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Research on IPO Underpricing Decomposition: Evidence from China's Science and Technology Innovation Board

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Abstract: The study focuses on the phenomenon of initial public offering (IPO) underpricing in China's Science and Technology Innovation Board (STAR market). The study employs the stochastic frontier model to analyze IPO underpricing and decomposes it into two components: primary market underpricing and secondary market premium. Additionally, the research investigates the impact of research and development (R&D) investment on IPO underpricing. The empirical analysis is based on a sample of 480 companies listed on the STAR market between July 2019 and January 2023. The results reveal that IPO underpricing on the STAR market is substantial, with an average underpricing rate of 131.81%. The primary market underpricing component contributes 4.24% to the overall underpricing rate, while the secondary market premium accounts for the remaining 95.76%. Furthermore, the study explores various factors that influence the secondary market premium using multiple linear regression analysis. The findings indicate that variables such as issuance volume, underwriting fee, turnover rate, and R&D investment significantly impact the secondary market premium.

Keywords: IPO underpricing, SFA model, STAR market, secondary market premium

1. Introduction

The Science and Technology Innovation Board (STAR market) began trading in July 2019, marking a significant step in China's IPO landscape. Initial public offering (IPO) underpricing is the phenomenon that IPO stock issue price is significantly lower than the closing price of the first day, which broadly exists in global mature capital markets and emerging capital markets. There has been a long-held problem of IPO underpricing in China's A-share market. In the case of the STAR market, the average IPO underpricing rate for the 504 listed companies as of January 1, 2023, stood at a staggering 131.81%. Among them, Nanomicrotech's first-day closing price increase reached 1,273.98%, which was the highest of its kind. On the whole, IPO underpricing rate is more than 100%, far exceeding the average level of 10%-20% in mature capital markets [1], which reflects the high cost of financing for equity offerings by Chinese companies and the low maturity of the market.

This paper focuses on the STAR market as the subject of study, examining IPO underpricing within the context of listing system innovation. Firstly, the paper adopts the stochastic frontier model [2] to deconstruct IPO underpricing into two components: primary market underpricing and secondary market premium, thereby analyzing the primary drivers behind IPO underpricing.

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Secondly, building upon the findings from the first part, the paper investigates the influence of R&D investment—a theoretically significant factor—on IPO underpricing.

2. Methodology

Previous research has discovered a correlation between the measurement of IPO pricing efficiency and the measurement of production efficiency [3]. The stochastic frontier model is used to investigate the deviation [4] between the IPO price and the stock's intrinsic value, and then evaluate the IPO pricing efficiency in the primary market. The performance of the secondary market can be estimated by the stochastic frontier model of the cost function.

2.1. Modeling Process

In contrast to other sectors of the Chinese stock market, the STAR market does not impose a maximum limit on the price increase or decrease within five days after listing. This issuance rule just avoids the untrue IPO underpricing rate due to the existence of price limits, so the IPO underpricing rate can be directly expressed by the first-day excess return rate:

$$\mathrm{UR} = 1 + (\mathrm{CP} - \mathrm{OP})/\mathrm{OP} \tag{1}$$

where, CP denotes the closing price of the first day of stock issuance while OP represents the offering price. In order to make UR positive, add one to the original formula.

The author sets the intrinsic value of the company as the maximum frontier of the production function, and the offering price of the stock is empirically lower than its intrinsic value. This paper defines the stock pricing function as:

$$\mathrm{OP_i} = f(X_i, \alpha) \times \xi_i \times e^{\mu_i} \tag{2}$$

where, $\mathrm{OP_i}$ is the offering price of company i, X_i is the set of explanatory variables, and α is the set of parameters to be estimated. ξ_i represents the pricing efficiency level satisfying $0 < \xi_i \leq 1$. When $\xi_i = 1$, it means that the offering price of company i reaches the pricing frontier precisely, which means there is no IPO underpricing regarding company i. e^{μ_i} is a random shock, which means that the frontier of the pricing function is random.

Taking the logarithm on both sides of equation(2) to get equation(3):

$$\ln\mathrm{OP_i} = \alpha_0 + \sum_{i=1}^{n} \alpha_i x_i + v_i - \mu_i \,, \mu_i = \ln\xi_i \;\;,\;\; \varepsilon_i = v_i - \mu_i \tag{3}$$

where v_i is referred to as idiosyncratic error and μ_i represents the inefficiency term. Firstly, we assume that μ and v are i.i.d. and independent of each other, and they are independent of the explanatory variable X. Secondly, suppose the distribution of μ and v as equation(4) where μ obeys the normal distribution with expectation of μ and the tail is broken on the left side of the origin, so it is called "truncated-normal distribution".

$$\mu_i \sim N^+(\mu, \sigma_\mu^2) \,, v_i \sim N(0, \sigma_v^2) \tag{4}$$

It can be proved that the density function of ε_i is[3] :

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$$f(\varepsilon_i) = \frac{2}{\sigma}\varphi(\varepsilon_i/\sigma)\Phi(-\varepsilon_i\lambda/\sigma) \tag{5}$$

where, $\sigma = \sqrt{\sigma_\mu^2 + \sigma_v^2}$,$\lambda = \sigma_\mu/\sigma_v$,$\varphi(\cdot)$ denotes the density function of normal distribution and $\Phi(\cdot)$ denotes the cumulative distribution function of normal distribution.

Applying the log-likelihood function of company i, assuming that the sample is i.i.d., the sample likelihood function with a sample size of N can be expressed as :

$$\ln L = -N\ln\sigma - N\ln\Phi(-\mu/\sigma^2) - \frac{1}{2}\sum_{i=1}^{N}(\frac{\varepsilon_i + \mu}{\sigma})^2 + \sum_{i=1}^{N}\ln\Phi(\frac{\mu}{\sigma\lambda} - \frac{\varepsilon_i\lambda}{\sigma}) \tag{6}$$

The MLE estimation of the semi-normal model is obtained by maximizing equation(6).

2.2. Variables Design

Concerning variable selection and construction, the reasonable issue price of known new shares is related to the intrinsic value and development potential of the company, including company operation ability, debt paying ability, research and development ability, asset scale, etc. Therefore, four company characteristic variables are selected. At the same time, the primary market indexes and the secondary market indexes are selected as control variables. table 1 presents the explanatory variables used in the model with reference to previous literature [5].

Table 1: Variable symbols and definitions.

symbol	definition	unit
volume	new share issuance	10000 shares
fee	underwriting and sponsorship fee	100 million CNY
subscription	subscription ratio	%
turnover	turnover rate on the first day of listing	%
indPE	industry price-earnings ratio	/
roa	return on equity 1 year before IPO	%
asset	total asset 1 year before IPO	100 million CNY
rdinv	R&D investment 1 year before IPO	100 million CNY
liquid	liquidity ratio 1 year before IPO	%

2.3. Data Cleaning

504 companies listed on the Science and Technology Innovation Board between July 22, 2019, and January 1, 2023, were included in the study. Data was collected from the Wind financial terminal and company prospectuses. After removing entries with missing values, the dataset consisted of 480 companies.

3. Results and Analysis

3.1. Results of SFA Model

The stochastic frontier analysis of the constructed model is carried out by using the sfa method in Benchmarking package of RStudio. The variables are manually converted into logarithms to fit in the model. lnx6=ln(roa+200) is set because the minimum roa value is -195.9. In this paper, four explanatory variables related to company characteristics are selected, They are (1) roa; (2)asset; (3)rdinv; (4)liquid [6]. The higher the liquidity ratio, the stronger the asset realization ability of the company. Based on four explanatory variables and other control variables, we solves the sfa model to find the frontier side of the primary market pricing. The results of table 2 are obtained.

Table 2: SFA model redults.

	estimate	Pr(>|t|)	variable specification
(Intercept)	-240.3555	0.0000	
lnx1	-0.9018	0.0000	ln(volume)
lnx2	-0.0935	0.2390	ln(fee)
lnx3	0.9471	0.0000	ln(subscription)
lnx4	-0.4323	0.0000	ln(turnover)
lnx5	-0.0426	0.4780	ln(indpe)
lnx6	25.8393	0.0000	ln(roa + 200)
lnx7	0.0939	0.0030	ln(asset)
lnx8	0.1349	0.0000	ln(rdinv)
lnx9	0.0575	0.0590	ln(liquid)
λ	0.0508	0.9150	
σ^2	0.11263		
σ_v^2	0.1123423		
σ_u^2	0.0002903505		
log likelihood	-156.6188		

Table 3: Estimate efficiency for each company.

	te	teJ	teBC
Min.	0.9851	0.9850	0.9851
Max.	0.9880	0.9880	0.9880
Mean	0.9865	0.9865	0.9865

The estimator of λ is 0.0508, so idiosyncratic error v dominates the composite error term $\varepsilon = v - \mu$. The results demonstrate that μ is statistically significant at a 1% level, indicating that systematic underpricing in the primary market of the sample stocks evidently exists, yet this underpricing is not numerically large.

Calculation of technical efficiencies for each unit can be done by the method te.sfa as shown in table 3. Efficiencies estimated by minimizing the mean square error are represented as te and teBC. Efficiencies estimates using the conditional mean approach are represented as teJ. The average value of technical efficiency is 98.65 %, indicating that the issue price can reflect the intrinsic value at the average level of 98.65 %.

The UR is decomposed into two parts : primary market underpricing and secondary market premium as shown is formula (7).

$$UR = \frac{(VALUE - OP)}{OP} + \frac{(CP - VALUE)}{OP} + 1 \quad (7)$$

Where, VALUE represents the intrinsic value of the stock, which is calculated as the frontier value obtained by the SFA model.

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The efficiency of the first day closing price CP and intrinsic value VALUE isevaluated using formula (7) , and the average underpricing rate of the secondary market is 31.42 %. By measuring the contributions of the primary market and the secondary market to the IPO underpricing rate, results showsthat 95.76% of the IPO underpricing rate comes from the secondary market premium and 4.24% from the primary market underpricing.

3.2. Multiple Linear Regression Analysis for Premium in Secondary Market

The results of SFA show that 95.76% of IPO underpricing of STAR market are from the secondary market premium. Based on the findings mentioned, the subsequent part of this research will focus on investigating the factors that influence IPO underpricing from the perspective of secondary market. effSec is used to represent the pricing efficiency of the secondary market, which is calculated by $(\mathrm{CP}-\mathrm{VALUE})/\mathrm{OP}$. The variables selected in the SFA model can also explain the premium rate in the secondary market, which can be demonstrated by formula (8) :

$$\mathrm{effSec} = \theta_0 + \theta_1 \mathrm{volume} + \theta_2 \mathrm{fee} + \theta_3 \mathrm{subscription} + \theta_4 \mathrm{turnover} + \theta_5 \mathrm{indPE} + \theta_6 \mathrm{roa} + \theta_7 \mathrm{asset} + \theta_8 \mathrm{rdinv} + \theta_9 \mathrm{liquid} + \gamma \quad (8)$$

$$\mathrm{lneffSec} = \vartheta_0 + \vartheta_1 \mathrm{lnx1} + \vartheta_2 \mathrm{lnx2} + \vartheta_3 \mathrm{lnx3} + \vartheta_4 \mathrm{lnx4} + \vartheta_5 \mathrm{ilnx5} + \vartheta_6 \mathrm{lnx6} + \vartheta_7 \mathrm{lnx7} + \vartheta_8 \mathrm{lnx8} + \vartheta_9 \mathrm{lnx8} + \delta \quad (9)$$

The results of the Quantile-Quantile plot test show that the error is right-biased and the model does not conform to the linear regression relationship. All variables are logarithmicized as in formula (9). The Q-Q plot result is shown in figure 1, which shows that the linear relationship is basically satisfied.

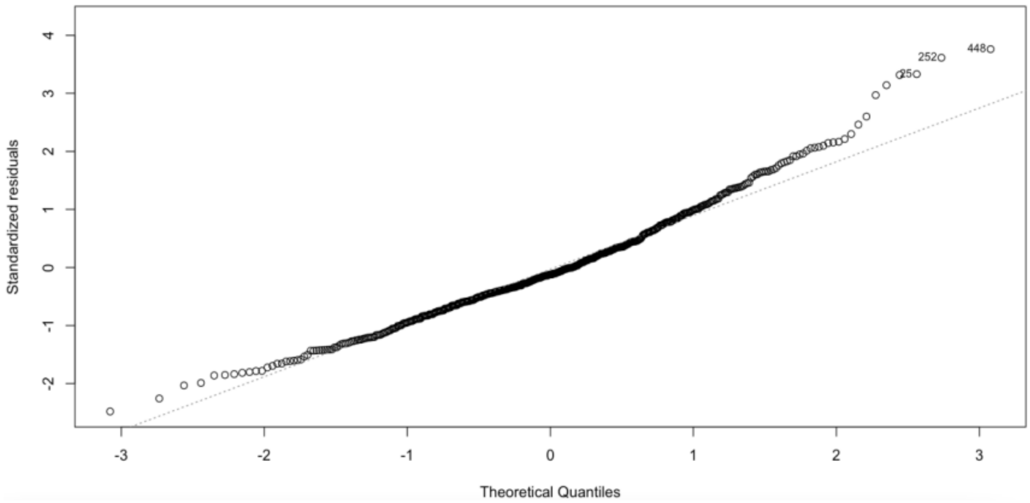

Figure 1: Normal Q-Q.

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Table 4: Results of multiple linear regression.

label	coefficients	Estimate	Std.Error	t-value	Pr(>|t|)
	Intercept	-52.2022	87.3476	-0.598	0.5503
volume	lnx1	0.1299	0.0360	3.605	0.0003***
subscription	lnx2	-0.1081	0.0943	-1.283	0.2000
fee	lnx3	-0.3176	0.0395	-9.040	0.0000***
turnover	lnx4	1.8881	0.1310	14.411	0.0000***
indPE	lnx5	0.1035	0.0568	1.821	0.0691
roa	lnx6	4.8411	9.3055	0.520	0.6031
asset	lnx7	-0.0278	0.0317	-0.877	0.3810
rdinv	lnx8	0.0794	0.0244	3.244	0.0012**
liquid	lnx9	-0.0059	0.0283	-0.210	-.8340
Multiple R-squared: 0.5225			Adjusted R-squared: 0.5133		
F-statistic: 57.13 on 9 and 470 DF, p-value: < 2.2e-16					

The regression results, presented in table 4, reveal that the adjusted R-squared value is 0.5133. This indicates that the set of variables used in the analysis can account for 51.33% of the variation observed in the secondary market premium. It shows that the fitting effect of the model in the empirical research is good. F test is then carried out. The results show that the p-value is less than 2.2×10^{-16}, which means the original hypothesis is rejected. In the sample set, volume, fee, turnover and rdinv were all statistically significant at the 1% level. Specifically, every 1% increase in volume increases the IPO secondary market premium rate by 0.13%, which means that the size of new shares issued has a negative impact on the IPO pricing efficiency. Underwriting fee is negatively correlated with IPO underpricing rate at the significance level of 1%. The reason may be that the underwriting fee is the commission paid by the issuing company to the underwriter. The higher the commission, the larger the scale and financing amount of the IPO company, the more investors, mainly institutional traders, participate in the inquiry, the more information they provide, and the closer the closing price of the stock on the first day after its issuance in the secondary market is to its intrinsic value. For every 1% increase in the turnover rate on the first day of trading, the IPO secondary market premium increases by 1.9%. Because the turnover rate reflects investor sentiment, a high turnover rate indicates that there is a large divergence between the long and short sides, and there are many uncertain factors, so the pricing efficiency is naturally low. The R&D input index has a significant positive impact on the premium of the secondary market. When R&D input increases by 1%, IPO underpricing rate will increase by 0.0794%. Due to the high-tech nature of most companies on the STAR market, the R&D input data disclosed in their financial statements or prospectus holds significant importance as a reference index for investors when making investment decisions. Increased investment in research and development is perceived by investors as an indicator of greater growth potential, leading to positive expectations. Consequently, R&D input is negatively associated with IPO secondary market pricing efficiency.

4. Conclusion

This paper takes the phenomenon of IPO underpricing in China's Science and Technology Innovation Board as the research object, and studies the composition and influencing factors of IPO underpricing. First, the IPO underpricing rate is decomposed based on intrinsic value of the firm. The pricing efficiency of the primary market is analyzed by the stochastic frontier model to obtain the underpricing rate of the primary market, and then the premium rate of the secondary market is derived. Results show 95.76% of IPO underpricing came from secondary market premium. Then

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this paper construct multiple regression model for secondary market premium rate and analyze the main influencing factors. In this paper, four important factors affecting the secondary market premium are obtained, which are (1) the number of new shares issued, (2) the underwriting fee, (3) first day turnover rate, and (4) the R&D investment. This paper analyzes the regression results from the perspective of investment environment and investor sentiment. Future research can focus on investigating investor behavior in the secondary market of the Chinese stock market.

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