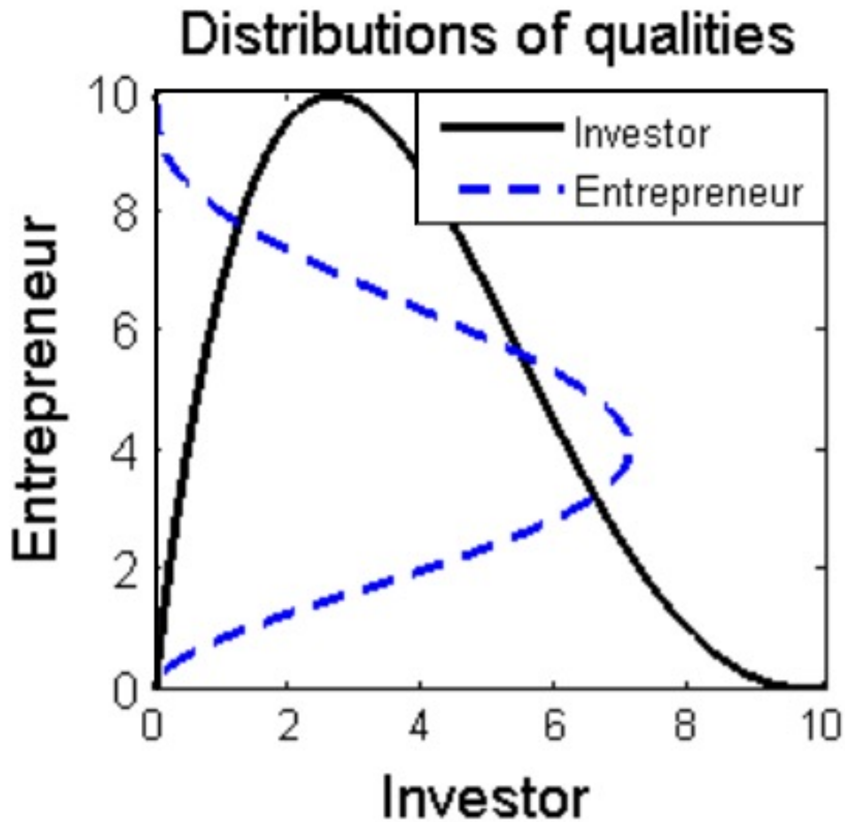
Outcome / contract filter		(1) IPO		(2) Followon rnd		(3) Imputed terms	
Parameter		Value	St.Err.	Value	St.Err.	Value	St.Err.
κ_0	Probability of success, intercept	-4.072***	1.157	-6.661	7.328	-4.091***	1.235
κ_1	Probability of success, total value	0.075***	0.029	0.458	0.488	0.113***	0.043
β_1	Total value, share of VC equity	0.682*	0.367	0.754***	0.108	0.650**	0.312
β_2	Total value, share of VC equity squared	-2.347***	0.639	-2.692***	0.326	-2.375***	0.322
β_3	Total value, participation	-0.163***	0.032	-0.168**	0.083	-0.163***	0.043
β_4	Total value, pay-to-play	0.024	0.066	0.031	0.047	0.023	0.027
β_5	Total value, VC board seat	-0.026***	0.010	-0.028*	0.016	-0.026***	0.007
β_6	Total value, part. x pay-to-play	0.016	0.091	0.013	0.035	0.017	0.026
β_7	Total value, part. x VC board seat	0.033	0.032	0.039	0.083	0.032	0.043
β_8	Total value, pay-to-play x VC board seat	0.019	0.020	0.013	0.038	0.019	0.058
γ_1	Split of value, intercept	-0.211*	0.116	-0.215***	0.058	-0.211***	0.032
γ_2	Split of value, participation	-0.175***	0.054	-0.157*	0.089	-0.171***	0.055
γ_3	Split of value, pay-to-play	0.056	0.057	0.053*	0.051	0.057***	0.008
γ_4	Split of value, VC board seat	-0.040***	0.006	-0.041***	0.015	-0.040***	0.002
γ_5	Split of value, part. x pay-to-play,	0.016	0.114	0.011	0.035	0.016	0.026
γ_6	Split of value, part. x VC board seat	0.029	0.054	0.028	0.089	0.029	0.055
γ_7	Split of value, pay-to-play x VC b'd seat	0.012	0.094	0.011	0.036	0.013	0.068

Appendix: VC and entrepreneur qualities

$$F_i \sim Beta(a_i, b_i) \text{ and } F_e \sim Beta(a_e, b_e)$$

Using model estimates, we can estimate sensitivities of VC and ent. qualities to observables:

- Let $i = Y_i'\gamma_i$, $e = Y_e'\gamma_e$, where (Y_i, Y_e) are VC and ent. observables.
- For any (γ_i, γ_e), compute theoretical startup-level contracts and outcomes using model estimates.
- Estimated sensitivities $(\widehat{\gamma}_i, \widehat{\gamma}_e)$ minimize distance between theoretical and empirical startup-level contracts and outcomes.
- Concern: first-stage estimation error.



Appendix: qualities and firm value

$$\log \pi = \log Constant\ Elasticity\ of\ Substitution(i, e; \rho) + Contract$$

Fix the contract.

Consider a startup formed by average-quality VC and entrepreneur.

A one st.dev. improvement in VC quality raises firm value by 53%:

- $\pi(5.20, 4.31, c)/\pi(3.49, 4.31, c) = 1.53.$

A one st.dev. improvement in entrepreneur quality raises firm value by 29%:

- $\pi(3.49, 6.03, c)/\pi(3.49, 4.31, c) = 1.29.$

Appendix: Pareto inefficient contracts

The model can produce any combination of contract terms.

However, at estimated parameters, the model cannot produce contracts that combine participating preferred and pay-to-play:

- 8% of the sample.
- Reassuringly, these contracts are only slightly below the Pareto-efficient frontier (the difference between values with and without pay-to-play is small).

This observation is unimportant for method-of-moments estimation (we do not use individual observations to recover qualities).

…but implies interesting questions for future research:

- How to increase model flexibility to rationalize these contracts as efficient?
- Can these contracts really be Pareto inefficient (not all VCs are fully rational)?

Appendix: 76% of the 13.5% gap is 1X liquidation preference

At the value-maximizing contract – 14.7% VC equity, pay-to-play, 1X liquidation preference, etc. – VC receives 28.2% of total firm value.

- How to rationalize this 13.5% gap?

Consider start-up raising \$1m at a \$4m valuation (CP, 1X) that converts to a 15% equity.

- $r^f = 2\%, T = 5$, no future capital needs.
- ⇨ Black-Scholes value of convertible preferred is \$1m, or 25% of equity.
- Relative to 14.7%, conv. preferred is worth 25-14.7=10.3% of firm value.
- In other words, conv. preferred explains 76% of the 13.5% gap between common equity and the value-maximizing contract.
  - Remaining gap is due to other always present terms: veto, antidilution, etc.

- Gap between common equity and convertible preferred in the average observed contract is much smaller: 7.2%.

Appendix: some robustness tables

Subsample/Modification		(1) IT		(2) Healthcare		(3) Match Shock	
Parameter		**Value**	**St.Err.**	**Value**	**St.Err.**	**Value**	**St.Err.**
ρ	Substitutability of qualities	-1.155***	0.094	-1.597***	0.175	-1.506***	0.156
β_1	Total value, share of VC equity	0.701**	0.290	0.738***	0.233	0.507	0.317
β_2	Total value, share of VC equity squared	-2.452***	0.204	-2.113***	0.376	-2.215***	0.297
β_3	Total value, participation	-0.170*	0.099	-0.147***	0.022	-0.143***	0.006
β_4	Total value, pay-to-play	0.029	0.131	0.022	0.050	0.019**	0.009
β_5	Total value, VC board seat	-0.026***	0.009	-0.025***	0.008	-0.021***	0.004
β_6	Total value, part. x pay-to-play	0.016	0.097	0.014	0.042	0.015	0.213
β_7	Total value, part. x VC board seat	0.033	0.099	0.034*	0.020	0.032	0.042
β_8	Total value, pay-to-play x VC board seat	0.016	0.035	0.018	0.089	0.019	0.016
γ_1	Split of value, intercept	-0.206***	0.070	-0.174***	0.054	-0.271***	0.058
γ_2	Split of value, participation	-0.177*	0.096	-0.179***	0.031	-0.176***	0.024
γ_3	Split of value, pay-to-play	0.058	0.172	0.058*	0.034	0.062***	0.018
γ_4	Split of value, VC board seat	-0.041***	0.006	-0.043***	0.005	-0.044***	0.014
γ_5	Split of value, part. x pay-to-play,	0.018	0.121	0.016	0.079	0.016	0.136
γ_6	Split of value, part. x VC board seat	0.028	0.096	0.030	0.031	0.031	0.024
γ_7	Split of value, pay-to-play x VC b'd seat	0.012	0.025	0.012	0.074	0.013	0.071
σ	St.Dev. of match-specific shock	--------		--------		0.323*	0.171