ARE IPOS UNDERPRICED? EMPIRICAL EVIDENCE FROM SAUDI ARABIA

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Abstract

Underpricing of initial public offerings (IPOs) is a common phenomenon that widely studied over many periods and a broad range of countries. This paper examines the extent of underpricing of IPOs in Saudi Arabia by using the data of 44 IPOs listed on the Saudi Stock Exchange from January 2010 till October 2021. We found that IPOs on average were underpriced by 49.4%. The stepwise multiple regression results showed that the number of individual subscribers, the level of over-subscription by individuals, and the firm size have a significant relationship with IPO returns. The outcomes are hence consistent with the prediction of *ex-ante* uncertainty and the winners' curse hypothesis.

Keywords: Initial Public Offerings (IPOs), Underpricing, Offer Risk, Investor Sentiment, Listing Fee, Market Volatility

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1. INTRODUCTION

Underpricing of initial public offerings (IPOs) is a common phenomenon that documented over many periods and in a broad range of countries (Loughran et al., 1994). IPO research has allowed for the study of numerous market characteristics as well as a deeper understanding of market and investor behavior. IPO underpricing is a situation where the IPO offer price is lower than the closing share price on the first day of trading which is called initial return. From an issuer's perspective, it describes the additional amount of money left on the table that could have been raised by the issuer if the offer price had been set at an appropriate level. Plenty of research endeavors to interpret the causes and factors that triggered such phenomena where no consensus reached. This phenomenon has not been fully explained and is sometimes regarded as one of the puzzles in finance (Loughran & Ritter, 1995). The degree of underpricing level is varying where it recorded a very high of 270.1% in the United Arab Emirates whereas a low level of 3.3% was documented in Russia (Loughran et al., 1994).

Research outcomes offer various theories suggesting that underpricing is inevitable. The majority of outcomes are divided into main two explanations. First, the assumption of mispricing is inherent in IPOs; the issuer could merely predict the fair value of the firm, not wanting to offer too low and lose revenue or too high and have IPO failure. Second, the assumption that underpricing is a deliberate act by either the underwriter or the issuer compensating investors for information asymmetry among the parties involved in the IPO process regarding the fair value of the firm which caused *ex-ante* uncertainty in the primary market (Chen et al., 2004; Loughran et al., 1994; Yu & Tse, 2006). Some theories attributed underpricing phenomenon to investors' sentiment and behavior. The notion of sentiment described the presence of irrational investors who exhibit over-optimism and undue interest in IPOs prospects (Ljungqvist et al., 2003). Such irrational exuberance leads rational investors to pay a price above their fundamental value as they can sell their stock to sentiment investors at any time.

In this paper, the Saudi stock market is selected to conduct our analysis concerning IPO underpricing. Saudi Arabia is an emerging country and a member of the Group of Twenty (G20). The stock market officially started in Saudi Arabia in 1984. The Saudi Arabian stock exchange, which is managed by Tadawul, ranked as the 9th largest stock market among the 67 members of the World Federation of Exchanges and is the dominant market in the Gulf Cooperation Council (GCC), based on the value of shares traded ($2.62 trillion) as of August 2021. It is the 3rd largest stock market amongst its emerging market peers. Saudi stock market went through several structural reforms that are related to the implementation of global corporate governance, more disclosure, and allowing for foreign investors' participation.

Therefore, the first objective of this paper is to analyze the extent of underpricing of IPOs in Saudi Arabia. Thus, we use a sample of all available IPOs from January 2010 till October 2021, having 44 IPOs (total of 73 IPOs) excluding real estate investment trusts (REITs), firms under formation, and 3 firms listed while they have negative earnings per share (EPS) during the offering period. Additionally, we expect to identify the reasons for the underpricing of stocks and the association between the initial returns and the selected independent variables. In our study, we attempt to differentiate between the effects of investor sentiment and *ex-ante* uncertainty to attain which factor is more capable of explaining the initial returns.

The remainder of this paper is organized as follows. Section 2 presents a brief literature review and demonstrates the main hypotheses. Section 3 includes the data and methodology. Section 4 presents a discussion of empirical findings and Section 5 concludes the study.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Plenty of theoretical models have been developed in previous research to explain IPO underpricing. The review of this study mainly focuses on selected theories. The most important factor contributing to IPO underpricing is the *ex-ante* uncertainty that exists within the issuing firm. A positive association is well documented between underpricing and *ex-ante* uncertainty (Chen et al., 2004; Loughran et al., 1994; Yu & Tse, 2006). Over the last five decades, many attempts have been conducted to explore the determinants that could impact the IPOs initial returns. Initial returns are the difference between the offer price and the closing price of the first trading day on the exchange. If the first-day day trading closing price is greater than the offer price, then the offering is regarded to be underpriced. Conversely, if the closing price is lower than the offer price, the IPO is regarded to be overpriced.

One of the most popular theories is based on asymmetric information. This theory assumes that there are two parties of investors in the investment community; the first party includes the investors who could access the information that is valuable for the investment decision-taking whereas the investors who could not access information are the second party. Rock (1986) developed the "winners curse hypothesis" that is based on the information asymmetry among investors. He identified uninformed investors as the losers who could not distinguish which IPOs are profitable and thus would bid for the high volume of overpriced shares and they receive all their bids. However, their bid will be scaled down when the offer is underpriced. However, informed investors who are dealing with the most underpriced IPOs.

Empirical outcomes show that the prices, on average, of IPOs, jumped on the first day of listing, leaving a substantial amount of money on the table in both advanced and emerging markets. However, researchers have documented that higher degree of underpricing in emerging markets in comparison with developed markets (Loughran et al., 1994). Loughran et al. (1994) published an updated list on March 22, 2021, for some of the 54 countries as shown in Table 1.

Table 1. Equally weighted average initial returns for 54 countries (Part 1)

Country	*Source*	*Sample size*	*Period*	*Ave. initial return*
Argentina	Eijgenhuijsen & van der Valk; Dealogic	30	1991–2018	5.7%
Australia	Lee, Taylor, & Walter; Woo; Pham; Dealic	2,069	1976–2018	19.8%
Austria	Aussenegg; Dealogic	106	1971–2018	6.2%
Belgium	Rogiers, Manigart, & Ooghe; Manigart DuMortier; Dealogic	154	1984–2017	11.0%
Brazil	Aggarwal, Leal, & Hernandez; Saito; Ushisima; Dealogic	310	1979–2019	29.6%
Bulgaria	Nikolov	9	2004–2007	36.5%
Canada	Jog & Riding; Jog & Srivastava; Kryzanowski, Lazrak, & Rakita; Ritter	758	1971–2017	6.4%
Chile	Aggarwal, Leal, & Hernandez; Celis & Maturana; Dealogic	88	1982–2019	6.8%
China	Chen, Choi, & Jiang; Jia, Xie, Zhang, & Ritter; Qian; Jin; Dealogic	4,177	1990–2020	170.2%
Cyprus	Gounopoulos, Nounis, and Stylianides; Chandriotis	73	1997–2012	20.3%
Denmark	Jakobsen & Sorensen; Ritter	173	1984–2017	7.4%
Egypt	Omran; Hearn	74	1990–2017	9.4%
Finland	Keloharju; Dealogic	209	1971–2018	14.2%
France	Husson & Jacquillat; Leleux & Muzyka; Paliard & Belletante; Derrien & Womack; Chahine; Ritter; Vismara; Dealogic	834	1983–2017	9.7%
Germany	Ljungqvist; Rocholl; Vismara; Dealogic	840	1978–2020	21.8%
Greece	Nounis, Kazantzis, & Thomas; Thomadakis, Gounopoulos, & Nounis	373	1976–2013	50.8%
Hong Kong	McGuinness; Zhao & Wu; Ljungqvist & Yu; Fung, Gul, and Radhakrishnan; Dealogic	2,042	1980–2017	44.5%
India	Marisetty & Subrahmanyam; Dealogic; Seth using Chittorgarh.com	3,202	1990–2020	84.0%
Indonesia	Suherman; Dealogic	697	1990–2020	56.0%
Iran	Bagherzadeh	279	1991–2004	22.4%
Ireland	Dealogic	38	1991–2013	21.6%
Israel	Kandel, Sarig, & Wohl; Amihud & Hauser; Ritter	348	1990–2006	13.8%

Table 1. Equally weighted average initial returns for 54 countries (Part 2)

Country	*Source*	*Sample size*	*Period*	*Ave. initial return*
Italy	Arosio, Giudici, & Paleari; Cassia, Paleari & Redondi; Vismara; Dealogic	413	1985–2018	13.1%
Japan	Fukuda; Dawson & Hiraki; Hebner & Hiraki; Pettway & Kaneko; Hamao, Packer, & Ritter; Kaneko & Pettway; Kaneko; Dealogic	3,849	1970–2020	48.8%
Jordan	Al-Ali & Braik	53	1999–2008	149.0%
Korea	Dhatt, Kim, & Lim; Ihm; Choi & Heo; Mosharian & Ng; Cho; Joh; Dealogic; Lee	2,007	1980–2018	55.2%
Malaysia	Isa; Isa & Yong; Yong; Ma; Dealogic	571	1980–2019	50.3%
Mauritius	Bundoo	40	1989–2005	15.2%
Mexico	Aggarwal, Leal, & Hernandez; Eijgenhuijsen & van der Valk; Villarreal	149	1987–2017	9.9%
Morocco	Alami Talbi; Hearn	33	2000–2011	33.3%
Netherlands	Wessels; Eijgenhuijsen & Buijs; Jenkinson, Ljungqvist, & Wilhelm; Ritter	212	1983–2017	13.3%
New Zealand	Vos & Cheung; Camp & Munro; Alqahtani; Dealogic	269	1979–2018	15.9%
Nigeria	Ikoku; Achua; Dealogic	125	1989–2017	12.8%
Norway	Emilsen, Pedersen, & Saettem; Liden; Dealogic; Fjesme	266	1984–2018	6.7%
Pakistan	Mumtaz	80	2000–2013	22.1%
Philippines	Sullivan & Unite; Dealogic	173	1987–2018	17.3%
Poland	Jelic & Briston; Woloszyn; Sieradzki	350	1991–2019	11.7%
Portugal	Almeida & Duque; Dealogic	33	1992–2017	11.5%
Russia	Dealogic	64	1999–2013	3.3%
Saudi Arabia	Al-Anazi, Forster, & Liu; Alqahtani	80	2003–2011	239.8%
Singapore	Lee, Taylor, & Walter; Dawson; Dealogic	687	1973–2017	25.8%
South Africa	Page & Reyneke; Ali, Subrahmanyam, & Gleason; Dealogic	342	1980–2018	17.2%
Spain	Ansotegui & Fabregat; Alvarez Otera; Dealogic	199	1986–2018	9.2%
Sri Lanka	Samarakoon; Dealogic	134	1987–2018	28.9%
Sweden	Rydqvist; Schuster; de Ridder	405	1980–2015	25.9%
Switzerland	Kunz, Drobetz, Kammermann & Walchli; Dealogic	164	1983–2018	25.2%
Taiwan	Chen; Chiang	1,915	1980–2019	37.2%
Thailand	Wethyavivorn & Koo-Smith; Lonkani & Tirapat; Ekkayokkaya & Pengniti; Vithessonthi; Dealogic	697	1987–2018	40.0%
Tunisia	Hearn; Dealogic	38	2001–2014	21.7%
Turkey	Kiymaz; Durukan; Ince; Kucukkocaoglu; Elma; Dealogic	404	1990–2014	9.6%
United Arab Emirates	Alanzi & Al-Zoubi	24	2003–2010	270.1%
United Kingdom	Dimson; Vismara; Levis; Vismara; Doukas & Hoque; Khurshed	5,309	1959–2020	15.7%
United States	Ibbotson, Sindelar, & Ritter; Ritter	13,409	1960–2020	17.2%
Vietnam	Tran, Le, & Hoang; Nguyen, Trinh, & Ninh	167	2005–2017	33.3%

Source: Loughran et al. (1994).

It is important to examine in the broader framework the theoretical contributory factors to IPO underpricing. In this study, the choice of independent variables was based on the previous research. Higher underpricing was found by Signori (2018) in zero-revenue European firms' IPOs and experience more volatile aftermarket trading than the IPOs of the firms who have a profit history before issuing IPOs. Also, this study noted that zero-revenue firms' IPOs have high levels of information asymmetry and ex-ante uncertainty that would increase the cost of raising capital.

Age is a widely used proxy for *ex-ante* uncertainty which implies the operating history of a firm before the IPO issue as suggested by Ritter (1991). As existing and mature firms have more publicly available information in comparison with younger firms, they are anticipated to have lower *ex-ante* uncertainty (Chen et al., 2004; Kirkulak & Davis, 2005; Loughran et al., 1994). Therefore, a negative association is expected between age and initial returns. Age is calculated as the difference between the foundation date and the listing date of the firm.

H1: The age of the firm (AGE) is negatively related to initial returns (IR).

Loughran and Ritter (2002) argued that the principal-agent problem arises from a conflict of interest between the issuers and the underwriters, where an agent (underwriter) will not always act in the best interests of the issue (principal). They suggest that the underwriting service fees should be a percentage of the IPO proceeds to avoid the agency problem. Researchers argue that IPO underpricing is a form of indirect compensation to underwriters. Baron (1982) suggested that marketing costs incurred by investment banks for roadshows would be reduced through underpricing as an incentive signal. Also, Benveniste and Spindt (1989) mentioned that underwriters reward informed investors for truthfully revealing their private information by allocating issued stocks at a discount. The listing fee is a percentage of gross proceeds from the IPO being analyzed to see its effect on underpricing. Therefore, consistent with the size effect, we hypothesized a negative relationship between the listing fee and initial return.

H2: The listing fee (FEE) is negatively related to initial returns (IR).

In reality, the price setting for IPOs represents a complicated process among the firm going public, the underwriter, and the investors. It is well known in the IPO literature (Benveniste & Spindt, 1989) that underwriters do not fully incorporate all private information into the offer price. In other words, underwriters only partially adjust the final offer price and thus leave some money on the table for its regular clients. The rationale is that underwriters have to rely on underpricing to induce investors to truthfully reveal their private information about an IPO. Their regular investors are forced to truthfully reveal their information for fear of various penalty schemes such as exclusion from future

lucrative IPOs. For instance, Lee et al. (1999) find evidence that informed investors request more, and preferentially receive more, allocations of shares.

IPO size represents the magnitude of the offering which is another proxy of the *ex-ante* uncertainty. Abdul Rahim and Yong (2010) indicated that a smaller IPO indicates some investors would not get what they demand, which results in greater pressure on the share price on the first day of trading and vice versa for large issues. Based on previous studies, higher underpricing is associated with smaller IPO and vice versa (Alanazi & Al-Zoubi, 2015; Chi & Padgett, 2005; Yu & Tse, 2006). A similar line of argument underlies the assumption of Beatty and Ritter (1986) that smaller IPOs suffer from higher underpricing due to their inherent riskiness.

It is worth mentioning that firm size has a similar premise to IPO size. Large-size firms, in general, are usually well-known and have more available information which results in less *ex-ante* uncertainty regarding the firms' future existence. In this study, IPO size was measured by multiplying the IPO offer price by the number of shares issued. This variable is used, for instance by McGuinness (1992), Clarkson and Merkley (1994), and Beatty and Ritter (1986), in literature as a proxy measure of IPO ex-ante uncertainty. Therefore, we hypothesized a negative relationship between firm size and initial return.

H3: The size of the firm (SIZE) is negatively related to initial returns (IR).

The *ex-ante* uncertainty could be simulated by the time lag in the days between the IPO announcement date and the first trading date. Chen, et al. (2004) and Yu and Tse (2006) indicated that a longer time lag contributed to IPO underpricing and high ex-ante uncertainty where the underwriter is uncertain about the potential demand for the offered shares which leads to an increase in the period in which the investors can place orders. However, Komenkul and Siriwattanakul (2016) found that the time lag proxy is not related to the initial returns in the Thailand stock market. Thus, a positive association is expected with initial returns.

H4: The time lag (LAG) is positively related to initial returns (IR).

Interestingly, some research focuses on behavioral finance and bounded rationality to explain the initial returns that are based on the investor sentiment theory (Boulton et al., 2011; Ritter & Welch, 2002; Song et al., 2014). Ritter and Welch (2002) suggest that over-enthusiasm among retail investors may interpret the pattern of high initial returns. This argument is supported by Ljungqvist and Wilhelm (2004) who conclude that IPO researchers should study behavioral approaches to explain the underpricing phenomenon. When the investors assume the overall market is trending up, the investors may be overly optimistic and the demand for the IPO stocks would increase resulting in higher initial returns. Conversely, when investors assume that the overall market is trending down, the initial returns would be little or negative in some cases. Empirically, researchers used market returns before the first day of listing as a proxy for investor sentiment (Boulton et al., 2011; Kiymaz, 2000; Mumtaz et al., 2016; Khin et al., 2017). Many researchers suggest that IPO underpricing could be attributed to bull stock markets and that initial returns are at least partly predictable based on market returns as mentioned by Loughran and Ritter (2002) and Derrien (2005). Investor sentiment measures the overall market index movement one month before the offering day. We hypothesize that investor sentiment and IPO initial returns are positively related in line with Boulton et al. (2011), Mumtaz et al. (2016), Samarakoon (2010), Khin et al. (2017).

H5: The investor sentiment (SENT) is positively related to initial returns (IR).

The volatility of market return is used as a proxy for market risk and uncertainty, supporting the risk-return trade-off theory. High market volatility prior to listing reflects substantial uncertainty in the market returns, which may cause underpricing. The market volatility is calculated as the standard deviation of daily market returns over the first 30 trading days prior to listing day. It is expected to have a positive relationship between these two variables is supported by previous studies (Al-Hassan et al., 2010; Butler et al., 2014; Deng & Zhou, 2015; Mumtaz et al., 2016; Khin et al., 2017).

H6: The market volatility (MV) is positively related to initial returns (IR).

The risk-return trade-off theory states that firms with higher offer risk are expected to have a higher return. In the literature (Bradley & Jordan, 2002; Badru & Ahmad-Zaluki, 2018; Abdul Rahim & Yong, 2010), a commonly used proxy measure for the IPO risk is the reciprocal of the offer price. Previous studies found that IPO risk is positively associated with underpricing (Badru & Zaluki, 2018; Mayes & Alqahtani, 2015; Khin et al., 2017). In contrast, Abdul Rahim and Yong (2010) found a significant negative relationship between offer risk and initial returns. In line with the theory, a positive association between offer risk and initial returns is expected.

H7: The offer risk (RISK) is positively related to initial returns (IR).

Previous empirical studies indicate that there is a positive relationship between the demand sides as measured by oversubscription (Low & Yong, 2011; Rock, 1986; Abdul Rahim & Yong, 2010; Bubna & Prabhala, 2007; Chowdhry & Sherman, 1996). We add several individual subscribers to study the effect of retail investor behavior and it is another measure of demand. We expect a positive association between initial return and both demand indices which are oversubscription rate and the number of individual subscribers.

H8: The level of individual oversubscription (LOS) is positively related to initial returns (IR).

H9: The number of individual subscribers (NIS) is positively related to initial returns (IR).

The P/E multiplier is used as a new proxy that helps investors gauge the valuation of the market compared to the company. The P/E multiplier is measured by dividing the P/E of IPO firms by the P/E of the market index at the time of offering to study the relative valuation effect in initial return. We expect a negative association between the initial return and the P/E multiplier.

H10: The P/E multiplier (PEM) is negatively related to initial returns (IR).

3. DATA AND METHODOLOGY

In this study, we analyze all IPOs from January 2010 to October 2021 in the Saudi market. There were 44 offerings excluding REITs, under-formation firms, and 3 firms having negative EPS during the offering period. Al-Hassan et al. (2010) indicated that some GCC countries (particularly Saudi Arabia, UAE, and Qatar) have implicit or explicit policies regarding public firms that are being privatized and newly licensed firms in regulated sectors. Offering prices of these firms are related to the nominal value of the shares (SAR 10 per share) and not to their economic value, as a means to distribute wealth among the population at large. Other researchers demonstrated these offerings as solely capital rising. Since all under-formation firms fall within this category, we decided to eliminate them from our analysis.

It is worth mentioning that since the Saudi market inception, there was no fluctuation in price limit on the first day of the new listing whereas plus or minus 10% daily limit aftermarket trading. On May 12, 2013, the Capital Market Authority (CMA), the regulatory body of the stock market, imposed a plus or minus limit for the first day of new listing like regular trading days. This will delay the arrival of the stock price to a fair level if we assume there is underpricing. Recently, on November 8, 2020, Tadawul (the exchange) raised the limit to plus or minus 30% for the first 3 trading days of the new listing. Thus, our approach was to follow stock price movement daily as it hits the price limit and circuit breakers are initiated. Till the price stopped hitting the upper limit, it would be considered as the closing price of the first day of trading where it reached its fair level. All data used in this paper, including market data and prices, was sourced from the Saudi Stock Exchange (Tadawul) database (www.tadawul.com.sa). The IPO documentation and IPO prospectus were obtained from the CMA official website (www.cma.org.sa).

Our approach is to study the underpricing phenomena of IPOs in Saudi Arabia. We use the initial return that is computed as the percentage change between the first day's closing price of the stock and its issuing price:

$$IR = \frac{First\ day's\ closing\ price - Issuing\ price}{Issuing\ price} \quad (1)$$

We do not adjust for market returns in reporting first-day returns throughout the article. This is because market movements are minor in comparison (an average of 0.03% per day) and thus have little impact on the conclusions.

Also, the IPO size variable is eliminated from our study due to the high correlation with the firm size (the correlation is 97.6%). The inclusion of this variable would lead to multicollinearity and hence a poorly determined coefficient.

Table 2. The variables used and their expected signs

Variable	*Symbol*	*Definition*	*Type*	*Influence*
Age (years)	*AGE*	The difference between the foundation date of the company and the date of the IPO	Continuous	-
Listing lag (days)	*LAG*	The gap between the IPO listed date and the first trading date	Continuous	+
P/E multiplier	*PEM*	P/E of IPO firm divided by P/E of a market index (TASI)	Continuous	-
Level of over-subscription by individual (%)	*LOS*	The level of IPO subscription on the day of a public offer	Continuous	+
Number of individual subscribers (000')	*NIS*	Number of individual subscribers in thousands	Continuous	+
Firm size (SAR MM)	*SIZE*	Number of shares being offered to the public * issue price	Continuous	-
Offer risk (%)	*RISK*	The reciprocal of the nominal offering price (1/IPO offer price)	Continuous	+
Investor sentiment (%)	*SENT*	The % change of TASI last month before the IPO issue.	Continuous	+
Market volatility (%) (30 days)	*MV*	The standard deviation of the daily TASI for the last 30 trading days prior to the IPO	Continuous	+
Listing fee (%)	*FEE*	The percentage of total proceeds	Continuous	-

To determine which factors, influence underpricing in the Saudi Arabian market, we use the following equation by ordinary least squares (OLS) regression:

$$IR_i = \beta_0 + \beta_1 LOG(AGE)_i + \beta_2 LAG_i + \beta_3 LOS_i + \beta_4 NIS_i + \beta_5 SIZE_i + \beta_6 PEM_i + \beta_7 RISK_i + \beta_8 FEE_i + \beta_9 SENT_i + \beta_{10} MV_i + \varepsilon_i \quad (2)$$

4. RESULTS AND DISCUSSION

There is strong evidence of IPO underpricing as indicated in Table 3 where the initial return is 49.4%. There is a substantial reduction in the discount in comparison with Mayes and Alqahtani's (2015) outcome of 266.7% that covered the period from January 2004 to September 2010 (72 IPOs). It can be seen that the level of underpricing (money left available) has declined in Saudi Arabia over time and during different market conditions. Another explanation is that our methodology is different in terms of IPO selection. Our approach is to include the firms that pass through all IPO requirements such as valuation, book-building, listing lag, P/E multiplier, level of over-subscription by individual, number of individual subscribers, firm size, investor sentiment, market volatility, and listing fee. The mean of over-subscription is six times the size of the issue and the highest is 33.85 times. Under-subscription is rare and the greatest shortfall was 60% of the issue size. The mean listing lag was 33 days. The average number of individual subscribers was 1.1 million and the highest is 5.1 million during Aramco's IPO which was the largest in the history of the exchange. To provide general information, Table 3 shows some details based on descriptive statistics.

Table 3. Descriptive statistics

Measures	*IR*	*SIZE*	*NIS*	*SENT*	*PEM*	*AGE*	*FEE*	*LOS*	*MV*	*LAG*	*RISK*
Mean	49.4%	151,582	1,050	-1%	0.85	23	4.2%	680.7%	0.9%	33	3.1%
Median	28.8%	1,800	776	1%	0.84	18	3.9%	330.0%	0.7%	28	2.2%
SD	65.4%	964,003	1,076	6%	0.28	15	1.9%	772.7%	0.5%	16	2.2%
Minimum	-4.4%	720	8	-24%	0.25	4	0.1%	60.0%	0.3%	12	0.7%
Maximum	351.9%	6,400,000	5,056	13%	1.72	61	9.0%	3385.4%	2.9%	78	10.0%

This finding is consistent with several research conducted worldwide. For instance, Rock (1986) indicated that firms go public and sell stocks in the market at a discount to compensate new investors for information asymmetry and the *ex-ante* uncertainty about the firm's current and future performance.

Mayes and Alqahtani (2015) argue about the Saudi market structural dimension that all the 72 IPOs were underwritten by 21 institutions which implies that issuers have limited choices when it comes to hiring an underwriter in the Saudi market. This in turn gives underwriters a better negotiating power over issuers to accept a greater discount on the offerings to reduce marketing effort and mitigate the risk of shares not being taken up which can harm their reputation (Baron, 1982; Holmes et al., 2003; Ritter, 2011). Mayes and Alqahtani (2015) mentioned that another possible explanation for the high level of IRs in the Saudi Arabian market is due to limited alternative investment channels available for investors, such as debt and derivatives markets. Therefore, the equity market, which only consists of 152 firms at that time, is the only available investment option which places great pressure on it.

Initial return distribution shows positive skewness and high frequency between -4% and 40% as appeared in Figure 1.

Figure 1. Histogram for initial return (IR) distribution

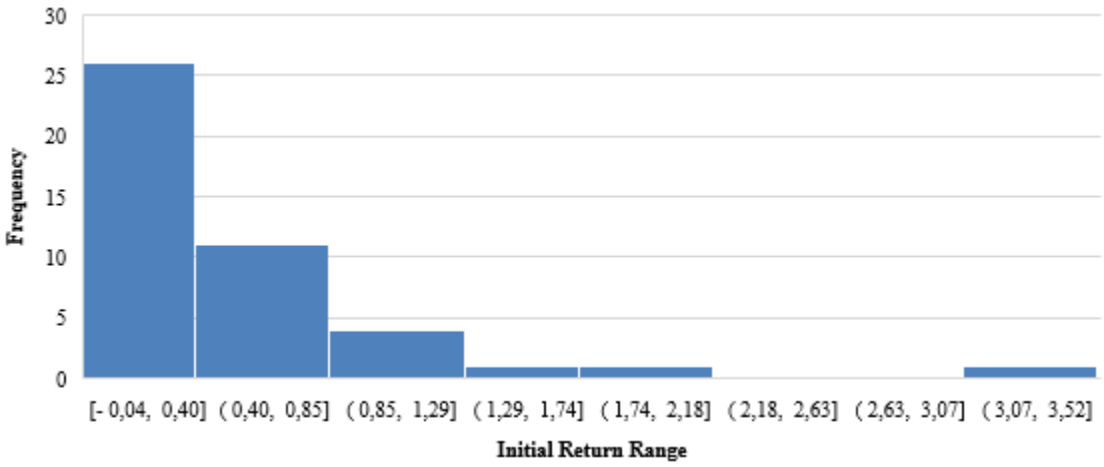

Table 4. Sample analysis per sector

Sector	*Number of IPOs*	*Firms size (SAR MM)*	*Aggregate proceeds (SAR MM)*	*Average IR*	*Average over-subscription (individual)*	*No. of individual subscribers (000')*
Agriculture and food industries	2	5,805	1,742	15.25%	2.30	1,683
Bank	2	91,450	22,935	41.25%	24.85	1,512
Building and construction	4	8,099	2,430	34.53%	3.40	3,975
Cement	3	5,392	2,696	133.17%	3.10	9,747
Commercial and professional services	1	2,588	776	20.87%	2.30	31
Consumer services	3	4,701	1,412	5.88%	3.37	141
Energy	1	6,400,000	96,000	15.00%	1.50	5,056
Food and staples retailing	2	12,313	2,597	43.92%	12.80	1,020
Health care equipment and services	5	28,495	5,926	120.14%	4.50	6,110
Hotel and tourism	2	7,310	2,193	40.22%	2.85	2,718
Industrial investment	4	4,805	1,442	53.13%	4.18	4,201
Materials	2	1,870	561	0.61%	1.85	247
Media and entertainment	1	5,000	1,500	4.00%	14.80	650
Real estate management and development	2	13,610	2,848	8.49%	2.60	1,123
Retail	4	5,491	1,647	56.64%	4.20	3,161
Software and services	2	18,840	3,840	24.63%	12.58	1,050
Transportation	2	11,120	3,336	48.49%	18.63	2,271
Utilities	2	42,737	5,087	46.11%	17.51	1,485
Total	44	6,669,624	158,967	49.38%	6.81	46,180

Table 5. Sample analysis per year

Year	*Number of IPOs*	*Firms size (SAR MM)*	*Aggregate proceeds (SAR MM)*	*Average IR*	*Average over-subscription (individual)*	*No. of individual subscribers (000')*
2010	4	5,942	1,783	10.09%	2.43	3,271
2011	2	2,425	728	19.16%	1.60	458
2012	6	15,154	5,266	65.76%	3.25	9,759
2013	3	4,811	1,805	215.20%	4.30	7,518
2014	5	98,180	24,954	86.56%	7.92	7,796
2015	4	13,840	4,152	53.38%	4.73	5,366
2016	3	9,310	2,793	14.37%	3.47	1,598
2017	1	765	230	-4.37%	2.60	50
2018	2	3,541	1,064	1.67%	2.90	102
2019	5	6,416,818	99,810	10.24%	2.04	5,160
2020	3	29,922	5,254	23.54%	15.90	815
2021 till October	6	68,917	11,129	40.63%	19.84	4,287
Total	44	6,669,624	158,967	49.38%	6.81	46,180

The highest number of IPOs was in healthcare equipment and services where 5 firms were listed during the mentioned period as appeared in Table 4. The energy sector which covered Aramco Company only was the highest in terms of market capitalization (SAR 6.4 trillion) and aggregate proceeds (SAR 96 billion). Cement and healthcare equipment & services sectors were the most underpriced among others where IRs were 133.17% and 120.14%, respectively. Banks were the most covered sectors where the level of over-subscription was 24.85 times. Table 5 demonstrates a sample breakdown per year which shows 2021 would be the highest in terms of offerings. No doubt in seeing 2019 had the highest market capitalization and aggregate proceeds since it contained the Aramco offering which is the largest-ever IPO in the Saudi market. The level of individual over-subscription was at a record high during 2020 and 2021.

The next part focuses on the determination of the individual variables that are predicted to have a relationship with the IPO initial returns. The individual ten variables measured in the prior sections are used in simple regressions with the dependent variable expecting minor adjustment in the *SIZE* variable. We have taken the log value to normalize the date. The regression results are shown in Table 6.

These individual regression results provide collaborative evidence for the initial IPO performance analyzed in the empirical results. The regression results show that the *NIS*, *RISK*, *MV*, and *PEM* variables have significant explanatory power on the dependent variables. The initial returns and other variables, such as *LOS*, *LOG (SIZE), FEE*, *AGE*, *SENT* and *LAG* have low explanatory power, which is not statistically significant. Only the estimated coefficients on *MV* have opposite sign, which differs from what was expected. The sign of the coefficients on the *AGE* and *LOG (SIZE)* variables are negative, while *LAG* has a positive coefficient, demonstrating the existence of the *ex-ante* uncertainty hypothesis.

Although investor sentiment is positively related to the IPO initial returns, this relationship is insignificant. The reason might support the literature findings of abnormal negative returns in the short period (Rathnayake et al., 2022). In contrast, the univariate regression results are not consistent with the risk-return trade-off theory since the *MV* variable has a significant negative relationship with the *IR* at the 10% level.

Table 6. Univariate regression results with dependent variable IR

Model	*1*	*2*	*3*	*4*	*5*	*6*	*8*	*9*	*7*	*10*
Intercept	0.479***	1.029**	0.167	0.158	0.683***	0.653***	0.502***	0.462*	0.832***	1.038***
LOS	0.002									
LOG (SIZE)		(-0.154)								
NIS			0.000***							
RISK				10.997**						
FEE					(-4.507)					
AGE						(-0.007)				
SENT							1.517			
LAG								0.001		
MV									(-37.742)*	
PEM										(-0.644)*

*Note: ***, **, * denote significant at the 1%, 5%, and 10% level, respectively.*

Table 7 shows the correlation matrix of all variables. The aim is to avoid the inclusion of any variables that have a high correlation which would lead to a multicollinearity issue and a poorly determined coefficient. As shown in the correlation matrix, *NIS* and *LOG (SIZE)* variables are interrelated with the *FEE* variable. In addition, *SENT* with *MV* are interrelated. However, based on the sample correlation coefficients, the variables do not appear to be substituted for each other since the highest correlation between variables is less than 0.6.

Table 7. Correlation matrix

Variable	*IR*	*NIS*	*LOG (SIZE)*	*LOS*	*RISK*	*FEE*	*AGE*	*SENT*	*MV*	*PEM*	*LAG*
IR	1.00										
NIS	0.51	1.00									
LOG (SIZE)	-0.16	0.44	1.00								
LOS	0.03	-0.13	0.19	1.00							
RISK	0.38	0.51	-0.18	-0.14	1.00						
FEE	-0.13	-0.55	-0.58	-0.27	-0.04	1.00					
AGE	-0.16	-0.13	0.03	0.11	-0.21	0.10	1.00				
SENT	0.14	-0.01	-0.15	0.13	-0.13	0.12	0.05	1.00			
MV	-0.29	-0.14	0.21	-0.11	-0.03	-0.08	0.05	-0.53	1.00		
PEM	-0.27	-0.29	0.22	0.00	-0.51	0.01	-0.30	-0.09	0.20	1.00	
LAG	0.02	0.01	-0.26	-0.43	0.12	0.24	0.25	0.12	0.04	-0.09	1.00

In line with previous research, we adopted a stepwise backward multiple regression analysis to determine the most relevant variables to explain the underpricing level on the day of listing. Table 8 shows that Model 7 has the highest explanatory power with the least variables where the adjusted R-squared is 46.1%. The coefficient of the *NIS* has a significant positive relationship with *IR* in all models; the relationship is showing significance at the 1% level. Similarly, the relationship between the *LOG (SIZE)* variable and *IR* is negative and significant at a 1% level in all models. Thus, these findings for *LOG (SIZE)* are consistent with previous studies (Alanazi & Al-Zoubi, 2015; Chen et al., 2004; Yu & Tse, 2006), and our results support the *ex-ante* uncertainty hypothesis in terms of the *SIZE* variable. Also, the *LOS* variable is significant at the 5% level to expect for Models 1 and 8. Other variables are not statistically related to IPO initial returns in the Saudi stock market. The coefficient sign of the *AGE* variable is negative which is in line with *ex-ante* uncertainty and our expectation. Further, this outcome is consistent with previous researchers' findings (Chen et al., 2004; Kirkulak & Davis, 2005; Yu & Tse, 2006). *LAG* has a positive sign coefficient consistent with a previous study (Chen et al., 2004; Rathnayake et al., 2019; Yu & Tse, 2006). First-day initial returns are negatively related to *SENT* across all models. The coefficient *SENT* is insignificant and negatively related to *IR*. This outcome is not consistent with the investor sentiment hypothesis and is contrary to the results of previous studies (Boulton et al., 2011; Mumtaz et al., 2016; Samarakoon, 2010; Khin et al., 2017). The regression results are consistent with the risk-return trade-off theory, as the *RISK* variable has a positive relationship, but it is statistically insignificant. The initial returns are not significantly affected by the market volatility observed at the time of setting the offer price. However, the sign of this variable is positive which implies the risk and return hypothesis is accepted. These results are consistent with previous studies (Butler et al., 2014; Deng & Zhou, 2015; Mumtaz et al., 2016; Khin et al., 2017). As predicted, the coefficient of the *PEM* variable is negative which indicates *IR* is reduced in case of higher valuation relative to the overall market. However, it is insignificant and poorly estimated IR.

Table 8. Coefficients estimation of multiple regression analysis

Model	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Intercept	1.813**	1.815**	1.801**	1.804**	1.785**	1.724**	2.019***	1.654***
NIS	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.000***
LOG (SIZE)	(-0.579)***	(-0.580)***	(-0.581)***	(-0.578)***	(-0.568)***	(-0.573)***	(-0.600)***	(-0.515)***
LOS	0.025*	0.025**	0.025**	0.025**	0.024**	0.023**	0.02**	0.020*
RISK	(-6.842)	(-6.832)	(-6.725)	(-6.668)	(-6.296)	(-5.616)	(-5.123)	
FEE	4.818	4.817	4.788	4.743	4.485	3.758		
AGE	(-0.005)	(-0.005)	(-0.004)	(-0.004)	(-0.004)			
SENT	(-0.280)	(-0.276)	(-0.272)	(-0.308)				
MV	1.166	1.191	1.080					
PEM	(-0.018)	(-0.017)						
LAG	0.000							
Adj. R^2	0.385	0.403	0.420	0.436	0.450	0.454	0.461	0.457
F	3.688	4.222	4.889	5.746	6.871	8.147	10.208	13.081
Significance F	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000

5. CONCLUSION

Several researchers have dedicated considerable time to analyzing IPOs' behavior (Loughran et al., 1994; Ritter & Welch, 2002). Loughran et al. (1994) found that IPO underpricing is a common phenomenon in stock markets worldwide and varies by country. However, the degree of underpricing is more pronounced in developing countries in comparison with developed ones.

Many theoretical models were developed in previous research to interpret the behavior of IPO initial returns. The most reasonable explanation of underpricing is based on the information asymmetry that poses a form of ex-ante uncertainty.

We use a sample of 44 IPOs on the Saudi stock market from January 2010 till October 2021. The data was sourced from the Saudi Stock Exchange (Tadawul) database and the companies' prospectus from Capital Market Authority (CMA). The data shows that, on average, IPOs are underpriced by 49.4%. The stepwise multiple regression was used to investigate the relationships between initial returns and ten independent variables. We found that number of individual subscribers, level of over-subscription by individuals, and the firm size has a significant relationship with IPO returns while other variables, namely, the age of the firm, the listing lag, P/E multiplier, offer risk, investor sentiment, market

volatility, and listing fee are not statistically related to IPO initial returns on the Tadawul exchange. The results are consistent with the prediction of *ex-ante* uncertainty and previous studies. Interestingly, the level of underpricing has declined in Saudi Arabia over time and the number of IPOs surged in the latest years.

The results of the current study might be used by regulators and policymakers for taking decisions regarding future policymaking. The paper may help the current investors and proposed investors in the Saudi IPO market for making informed decisions.

In the future study, we suggest the consideration of the effect of underwriter reputation, industry characteristics, and the effect of macroeconomic factors on IPOs.

REFERENCES

1. Abdul Rahim, R., & Yong, O. (2010). Initial returns of Malaysian IPOs and Shari'a-compliant status. *Journal of Islamic Accounting and Business Research, 1*(1), 60–74. https://doi.org/10.1108/17590811011033415
2. Alanazi, A. S., & Al-Zoubi, H. A. (2015). Extreme IPO underpricing and the legal environment in wealthy emerging economies. *Journal of Multinational Financial Management, 31*, 83–103. https://doi.org/10.1016/j.mulfin.2015.05.004
3. Al-Hassan, A., Delgado, F., & Omran, M. (2010). The under-pricing of IPOs in the Gulf cooperation council countries. *Research in International Business and Finance, 24*(3), 344–360. https://doi.org/10.1016/j.ribaf.2010.03.002
4. Badru, B. O., & Ahmad-Zaluki, N. A. (2018). Explaining IPO initial returns in Malaysia: Ex-ante uncertainty vs signaling. *Asian Review of Accounting, 26*(1), 84–106. https://doi.org/10.1108/ARA-11-2016-0133
5. Baron, D. (1982). A model of the demand for investment banking advising and distribution services for new issues. *The Journal of Finance, 37*(4), 955–976. https://doi.org/10.1111/j.1540-6261.1982.tb03591.x
6. Beatty, R. P., & Ritter, J. R. (1986). Investment banking, reputation, and the underpricing of initial public offerings. *Journal of Financial Economics, 15*(1–2), 213–232. https://doi.org/10.1016/0304-405X(86)90055-3
7. Benveniste, L. M., & Spindt, P. A. (1989). How investment bankers determine the offer price and allocation of new issues. *Journal of Financial Economics, 24*(2), 343–361. https://doi.org/10.1016/0304-405X(89)90051-2
8. Boulton, T. J., Smart, S. B., & Zutter, C. L. (2011). Earnings quality and international IPO underpricing. *The Accounting Review, 86*(2), 483–505. https://doi.org/10.2308/accr.00000018
9. Bradley, D. J., & Jordan, B. D. (2002). Partial adjustment to public information and IPO underpricing. *The Journal of Financial and Quantitative Analysis, 37*(4), 595–616. https://doi.org/10.2307/3595013
10. Bubna, A., & Prabhala, N. (2007). *When bookbuilding meets IPOs*. https://doi.org/10.2139/ssrn.972757
11. Butler, A. W., Keefe, M. O., & Kieschnick, R. (2014). Robust determinants of IPO underpricing and their implications for IPO research. *Journal of Corporate Finance, 27*, 367–383. https://doi.org/10.1016/j.jcorpfin.2014.06.002
12. Chen, G., Firth, M., & Kim, J.-B. (2004). IPO underpricing in China's new stock markets. *Journal of Multinational Financial Management, 14*(3), 283–302. https://doi.org/10.1016/j.mulfin.2003.07.007
13. Chi, J., & Padgett, C. (2005). The performance and long-run characteristics of the Chinese IPO market. *Pacific Economic Review, 10*(4), 451–469. https://doi.org/10.1111/j.1468-0106.2005.00285.x
14. Chowdhry, B., & Sherman, A. (1996). International differences in oversubscription and underpricing of IPOs. *Journal of Corporate Finance, 2*(4), 359–381. https://doi.org/10.1016/0929-1199(96)00002-8
15. Clarkson, P. M. (1994). The underpricing of initial public offerings, ex ante uncertainty, and proxy selection. *Accounting & Finance, 34*(2), 67–78. https://doi.org/10.1111/j.1467-629X.1994.tb00270.x
16. Clarkson, P. M., & Merkley, J. (1994). Ex ante uncertainty and the underpricing of initial public offerings: Further Canadian evidence. *Canadian Journal of Administrative Science, 11*(2), 54–67. https://doi.org/10.1111/j.1936-4490.1994.tb00054.x
17. Deng, Q., & Zhou, Z. (2015). The pricing of first-day opening price returns for ChiNext IPOs. *Review of Quantitative Finance and Accounting, 47*(2), 249–271. https://doi.org/10.1007/s11156-015-0500-x
18. Derrien, F. (2005). IPO pricing in "hot" market conditions: Who leaves money on the table? *The Journal of Finance, 60*(1), 487–521. https://doi.org/10.1111/j.1540-6261.2005.00736.x
19. Holmes, S., Hutchinson, P., Forsaith, D., Gibson, B., & McMahon, R. (2003). *Small enterprise finance*. John Wiley & Sons.
20. Khin, E. S. W., WB, R., & Ting, L. S. (2017). Initial public offering (IPO) underpricing in Malaysian settings. *Journal of Economic & Financial Studies, 5*(02), 14–25. https://doi.org/10.18533/jefs.v5i02.276
21. Kirkulak, B., & Davis, C. (2005). Underwriter reputation and underpricing: Evidence from the Japanese IPO market. *Pacific-Basin Finance Journal, 13*(4), 451–470. https://doi.org/10.1016/j.pacfin.2004.09.004
22. Kiymaz, H. (2000). The initial and aftermarket performance of IPOs in an emerging market: evidence from Istanbul stock exchange. *Journal of Multinational Financial Management, 10*(2), 213–227. https://doi.org/10.1016/S1042-444X(99)00027-4
23. Komenkul, K., & Siriwattanakul, D. (2016). How the unremunerated reserve requirement by the Bank of Thailand affects IPO underpricing and the long-run performance of IPOs. *Journal of Financial Regulation and Compliance, 24*(3), 317–342. https://doi.org/10.1108/JFRC-09-2015-0052
24. Lee, P. J., Taylor, S. L., & Walter, T. S. (1999). IPO underpricing explanations: Implications from investor application and allocation schedules. *The Journal of Financial and Quantitative Analysis, 34*(4), 425–444. https://doi.org/10.2307/2676228
25. Ljungqvist, A., & Wilhelm, W. (2004). *Does prospect theory explain IPO market behavior?* https://doi.org/10.2139/ssrn.485302
26. Ljungqvist, A., Nanda, V., & Singh, R. (2003). *Hot markets, investor sentiment, and IPO pricing* (NYU Working Paper No. S-FI-01-05). https://doi.org/10.2139/ssrn.282293
27. Loughran, T., & Ritter, J. R. (1995). The new issues puzzle. *The Journal of Finance, 50*(1), 23–51. https://doi.org/10.1111/j.1540-6261.1995.tb05166.x
28. Loughran, T., & Ritter, J. R. (2002). Why don't issuers get upset about leaving money on the table in IPOs? *The Review of Financial Studies, 15*(2), 413–444. https://doi.org/10.1093/rfs/15.2.413
29. Loughran, T., Ritter, J. R., & Rydqvist, K. (1994). Initial public offerings: International insights. *Pacific-Basin Finance Journal, 2*(2–3), 165–199. https://doi.org/10.1016/0927-538X(94)90016-7

30. Low, S.-W., & Yong, O. (2011). Explaining over-subscription in fixed-price IPOs — Evidence from the Malaysian stock market. *Emerging Markets Review, 12*(3), 205–216. https://doi.org/10.1016/j.ememar.2011.03.003
31. Mayes, D., & Alqahtani, F. (2015). Underpricing of IPOs in Saudi Arabia and Sharia compliance. *Journal of Islamic Accounting and Business Research, 6*(2), 189–207. https://doi.org/10.1108/JIABR-12-2013-0042
32. McGuinness, P. (1992). An examination of the underpricing of initial public offerings in Hong Kong: 1980–90. *Journal of Business Finance & Accounting, 19*(2), 165–186. https://doi.org/10.1111/j.1468-5957.1992.tb00617.x
33. Mumtaz, M. Z., Smith, Z. A., & Ahmed, A. M. (2016). Examinando el desempeño de corto plazo de las ofertas públicas iniciales de acciones con el análisis de límites extremos [An examination of the short-run performance of IPOs using extreme bounds analysis]. *Estudios de economía, 43*(1), 71–95. https://doi.org/10.4067/S0718-52862016000100004
34. Rathnayake, D. N., Louembé, P. A., Kassi, D. F., Sun, G., & Ning, D. (2019). Are IPOs underpriced or overpriced? Evidence from an emerging market. *Research in International Business and Finance, 50,* 171–190. https://doi.org/10.1016/j.ribaf.2019.04.013
35. Rathnayake, D. N., Zhang, Z., Yang, B., & Louembé, P. A. (2022). The aftermarket performance of initial public offerings: New evidence from an emerging market. *PLoS ONE, 17*(8), Article e0272092. https://doi.org/10.1371/journal.pone.0272092
36. Ritter, J. R. (1991). The long-run performance of initial public offerings. *The Journal of Finance, 46*(1), 3–27. https://doi.org/10.1111/j.1540-6261.1991.tb03743.x
37. Ritter, J. R. (2011). Equilibrium in the initial public offerings market. *Annual Review of Financial Economics, 3*(1), 347–374. https://doi.org/10.1146/annurev-financial-102710-144845
38. Ritter, J. R., & Welch, I. (2002). *A review of IPO activity, pricing and allocations* (Yale ICF Working Paper No. 02-01). https://doi.org/10.2139/ssrn.296393
39. Rock, K. (1986). Why new issues are underpriced. *Journal of Financial Economics, 15*(1–2), 187–212. https://doi.org/10.1016/0304-405X(86)90054-1
40. Samarakoon, L. P. (2010). The short-run underpricing of initial public offerings in the Sri Lankan stock market. *Journal of Multinational Financial Management, 20*(4–5), 197–213. https://doi.org/10.1016/j.mulfin.2010.07.003
41. Signori, A. (2018). Zero-revenue IPOs. *International Review of Financial Analysis, 57*, 106–121. https://doi.org/10.1016/j.irfa.2018.03.003
42. Song, S., Tan, J., & Yi, Y. (2014). IPO initial returns in China: Underpricing or overvaluation? *China Journal of Accounting Research, 7*(1), 31–49. https://doi.org/10.1016/j.cjar.2013.12.001
43. Yu, T., & Tse, Y. K. (2006). An empirical examination of IPO underpricing in the Chinese A-share market. *China Economic Review, 17*(4), 363–382. https://doi.org/10.1016/j.chieco.2005.07.001