

1. Introducing Signaling Game in Investment

1.1 Why do we use signaling model?

The signaling game is aimed to evaluate the problem of **asymmetrical information** in investment. The existing asymmetry of information in market would not give investors clear pictures about the potential of their investments (Vrankić & Skoko, 2021). To support their investors' confidence and secure the funds they need; one possible method of firms could be using **equity offer as signals** to convince investors about their profitability.

1.2 What do we expect from signaling game?

According to Leland and Pyle (1977), firms with higher qualities and potentials would be more willing to **retain their equity** as much as possible. This feature was revealed in the model proposed in Gibbons (1992) to assess the lowest acceptable equity stake of investors and firms. It assumes **the project quality as public knowledge** while the **profitability of different firms as private information**. This project will revise this model and corroborate its properties by using the computation and visualization tool of Clojure.

2. Revising the Signaling Game Model

As is noted in Gibbons (1992), suppose there were two types of firms with different profitability π : H and L. To raise fund I for a project with potential revenue R, firms could incentivize their investors by offering equity stake $0 \leq s \leq 1$ as a signal for their profitability. It could be assumed that the revenue R would be **more attractive than** the profit reaping from using this fund I to invest in other fields, which could be depicted as $R \geq I(1+r)$, where r is the rate of return of firm by investing in its alternative projects.

For firms, the highest acceptable equity stake for firm to undertake the project should **secure a positive profit** after equity offering.

$$(1-s)(\pi+R) \geq \pi$$

$$s \leq \frac{R}{(\pi+R)} = \text{benchmark}_{\text{firm}}(\pi)$$

Correspondingly, for investors, the minimum value of their acceptable equity stake to accept the offer should ensure their income exceeding the profit from alternative investments. In light of the information asymmetry, the investor could only evaluate investees' quality **by their expectation about the probability q that firm has low profitability L**, which would constitute their investment confidence. Hence, according to Gibbons (as cited in Vrankić & Skoko, 2021), for investors, their lowest acceptable equity stake could be denoted as

$$s(qL + (1-q)H + R) \geq I(1+r)$$

$$s \geq \frac{I(1+r)}{(qL + (1-q)H + R)} = \text{benchmark}_{\text{investor}}(q)$$

3. Visualizing Game Model with Clojure

Given that both investors and investees would pursue the highest profit with lower cost, the investors' lowest acceptable equity stake would determine the equilibrium state of this signaling game.

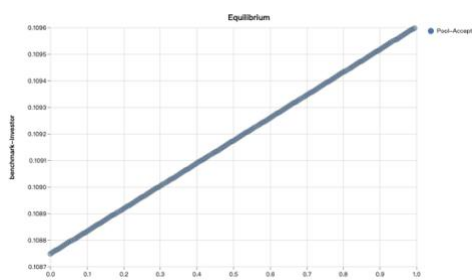


Fig.1

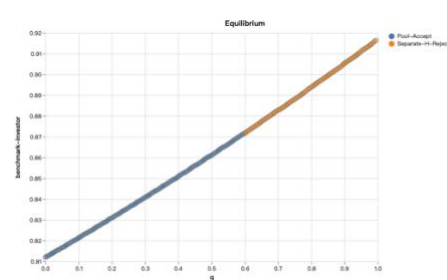


Fig.2

As is manifested in Fig. 1 and Fig. 2, it is indicated from the model of Gibbons (1992) that the equilibrium equity stake would **have a positive correlation with investors' expectation** about the probability of investing in a low profitability firm. In other words, the higher equity stake in investing game **would be negatively correlated with the investment confidence**

In Fig.2 where the equity benchmark of a high profitability firm is lower than the expected investor benchmark for a low-type firm: $\text{benchmark}_{\text{firm}}(H) < \text{benchmark}_{\text{investor}}(1)$, there would be possibility for high-type firms to **reject** to undertaking investment upon a higher equilibrium s and q (Vrankić & Skoko, 2021). This rejection would further support the negative correlation between equity stake and investment success.

References

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- Vrankić, I., & Skoko, P. (2021). The signaling game of a firm with unknown profitability and an investor. *Interdisciplinary Description of Complex Systems*, 19(3), 437-448. doi: <http://dx.doi.org/10.7906/indcs.19.3.7>
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4. Data Analysis and Discussion

4.1. Empirical Research Design

To corroborate the negative signaling effect of equity offer on investment confidence, we retrieved transaction detail of 231 venture capital investment in US over the past 10 years from Refinitiv Eikon. Given that the investor confidence would be hard to measure, we evaluated investment success with the number and dollar amount of investment the firm received to date. SWe included the offer size (*Investor_Equity_Total*) to avoid the scale problem of equity offering. Given that investors would have different estimation about the development situation of different industries (Vismara, 2016), the dummy variable *Industry_Sector* was incorporated to control this bias of investors' preference. To control the market fluctuation in different year, the time-series variable years was also included. According to the studies conducted by Vismara (2016), we controlled the firm's location advantage by invoking a dummy variable *Location* to indicate whether the firm is in New York. Furthermore, following the method of the studies conducted by Busenitz, Fiet, and Moesel (2005), we also incorporated variables to control the impact of firms' age (*Age*), and the duration of investment round (*Duration*).

4.2. Descriptive Statistics



4.3 Preliminary Analysis

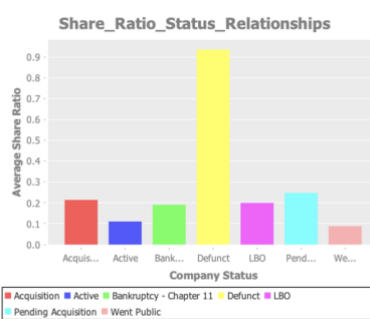


Fig. 1

Average Equity Ratio and Investment Amount		
Company_Status	Share_Ratio_avg	Invest_Amount_avg
Acquisition	0.214118334	3.25E+08
Active	0.110721516	3.82E+08
Bankruptcy - Chapter 11	0.19047619	1.36E+09
Defunct	0.934673031	3.80E+07
LBO	0.2	3000000
Pending Acquisition	0.247586419	1.44E+08
Went Public	0.088442637	1.62E+09

Table.1

4.4. Outcome of Regression

	Investment Amount (log)	Investment Number (log)
Round	0.6151***	0.3453***
Industry_Sector	-0.0191	0.0020
Investor_Equity_Total	0.8554***	0.04949***
Duration	0.0003**	3.65119E-05
Location	-0.1806	-0.0259
Age	-0.0053	0.0054***
years	-0.0155	-0.0749***
Share_Ratio	-1.8477***	-0.1377
R-square	0.741635561	0.732474618

Table.1

Machine Learning Outcome

Logistic Regression of Company Status				Poisson Regression of Investment Number			
colname	gain	importance-type	precision	colname	gain	importance-type	precision
years	0.9680506	gain	0.9984479	Round	1.8338207	gain	0.9999996
Location	0.8242959	gain	0.9984479	years	1.2537973	gain	0.9999996
Investor_Equity_Total	0.6391575	gain	0.9984479	Duration	1.1897981	gain	0.9999996
Duration	0.4510417	gain	0.9984479	Age	0.40436149	gain	0.9999996
Round	0.4489234	gain	0.9984479	Investor_Equity_Total	0.2978205	gain	0.9999996
Share_Ratio	0.4120775	gain	0.9984479	Share_Ratio	0.23702762	gain	0.9999996
Age	0.3213715	gain	0.9984479	Industry_Sector	0.11186664	gain	0.9999996
Industry_Sector	0.2787501	gain	0.9984479	Location	0.10310144	gain	0.9999996

Table.2

Apart from the investment amount and number, the Refinitiv Eikon also provided firms' current operating status, which would also illustrate the success of investments. When comparing firms' status with their investment share ratio, it would be manifested by Fig.1 that the firms maintaining an active status would normally propose a lower average equity offer ratio while the firms going bankruptcy or defunction would have a higher ratio. This property would also help support the signaling effect of the lower equity offering on investors' confidence about firms' quality.

We did OLS regression of investment number and dollar amount on equity offer. Following the study methods in Vismara (2016), we also used the machine learning function in Clojure to conduct logistic regression of company's status and Poisson regression of investment number on equity ratio as a robustness check. The results of the robustness test went align with the original OLS regression. When analyzing the regression statistics, it is found that the higher equity ratio would contribute to a negative variation in investment number and amount. Nevertheless, its contribution to explaining the variation in investment amount and number would be modest considering the lower coefficient, high p-value in t-test (Table. 1), and the lower importance value in the outcome of machine learning (Table. 2). Hence, in this statistical test, we might not find a sufficiently robust statistical support for the significant contribution of signaling effect to investment success.

5. Conclusion and Limitation

In conclusion, this project would help testify the signaling effect of equity offering in venture capital investment. It would support the argument that the lower equity offer would contribute to signaling the investor with a higher potential of firms and facilitate the investment success, while the significance of this effect might not be manifested in empirical data. Nevertheless, it is also noteworthy that the sample size and control variable amount in this project would be limited, which would undermine the persuasiveness of regression outcome. In addition, we did not further explore into link between investors' confidence and investment amount, whose robustness would still be uncertain. There needs to be further research with larger sample size and feasible measures of investors' confidence.