

An Examination of Adverse Selection Risk in Indian IPO After-Markets using High Frequency Data

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ABSTRACT

Using Volume-synchronized Probability of Informed trading (VPIN), we examine the evolution of ex-post adverse selection risk in the IPO aftermarket of a sample of 70 Indian firms. We find that adverse selection risk is highest on IPO listing day, and gradually reduces over the subsequent weeks. We observe that the degree of IPO underpricing is negatively related to ex-post adverse selection risk in the IPO aftermarket, suggesting that information production induced through IPO underpricing is able to mitigate adverse selection problems in IPO aftermarket. We also find that the ex-post adverse selection risk is related to various IPO, firm and liquidity characteristics.

Keywords: Initial Public Offerings (IPOs); adverse selection risk; probability of informed trading; underpricing.

JEL Classification: G12; G14.

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1. Introduction:

The event of an IPO listing by a private firm has attracted the attention of researchers for past several decades, and produced an extensively rich literature particularly in the area of corporate finance. However, the literature on empirical IPO microstructure is of relatively recent origin, as it had to depend on both the development of the market microstructure theory as well as the availability of high frequency data for the beginning of its own evolution. Within this niche segment of finance literature, we focus our attention in this paper on a particularly interesting and relatively unexplored area of the evolution of ex-post adverse selection risk during the transition of IPOs from the primary market book building phase to secondary market trading.

The aftermarket of an IPO has been of particular interest to researchers because of the unique information asymmetry structure that prevails immediately following an IPO. The finance literature has explored various aspects of the IPO aftermarket such as trading activity and order flow (Ellis, Michaely and O'Hara (2000), Ellis (2006), Aitken, McNish and Wong (2009) and Busaba and Chang (2010)), aftermarket performance (Bradley, et. al. (2009)), stabilization activities by underwriter (Schultz and Zaman (1994), Aggarwal (2000) and Wilhelm (2005)) and liquidity provision (Li, Zheng and Melancon (2005), Ellul and Pagano (2006), Zheng and Li (2008) and Popescu and Xu (2011)). In this paper, we extend this stream of literature by examining the evolution of ex-post adverse selection risk in the IPO aftermarket.

The paper that comes closest to our study is Li, McNish and Wongchoti (2005) who investigate the evolution of asymmetric information in the IPO aftermarket for a sample of NASDAQ listed firms. Similar to our study, this paper also examines the information production effects of underpricing in the IPO aftermarket. However, our research findings are novel in several ways. First, our paper is set in the context of Indian IPO market, which is distinct from the developed markets both in terms of institutional as well as legal frameworks. We expect the stock markets in the emerging

economies such as India to be characterized by larger information asymmetry problems and greater adverse selection risk, as the corporate and securities laws are relatively less structured here, and many of the investor protection rights and corporate governance norms are not strictly enforced.

Second, their paper measures asymmetric information with the adverse selection component of the spread, as suggested by the asymmetric information models in the empirical market microstructure literature (Glosten and Harris (1988), Lin, Sanger and Booth (1995) and Madhavan, Richardson and Roomans (1997)). In contrast, we measure the ex-post adverse selection risk in the IPO aftermarket using the Volume-synchronized Probability of Informed trading (VPIN). This order flow toxicity measure of adverse selection risk is based on a recently developed update of the well-known PIN model (Easley, Lopez de Prado and O'Hara (2012)).

Finally, while both the papers find that information production induced through higher IPO underpricing reduces the aggregate level of information asymmetry in the IPO aftermarket, Li, McNish and Wongchoti (2005) find that the level of asymmetric information is lower immediately after the IPO, and then increases subsequently. On the contrary, we find that the adverse selection risk is highest on IPO listing day, and gradually reduces over the subsequent weeks. The difference in our results may emerge from the difference in market microstructure of the two different exchanges², and highlights the importance of additional research on open limit order book markets such as the BSE.

The IPO literature has extensively documented the positive relationship between ex-ante level of information asymmetry in an IPO and IPO underpricing. However, the link between the IPO underpricing and ex-post level of information asymmetry has not been well examined so far. In our paper, we examine the evolution of ex-post adverse selection risk and its key determinants for a sample of 70 Indian firms in their IPO aftermarkets. First, we observe how the adverse selection risk, as measured by

² The NASDAQ stock exchange is a quote driven market, characterized by a specialist agent in the role of a designated liquidity provider. On the other hand, Bombay Stock Exchange (BSE) is organized as a purely order driven market which does not have any designated market maker, and liquidity is solely provided by the limit order traders.

volume-synchronized probability of informed trading (VPIN) metric, evolves over time immediately following an IPO listing. We examine the time series trend of the VPIN variable calculated over three different trading horizons - the first day, the first week and the first month of IPO aftermarket trading.

An IPO is one of the most significant corporate events in the life cycle of a private firm. It facilitates the production of incremental information about the company through regulatory filings, analyst reports, press coverage and marketing activities. We expect the time series trend of VPIN measure in the IPO aftermarket to capture the dynamics of the evolution of adverse selection risk at the beginning of secondary market trading.

The IPO literature suggests that investment banks often underprice IPO offerings to induce outside investors to truthfully reveal their private information about the firm value, to assist them in the process of price discovery and determination of the offer price (Chemmanur (1993) and Benveniste and Spindt (1989)). Following this argument, the degree of IPO underpricing is likely to indicate the level of information production during an IPO process. Consistent with this literature, we expect the VPIN measure of adverse selection risk to remain negatively associated with the degree of IPO underpricing. We examine this relationship by comparing the trend of VPIN values across groups of firms partitioned and ordered on the basis of increasing level of IPO underpricing.

Finally, we investigate various determinants of VPIN measure of adverse selection risk in the IPO aftermarkets. We initially conduct univariate non-parametric median tests on the VPIN measures across groups of firms partitioned on the basis of different firm characteristics (such as Total Assets and Promoter Holding), IPO characteristics (such as Issue Size and Syndicate Size) and post IPO trading characteristics (such as average daily Turnover Ratio) for various windows of trading horizon. We also run a multivariate regression analysis to find out the key determinants which significantly explain the ex-post information asymmetry risk in the IPO aftermarket, as measured by the VPIN metric, after controlling for the effects of other factors.

We observe that the order flow toxicity measure of adverse selection risk is highest during the first hour of aftermarket trading immediately following an IPO offering, and it reduces gradually and monotonically over time, in the subsequent trading hours on the day of IPO listing. The diminishing trend of adverse selection risk following an IPO continues in the subsequent weeks, till around the end of first month of IPO aftermarket. For example, the probability of informed trading, which is as high as 52% in the first trading hour, reaches an average level of 38% by the end of the first month of IPO aftermarket.

Our times series analysis of VPIN values across groups of firms partitioned on the basis of IPO underpricing shows that the adverse selection risk diminishes gradually and monotonically in the IPO aftermarket for firms with low and medium level of IPO underpricing, firms. However, we fail to observe the monotonic trend in VPIN values for the group of firms with very high level of underpricing. When we compare the VPIN values across groups of firms with different levels of IPO underpricing, we observe that the adverse selection risk is relatively higher for IPOs with lower level of underpricing. Interestingly, we find that this inverse relationship between the adverse selection risk and the degree of IPO underpricing holds true for various time horizons of VPIN estimation on the day of IPO listing, providing robustness to our findings.

Our univariate analysis of investigating the determinants of the ex-post adverse selection risk in the IPO aftermarket from various firm characteristics, IPO characteristics and post-IPO trading characteristics show that the probability of informed trading is significantly higher for IPOs with higher IPO issue size, larger IPO syndicate size, greater firm size, higher post-IPO promoter stake, and lower daily average turnover ratio. A multiple regression analysis of VPIN measures on these variables reconfirm our univariate results and indicates that each of the IPO characteristics (IPO issue size and IPO syndicate size), firm characteristics (pre-IPO total assets and post-IPO promoter stake) and trading characteristics (daily turnover ratio) significantly influences in determining the ex-post adverse selection risk in the IPO aftermarket.

Together, our results show that the ex-post adverse selection risk rapidly evolves in the IPO aftermarket, and monotonically decreases over the trading hours on the day of IPO listing, as more and more information become public and information asymmetry problems reduce. The diminishing trend continues over the subsequent weeks of secondary market trading, although at a much slower rate relative to the rate of hourly decline on the day of IPO listing. Our findings also highlight the determinants of order flow toxicity measure of adverse selection risk in the IPO aftermarket. We find a significantly strong, negative association between IPO underpricing and ex-post adverse selection risk in the IPO aftermarket. The results from the multivariate regression analysis indicate that the probability of informed trading in the IPO aftermarket is jointly determined by a combination of firm characteristics, IPO characteristics as well as post issue trading characteristics.

To the best of our knowledge, our study is one of the first in the IPO microstructure literature to investigate the evolution of adverse selection risk in the IPO aftermarket, adopting a volume-synchronized measure of probability of informed trading (VPIN). Our analysis of the high frequency trade level data from Indian IPOs also extends the scanty microstructure literature on an important and yet relatively unexplored limit order book market such as the BSE.

The rest of the paper is organized as follows. Section 2 discusses the related literature on IPO information asymmetry structure, associated adverse selection risk and its relation to IPO underpricing, and develops the testable hypotheses of our research. A brief overview of Indian primary capital market is also provided in this section. Section 3 describes the data and sample characteristics, followed by a discussion on the methodology adopted in our analysis. The results are discussed in Section 4. Section 5 concludes.

2. Literature Review:

Our literature review is broadly divided into three, inter-connected sections. The first section reviews the IPO literature which analyzes the information asymmetry structure around an IPO to

develop and test various models on IPO underpricing. The second section of the literature review explores some of the previous studies on adverse selection risks in IPOs which emerge from such information asymmetry problems. Finally, the last section scans the literature that connects the degree of IPO underpricing with the level of adverse selection risk existing in an IPO.

2.1 IPO and Information Asymmetry

The IPO literature is quite extensive and well-developed, and continues to remain as one of the most well researched field in the area of corporate finance. Among the various issues relating to an IPO, the three phenomena which have attracted most attention from researchers are the anomalies of short run IPO underpricing, long run IPO underperformance and the existence of hot issue markets. Various theoretical models have been proposed in the literature that assumes different information structures among the three key participants involved in an IPO process – the IPO issuer, the underwriter and the outside investor. The information asymmetry models primarily attempt to explain the three IPO anomalies assuming different information structures among these three key players involved in the IPO market.

In an IPO process, an informational advantage enjoyed by any one of the three parties can induce an information asymmetry cost on the other parties involved due to adverse selection risk and moral hazard problems. Some models assume that the investment banker is better informed than the IPO issuing firm about the demand for the IPO, and utilizes its superior knowledge and discretion in strategic allocation of IPO shares. (Cornelli and Goldreich (2001) and Aggarwal, Prabhala and Puri (2002)). Another class of models assume the existence of two types of investors, informed and uninformed, thereby creating a winner's curse problem. Rock (1986) develop a model on this information asymmetry structure, and show that IPO underpricing can be viewed as a deliberate compensation to overcome the winner's curse problem and secure the participation of uninformed investors.

Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990) further develop this structure and assume that both underwriter and IPO issuer are uninformed about the true value of the firm,

and some investors are more informed about the firm prospects than others. In their models, the informed investors truthfully reveal their private information about the firm's true value to the investment bank in exchange for a favorable allocation in the underpriced IPOs.

Allen and Faulhaber (1989), Grinblatt and Hwang (1989) and Welch (1989, 1992) assume that the IPO issuer is the only party who is informed about its own true value. They propose models in which the high quality firms choose underpricing as a form of costly signal to the outside investors in order to differentiate themselves from the low quality issuers.

More recently, market microstructure research has shed additional light on the process by which information gets incorporated into security prices in the secondary market. Microstructure models provide explicit estimates of the extent of private information and establish direct link between market microstructure variables and asset prices in secondary markets. We extend this growing stream of literature by studying the evolution of adverse selection risk in the immediate IPO aftermarket which is often characterized by high level of information asymmetry among the investors, large share turnover and significantly higher level of volatility.

This study of the evolution of information asymmetry in the IPO aftermarket supplements other studies done on the process by which newly listed securities from the primary pre-IPO market enter into the 'normal' secondary market. Studies by Krigman, Shaw and Womack (1999), Ellis (2006) and Griffin, et al. (2007) examine the early aftermarket of IPOs. Chen and Wilhelm (2008) develop a model of the transition from primary market to secondary market trading for an IPO, and observe sequential arrival of informed traders in the IPO aftermarket. Jiang and Li (2013) study the dynamics of investor sentiment during the transition from pre-IPO market to aftermarket trading.

The literature provides a broad consensus that price discovery process is incomplete in the primary market phase, as asymmetric information persists even after IPO listing, and there is a sequential arrival of incremental information in the early stages of secondary market trading that is crucial

to the price discovery process of a newly listed security. Consistent with this literature, we hypothesize that the ex-post adverse selection risk should be greatest at the start of the secondary market trading when information asymmetry problems are most acute. Thereafter, we expect the adverse selection risk to gradually decline over time as more and more information arrives in the public domain and information asymmetry becomes increasingly less pronounced. This leads to our primary hypothesis on the time series pattern of adverse selection risk in the IPO aftermarket:

H1a: Adverse selection risk is highest at the beginning of secondary market trading, and reduces monotonically over time in the IPO aftermarket.

Further, we argue that the time series pattern of adverse selection risk in the IPO aftermarket is a direct consequence of the dynamics of the information asymmetry structure existing in the IPO aftermarket. Therefore, ceteris paribus, we expect the pattern of diminishing adverse selection risk in the IPO aftermarket to hold true for all types of IPOs, irrespective of the degree of IPO underpricing. This leads to our secondary hypothesis on the time series pattern of adverse selection risk in the IPO aftermarket:

H1b: Adverse selection risk has a monotonically decreasing pattern over time in the IPO aftermarket, for each group of firms partitioned on the basis of degree of IPO underpricing.

2.2 Adverse Selection Risk in IPOs

Asymmetric information about the valuation or quality of any asset leads to an adverse selection risk, or a lemon's problem for the uninformed agent (Akerlof (1970)). Since an IPO market is characterized by such acute information asymmetry problems among the issuer, underwriter and different categories of investors, the IPO literature has extensively examined the information asymmetry structure prevalent in an IPO prior to its listing, and developed models which attempt to explain IPO underpricing as a function of uncertainty and adverse selection risk existing in the pre-IPO market.

For example, the IPO literature studies several IPO certification mechanisms and investigates the effectiveness of third-party certifications from investment banks (Beatty and Ritter (1986), Carter and Manaster (1990), Carter, Dark and Singh (1998)), auditors (Beatty (1989)), venture capitalists (Megginson and Weiss (1991) and Gompers (1996)) and private equities (Levis (2011)) in reducing the information asymmetry existing in the IPO market, and lowering the adverse selection risk faced by the uninformed investors.

Most of these studies investigate the ex-ante, unobservable adverse selection risk in the pre-IPO market, prior to IPO listing. However, the process of price discovery is incomplete in the pre-IPO market, and there is arrival of incremental information in the early stages of secondary market trading. For example, Ellul and Pagano (2006) find that information asymmetry persists even after IPO listing, and significantly explains aftermarket illiquidity. The amount of private information which remains undisclosed after the IPO may depend on various firm and IPO characteristics. Therefore, the study of evolution of ex-post adverse selection risk and its key determinants is pertinent particularly in the context of the IPO aftermarket.

Easley, Hvidkjaer and O'Hara (2002) find that the information risk, as measured by the probability of informed trading, is an important risk factor that is priced in the aftermarket trading. The microstructure literature provides extensive empirical evidence establishing the link between market microstructure variables and asset pricing models. In our study, we follow this literature to measure the order flow toxicity measure of adverse selection risk using volume synchronized probability of informed trading (VPIN) in the IPO aftermarket, and investigate its association with several IPO, firm and liquidity characteristics.

Beatty and Ritter (1986) suggest that smaller IPOs are more speculative, on average, than larger IPOs. Ritter (1984), Beatty and Ritter (1986) and Booth and Chua (1996) argue that inverse of IPO gross proceeds can proxy for ex-ante uncertainty of an IPO in the primary market. This suggests that we

should expect greater participation from informed, institutional investors on relatively larger sized IPOs. Therefore, the uninformed investors should be more concerned about adverse selection problems in the IPO aftermarket of larger IPOs. Consistent with this, we argue that the ex-post adverse selection risk in the IPO aftermarket should be higher for larger IPOs. This leads to our first hypothesis on the determinants of adverse selection risk in the IPO aftermarket:

H2a: Adverse selection risk in the IPO aftermarket is positively related to the size of the IPO issue proceeds.

The IPO literature on book-building emphasizes the role of information production activities by underwriters in the IPO price discovery process. Corwin and Schultz (2005) find strong evidence of information production by the syndicate members in an IPO through additional analyst coverage and market making activities. Inclusion of additional syndicate members also reduces the ex-ante adverse selection problem in the IPO market through additional certification of the IPO quality. On the contrary, presence of additional syndicate members may exacerbate the information asymmetry problem in the IPO aftermarket. For example, the IPO analyst reports are generally disseminated only to selective institutional clients of the syndicate members, and not publicly distributed. Therefore, additional information generated by the syndicates may only act to increase the amount of private information that remains undisclosed after the IPO. Consistent with this, we argue that the ex-post adverse selection risk in the IPO aftermarket should increase with increasing IPO syndicate size. This leads to our second hypothesis on determinants of ex-post adverse selection risk:

H2b: Adverse selection risk in the IPO aftermarket is positively related to the syndicate size of the IPO offering.

Barry and Brown (1984) suggest a positive relation between firm size and firm-specific information. Li and Masulis (2005) argue that larger firms and firms with more tangible assets are likely to be more diversified, and less risky. IPO literature also suggests that larger firms are more likely to have

lower level of information asymmetry, and exhibit lower underpricing (Michaely and Shaw (1994) and Schenone (2004)). Consistent with this literature, we suggest that ex-post adverse selection problems in the IPO aftermarket should be lower for larger firms with higher total assets. Accordingly, we develop our third hypothesis on determinants of ex-post adverse selection risk as follows:

H2c: Adverse selection risk in the IPO aftermarket is negatively related to the size of the IPO firm, as measured by its pre-IPO total assets.

Leland and Pyle (1977) and Ellul and Pagano (2006) have used the amount of shares sold by the insiders as a proxy for the presence of asymmetric information in the IPO process. Leland and Pyle (1977) argue that the percentage ownership retained by the insiders can be interpreted as a signal of private information possessed by the owners and managers. Similarly, insider ownership has been used as a control variable to explain underpricing in the IPO literature (Allen and Faulhaber (1989), Brennan and Franks (1997) and Marisetty and Subrahmanyam (2010)). Consistent with this literature, we suggest that the ex-post adverse selection risk should be higher in the aftermarket of those IPOs which have greater post-IPO promoter holdings. This leads to our fourth hypothesis:

H2d: Adverse selection risk in the IPO aftermarket is positively related to the post IPO promoter holding in the newly listed firm.

Brennan and Subrahmanyam (1996) find that illiquidity in financial markets is primarily caused by adverse selection problems emerging due to the presence of privately informed traders. Ellul and Pagano (2006) find similar result in the context of an IPO aftermarket, and model aftermarket illiquidity as a function of asymmetric information that persists after the IPO listing. Turnover ratio is frequently used as a proxy for liquidity in the market microstructure literature (Roll (1981), Amihud and Mendelson (1986), Mantecon and Poon (2009) and Deb and Marisetty (2010)). Microstructure literature also suggests that actively traded stocks face lower adverse selection problems. Consistent with this literature, we hypothesize that the ex-post adverse selection risk in the aftermarket would be lower for

more liquid IPO securities, which have higher turnover ratios. This leads to our final hypothesis on determinants of ex-post adverse selection risk:

H2e: Adverse selection risk in the IPO aftermarket is negatively related to the daily average turnover ratio of the newly listed security in the IPO aftermarket.

In our study, through these five hypotheses developed above, we attempt to examine the role of firm characteristics, IPO characteristics and post-IPO trading characteristics in determining the ex-post adverse selection risk in the IPO aftermarket.

2.3 Adverse Selection Risk and IPO Underpricing

IPO underpricing is a robust phenomenon extending across all the equity markets and different geographies and time horizons, and has been extensively studied in the finance literature. Several theories have been proposed by the researchers to explain the IPO underpricing anomaly. A significantly large portion of this literature assumes information asymmetry and the associated adverse selection risk as the key driver for IPO underpricing. For example, adverse selection models proposed by Rock (1986), Beatty and Ritter (1986) and Carter and Manaster (1990) suggest that IPO underpricing is an outcome of the winner's curse problem faced by the uninformed investors in IPO pre-markets. Similarly, signaling based models proposed by Allen and Faulhaber (1989), Grinblatt and Hwang (1989) and Welch (1989) build on the assumption that IPO issuers are more informed about the true IPO valuation than outside investors, and argue that IPO underpricing is a costly signal that high quality firms choose to send to the uninformed outside investors to differentiate themselves from other low quality issuers.

The literature on IPO book-building and allocation exploits the information asymmetry structure further to suggest that underwriters choose to underprice an IPO to induce informed, institutional investors to truthfully reveal their private information on the true value of the firm, in exchange for a favorable allocation in such underpriced IPOs (Beneviste and Spindt (1989), Loughran

and Ritter (2002) and Ljungqvist and Wilhelm (2003)). Chemmanur (1993) develops an information theoretic model of IPO pricing, where outside investors are induced to engage in information production through IPO underpricing. Consistent with this, Habib and Ljungqvist (2001) explains IPO underpricing as a substitute for costly marketing and information dissemination exercise. The IPO information production hypothesis also proposes that the underwriters generate valuable information on IPO demand and valuation during the book building process ultimately leading to the determination of the IPO offer which is the culmination of primary market price discovery process.

Although the information asymmetry based IPO underpricing literature is quite extensive, we find that it has largely limited its focus on the examination and consequence of adverse selection risks in IPO pre-markets only. The central finding of the adverse selection literature on IPOs is the robust positive relationship that exists between the ex-ante, unobservable adverse selection risk in the IPO pre-market and the expected initial underpricing of the IPO issue. However, the relationship between the IPO underpricing and ex-post, observable adverse selection risk prevailing in the IPO aftermarket has been left unexplored in the literature. In our study, we attempt to fill this research gap and extend this literature further by investigating whether the information production induced through IPO underpricing is able to mitigate the adverse selection risk existing in the IPO aftermarkets.

The conventional practice in the early IPO literature has been to assume that the true value of the IPO securities gets established as soon as the IPO gets listed. On the contrary, recent investigations on the IPO aftermarkets have revealed that price discovery is incomplete and partial in the primary market, and there is arrival of incremental information in the early stages of secondary market trading. Ellis (2006) finds significant role of underwriter stabilization activities in generating the early high trading volumes in IPO aftermarkets. Ellul and Pagano (2006) develop a model to suggest that the aftermarket illiquidity is an outcome of the information asymmetry problems that continues to persist even after the IPO listing.

Consistent with this literature, we argue that IPOs which are more heavily underpriced, should generate more public information in the IPO aftermarket, which in turn should reduce the amount of private information remaining undisclosed after the IPO listing. Therefore, if the IPO underpricing is able to resolve its desired objective of reducing the adverse selection problem, we would expect a higher level of initial underpricing to remain negatively associated with the degree of adverse selection risk prevailing in the immediate IPO aftermarket. This leads to our following hypothesis:

H3: Adverse selection risk in the IPO aftermarket is negatively related to the degree of initial underpricing in the IPO offering.

2.4 Indian Capital Market

2.4.1 Bombay Stock Exchange (“BSE”)

The Bombay Stock Exchange, more popularly known as the “BSE”, is one of the two most important stock exchanges in India, with the more recently developed National Stock Exchange (“NSE”) being its other counterpart. Infact, almost the entire public equity market trading within India takes place at one of these two stock exchanges. BSE is the oldest stock exchange in Asia, and the largest in the world in terms of companies listed on the exchange³. It got established in 1875 as “The Native Share & Stock Brokers Association”, and thereafter, played a significant role in the development of

³ According to reports from World Federation of Exchanges, there were 5,159 companies listed on the BSE, as on January, 2013.

Indian capital market. It is currently ranked 5th in the Asia-Pacific region in terms of size, with a market capitalization of 1.3 trillion dollars⁴.

BSE is organized as a purely order driven stock exchange. All the incoming orders are queued up in an open electronic limit order book, and matched anonymously by a trading computer on a strict price/time priority basis. Several financial products such as equity, debt instruments, derivatives and mutual funds are traded electronically on the BSE On-line Trading (BOLT) platform, normally between 09:15:00 hours to 15:30:00 hours from Monday to Friday, with a minimum tick size of 5 paisa and a settlement cycle of T+2 days.

BSE provides a separate trading window for execution of large trades, and information on such large Block Deals⁵ is disseminated to the public through its websites on the same day, after the market hours.

2.4.2 Indian Primary Capital Market

The Indian primary capital market has undergone significant reforms in the past two decades. From the early 1990s, a host of liberalization initiatives were undertaken to introduce important changes in the regulatory norms and market microstructure of the Indian securities market. Previously, the process of capital issuance in the primary market was controlled and governed by the Controller of Capital Issues (CCI), a department of the Ministry of Finance, through the Capital Issues (Control) Act, 1947. The price and volume of new issues arriving at the market were fixed by the CCI. Finally, in 1992, Securities Exchange Board of India (SEBI) was set up as the new regulator in place of CCI. Subsequently, SEBI brought many regulations to improve the efficiency of the price discovery process in

⁴ Source: World Federation of Exchanges (Ranking is based on market capitalization of stock exchanges, as on January, 2013).

⁵ In BSE, a Block Deal is defined as a trade with a minimum order size of 500,000 shares, or INR 50 million, executed through a single transaction.

the Indian primary market. For example, book building mechanisms were introduced to allow issuers to gauge the investor demand and discover the market clearing price in a much more efficient and transparent manner.

Currently, Indian companies who wish to raise capital from the primary market by way of an initial public offering (IPO) can place their shares through the fixed price method, book building method, or a combination of both. In a fixed price issue, the issue price is made known to the investors in advance, before the securities are offered. On the other hand, in a book building issue, the issuer can offer up to a 20% price band, and investors are allowed to submit bids anywhere between the floor price and the ceiling price. Retail individual investors⁶ have the additional option of choosing to bid at the cut off price. Bidding is done electronically on the exchanges, and bidding demand is displayed on the stock exchange at the end of each day during the book building period.

At the end of the book building period, the underwriters review the aggregate demand schedule and decide upon the issue price in consultation with the issuer. Finally, the offered shares are allocated to the winning bids within each investor category, on a proportionate basis. The book building method facilitates the price and demand discovery process, and therefore, remains the most popular mechanism of price discovery process in India, as well as abroad.

3. Data and Methodology:

3.1 Data and Descriptive Statistics

⁶ The Indian primary capital market classifies all investors under three broad categories. The institutional investors belonging to the class of mutual funds, venture capital funds, foreign institutional investors, public financial institutions, scheduled commercial banks, insurance companies and pension funds come under the classification of Qualified Institutional Buyers (QIB). Individual investors who are submitting bids for a value of not more than INR 200,000 belong to the segment of Retail individual investors (RII). Finally, investors who do not fall within the definition of the above two segments are classified as Non-Institutional Investors (NII). Please see SEBI (ICDR) regulations for additional details.

We identify all IPOs of Indian firms which were listed on the Bombay Stock Exchange (BSE) stock exchange between May 2010 and November 2011⁷. We hand collect data for each IPO from three sources, namely, Prowess database of Centre for Monitoring Indian Economy or CMIE (for financial, accounting and secondary market data of IPO issuing companies), Prime Database Services or PDS (for data relating to public issues) and SEBI website (for prospectuses of IPOs). In addition to that, we access the BSE trade level data for the first 20 days of IPO aftermarket trading for each of the 70 IPOs in our sample from the Finance Laboratory of Indian Institute of Management, Calcutta. The BSE trade level data contains the BSE scrip code of the security, the prices and volumes of each trade, the best bid and best ask quotes prevailing at the time of the trade, and the corresponding date and time stamp of each transaction.

Over the sample period, PDS reports 81 IPOs. Out of these, we exclude 8 IPOs because of ongoing SEBI investigations on these issuing companies for listing day price manipulation⁸ and IPO share allotment irregularities⁹. We also exclude another 3 IPOs because of unavailability of corresponding BSE trade level data¹⁰. This results in a final sample of 70 IPOs. For this sample, we filter out our relevant trade level information on 8,331,356 transactions that were traded on the BSE between 09:15:00 hours and 15:30:00 hours during the first 20 trading days of IPO aftermarket.

⁷ We have access to BSE trade level data starting from May 2010. Therefore, we choose IPOs in our sample which got listed on the BSE from May 2010 onwards.

⁸ We exclude 7 IPOs (BHARATIYA GLOBAL INFOMEDIA LTD., BROOKS LABORATORIES LTD., PG ELECTROPLAST LTD., RDB RASAYANS LTD., TIJARIA POLYPIPER LTD., ONELIFE CAPITAL ADVISORS LTD. and TAKSHEEL SOLUTIONS LTD.) from our analysis which were barred from trading following an investigation by SEBI for price manipulation on listing day. See the article by the Press Bureau published in the newspaper, *Business Line*, on December 28, 2011, under the title “SEBI bars 7 cos for listing-day price rigging”, for a brief description of the report.

⁹ We also exclude one IPO (VASWANI INDUSTRIES LTD.) from our analysis which was advised to withhold its listing of securities in the stock exchanges following an investigation by SEBI for irregularities in IPO share allotment. See the article by Press Bureau published in the newspaper, *The Indian Express*, on May 19, 2011, under the title “SEBI stops Vaswani Industries listing”, for a brief overview of the SEBI enquiry notice

¹⁰ We could not obtain BSE trade level data for each of the 20 trading days following the listing of 3 IPOs in our sample (CANTABIL RETAIL INDIA LTD., SHEKHAWATI POLY-YARN LTD., and SERVALAKSHMI PAPER LTD.). Therefore, we had to drop these IPOs from our sample.

We collect several variables on IPO characteristics (issue size, issue volume, issue price, average IPO grade¹¹, syndicate size, IPO oversubscription numbers for institutional investor category, retail investor category and the overall IPO issue) and firm characteristics (pre-IPO total assets, pre-IPO sales, pre-IPO PAT, age, book value of debt and equity and post-IPO promoter holding) for each firm from PDS and CMIE.

Table 1 reports the details about the composition of our final sample. There are 7 IPOs affiliated to domestic Indian business groups¹², and 5 IPOs affiliated to the government¹³. Almost all the IPOs, except one, are offered through book-building method. The remaining IPO is offered through fixed-price method. Overall, 41 IPOs are listed in 2010, while remaining 29 IPOs are listed in 2011. Table 2 describes the structure of the sample trade data used in our analysis. The definitions of all the variables are provided in Table 3.

Table 4.1 provides the descriptive statistics of the firm characteristics (Panel A) and IPO characteristics (Panel B), while Table 4.2 (Panel C) provides the descriptive statistics of the VPIN variables and post-issue trading and liquidity characteristics. The average size of firms in our sample is INR 25 billion, with an average post-IPO promoter holding of 59% and leverage ratio of 33%. The average underpricing for the entire sample is 15%. Marisetty and Subrahmanyam (2010) find underpricing in excess of 100% for Indian IPOs issued during 1991 – 2006, while Deb and Marisetty (2010) report an average underpricing of 21% for a sample of 163 IPOs during April 2006 – March 2009. In contrast, our sample focuses on a smaller set of 70 IPOs issued during May 2010 – November, 2011.

¹¹. The IPO grade is a rating provided by a SEBI-registered, independent rating agency based on the fundamentals of the company and characteristics of the IPO issue. In 2007, SEBI introduced a regulation which made IPO grading mandatory for Indian IPOs. See Deb and Marisetty (2010). However, on 24th December, 2013, SEBI amended this regulation and made IPO grading mechanism ‘voluntary’ instead of ‘mandatory’. See the article by Special Correspondent published in the newspaper, *The Hindu*, on December 24, 2013, under the title “SEBI makes IPO grading mechanism voluntary”, for a brief overview of the SEBI amendment.

¹² Most of the Indian domestic business groups are owned and controlled by families. See, for example, Khanna and Palepu (2000), and Marisetty and Subrahmanyam (2010).

¹³ These are the IPOs issued by companies that are controlled and regulated by the governments, both state and central (national). In our paper, we refer to such companies as Public Sector Units (PSUs).

We attribute the reduced level of underpricing in our sample to two main factors. First, there have been significant improvements in the Indian primary market price discovery process with the introduction of IPO book building mechanisms. Second, the ongoing global financial crisis affected both the primary and secondary capital market in India. However, consistent with the IPO underpricing literature, we still find significantly positive first day returns.

The average issue size in our sample is INR 5 billion in value terms, and 56 million shares, in terms of volume of shares issued. The syndicate size in our sample ranges between 1 and 9, with a mean value of 2 underwriters per IPO. Examining the IPO primary market demand, we find that the retail investor category is on an average 6.4 times oversubscribed, while the average oversubscription rate in the institutional investor segment is 7.8 times. However, we observe wide variation in primary market demand across different IPOs, indicated by the range in overall IPO subscription rates (from 0.9 times to 56.2 times).

The summary statistics for the VPIN variables are calculated by averaging the VPIN values over different horizons of trading in the IPO aftermarket. We observe a monotonically decreasing trend in the pattern of VPIN values in the IPO aftermarket. For example, the probability of informed trading during the first hour of aftermarket trading is 52%, and it subsequently reduces to 45% when averaged over the first day of IPO listing. The average adverse selection risk further reduces to 40% during the first week, and 38% during the first month of aftermarket trading. This pattern is consistent with our first hypothesis which suggests that the ex-post adverse selection risk should be greatest at the start of the secondary market trading when information asymmetry problems are most acute, and gradually decline thereafter as more and more information arrives in the public domain reducing the aggregate level of information asymmetry among the traders.

As evident from Table 4.2 (Panel C), we have calculated the mean of VPIN variables over overlapping intervals of IPO aftermarket trading. This is done to minimize the number of missing

values of VPIN variables. Panel B of Table 6 shows that the number of volume buckets reduces drastically after the initial few days of IPO listing. Since we require at least 50 volume buckets for VPIN estimation in each time interval, we do not exclude the initial observations while calculating the average VPIN values over a wider horizon of aftermarket trading. For example, the average VPIN value on the first day of IPO listing also includes all VPIN values calculated during the first hour of aftermarket trading. This method of designing the VPIN proxies does not qualitatively affect our results, and only provides a more robust support to our empirical findings.

In our sample, the daily average volume of shares traded is about 3 million, with a mean daily turnover ratio of 11.5%. This indicates that the IPO shares are highly liquid in the immediate aftermarket, and is consistent with empirical findings of other studies on IPO aftermarket. The average daily volatility is around 0.20%.

Table 5 presents a summary of the aftermarket trading and liquidity characteristics, averaged over different horizons in the IPO aftermarket. Consistent with the literature on liquidity studies of IPO aftermarket¹⁴, we find that there is an abnormally high level of liquidity on the day of IPO listing, and the liquidity level stabilizes over the subsequent weeks of aftermarket trading. For example, on an average, around 8.6 million shares get traded daily across 12,684 trades during the first week of listing, and this trading intensity gradually reduces to an average daily trading volume of 0.7 million shares across 2,521 trades during the 4th week of IPO aftermarket. Consistent with this, the average quoted spreads and the effective spreads are far tighter on the first week (17 paisa and 0.13%, respectively) than on the 4th week (31 paisa and 0.25%, respectively) of trading since IPO listing. Following the empirical

¹⁴ See, for example, Corwin, Harris and Lipson (2004), Li, Zheng and Melancon (2005), Ellul and Pagano (2006) and Zheng and Li (2008).

literature on liquidity analysis¹⁵, we adopt the daily turnover ratio as the liquidity proxy to account for the effect of liquidity characteristics on the ex-post adverse selection risk in the IPO aftermarket.

3.2 Methodology

In our paper, we adopt a measure of adverse selection risk based on the order flow toxicity, called Volume-Synchronized Probability of Informed Trading or VPIN. This approach based on the VPIN toxicity metric was initially proposed by Easley, Lopez de Prado and O'Hara (2012), as an update of the original PIN measure (Easley, et al. (1996)). The original PIN measure calculates the probability of an order coming from an informed trader by estimating few unobservable parameters assuming a mixture of Poisson distributions of daily buy and sell volumes on securities. On the other hand, the volume based VPIN metric does not require estimation of any non-observable parameters. In this new framework of measuring order flow toxicity in a high frequency trading environment, the buy and sell volumes are classified using a bulk volume classification algorithm which aggregates trades over volume intervals and estimates the fraction of buy and sell volume using the standardized price change during the volume intervals.

The VPIN metric has several advantages over the original PIN measure. First, the VPIN measure can be used as a real time risk management tool to monitor and capture adverse selection risk resulting from intraday variation in participation rates of informed and uninformed traders, which the original PIN model cannot capture (Abad and Yague (2012)). Second, the VPIN metric is updated after each volume bucket. Since volume is often considered a proxy of information arrival in the microstructure literature, the rate at which the VPIN metric gets updated can approximate the rate of information arrival in the market. Finally, while Lee-Ready algorithm (Lee and Ready (1991)) is a discrete trade classification technique and signs volume as either buy or sell, the bulk volume algorithm adopted for

¹⁵ See, for example, Roll (1981), Amihud and Mendelson (1986), Ellul and Pagano (2006), Mantecon and Poon (2009), Deb and Marisetty (2010) and Jiang and Li (2013).

VPIN calculation is a continuous classification technique where a fraction of the volume is classified as buys based on the standardized price change during each volume bucket.

Following Easley, Lopez de Prado and O'Hara (2012), we argue that order aggregation over short intervals and volume classification in probabilistic terms can mitigate the effects of order splitting. In high frequency trading, trades are not spaced equally in terms of time. Rather, intensity of trades varies over time, revealing different amounts of information to the market. Therefore, sampling by volume buckets enables us to partition the trading session into segments of equivalent information content. The VPIN metric then becomes a function of the trade imbalances in these different equal volume buckets and a signal of the presence of adverse selection risk, and is expected to have a significant economic impact on the liquidity providers.

In this paper, we calculate buy and sell volumes using one-minute time bars, during which all the trades are aggregated and price changes are computed. We also calculate the volume bucket size by dividing the average daily volume by 50 (which is the number of buckets over which the average order imbalance is calculated in our sample). We classify volumes in each time bar as buy or sell initiated in probabilistic terms, following the bulk volume classification procedure. Then, we calculate order imbalance as the absolute value of the difference between the buy and sell volume for each time bar. Finally, we obtain the VPIN metric as the average of order imbalances for the sample of 50 volume bucket, using the following formulae:

$$VPIN = \frac{\alpha\mu}{\alpha\mu + \varepsilon_b + \varepsilon_s} \approx \frac{E[V_\tau^{Sell} - V_\tau^{Buy}]}{E[V_\tau^{Sell} + V_\tau^{Buy}]} = \frac{\sum_{\tau=1}^n OI_\tau}{n * VBS}$$

The first equality follows from the original PIN model, where α is the probability of bad news, μ is the rate of arrival of informed traders, and ε denotes the rate of arrival of uninformed traders. In this framework, the numerator $\alpha\mu$ is the arrival rate of information based orders, while the denominator

$\alpha\mu + \varepsilon_0 + \varepsilon_s$ is the arrival rate of all orders. The second equality shows that VPIN is the ratio between the expected order imbalance and the expected total number of trades. The VPIN metric is updated after each volume bucket is filled, in a rolling window process. So, when we drop bucket 1 and fill bucket 51, the new VPIN is calculated on buckets 2 to 51. Since our sample size for VPIN (n) is 50, and the volume bucket size (VBS) is also one-fiftieth of the average daily volume, the VPIN metric calculated over 50 buckets would correspond to daily average VPIN on a day of average trading volume.

To examine the evolution of adverse selection risk in the IPO aftermarket, we follow Li, McNish and Wongchoti (2005) and conduct the Jonkheere-Terpstra (JT) trend analysis, which is a non-parametric test for ordered differences among classes. For example, in our study, the JT trend analysis tests the null hypothesis that the VPIN values calculated over different horizons of aftermarket trading are equal, against the alternative hypothesis that they are highest at the beginning of the secondary market trading, and reduces monotonically over time in the IPO aftermarket. We also conduct the JT test in our univariate trend analysis section to test the relationship between the degree of IPO underpricing and the level of aggregate information asymmetry among the traders in the IPO aftermarket.

In our univariate analysis on the determinants of adverse selection risk in the IPO aftermarket, we conduct non-parametric Wilcoxon signed rank test for the median difference of VPIN values between groups of firms partitioned on the basis of various firm characteristics, IPO characteristics and liquidity characteristics. Subsequently, we also follow up with a multiple linear regression analysis to find the effect of each of the determinants of adverse selection risk in the IPO aftermarket, after controlling for the effect of all the other factors. Our regression equation for the determination of ex-post adverse selection risk in the IPO aftermarket is as follows:

$$VPIN = \alpha_0 + \alpha_1 \text{underpricing} + \alpha_2 \log_pre_ipo_assets + \alpha_3 \text{post_ipo_promo_stake} + \alpha_4 \text{synd} + \alpha_5 \log_issue_size + \alpha_6 \text{turnover} \dots\dots\dots (1)$$

In the regression analysis mentioned above, we separately examine the effect of firm characteristics, IPO characteristics and liquidity characteristics on ex-post adverse selection risk measured at various time intervals away from the moment of IPO listing – 1 hour (model 1), 2 hours (model 2), 3 hours (model 3), 1 trading day (model 4), 1 trading week or 5 trading days (model 5) and 1 trading month or 20 trading days (model 6).

The set of explanatory variables in our regression model (1) follows from the hypotheses developed earlier in our paper. Consistent with the argument we put forward in the development of our hypotheses, we expect a positive relation between the VPIN measure of ex-post adverse selection risk in the IPO aftermarket and the IPO issue size, IPO syndicate size and Post-IPO promoter holding. Similarly, we also expect a negative relation between the VPIN measure of ex-post adverse selection risk in the IPO aftermarket and the initial IPO underpricing, firm size and daily average turnover ratio.

In our regression results, we calculate and present the t-statistics based on White (1980) heteroskedasticity-consistent standard errors for all the models.

4. Results and Analysis:

4.1 Evolution of Adverse Selection Risk in the IPO Aftermarket

In this section, we investigate the evolution of ex-post adverse selection risk in the IPO aftermarket, by examining the time series pattern of VPIN values calculated over different horizons of aftermarket trading. In particular, we test our hypothesis H1a and H1b, which proposes that the order flow toxicity measure of ex-post adverse selection risk should have a monotonically decreasing pattern in the IPO aftermarket, as more and more information arrives in the public domain and information asymmetry problems become increasingly less pronounced.

Panel C in Table 4.2 shows the descriptive statistics of VPIN values calculated over different horizons of aftermarket trading. We clearly observe that the average VPIN value declines

gradually and monotonically over time in the IPO aftermarket. For example, on the day of IPO listing, the mean (median) value of VPIN over the first hour of trading is 0.52 (0.55), and it subsequently drops to 0.45 (0.46) when averaged over the first five hours of trading. Similarly, the mean (median) value of VPIN averaged over the first day, first week and first month of aftermarket trading show a declining trend from 0.45 (0.46) to 0.40 (0.41), and finally to 0.38 (0.38) respectively. The evidence supports our hypothesis H1a, suggesting a monotonic, decreasing trend of adverse selection risk in the IPO aftermarket.

Panel C in Table 6 shows the VPIN distribution for first 100 volume buckets for all IPOs in our sample, as well as for the Hot and Cold IPOs. The three graphs indicate that the ex-post adverse selection risk undergoes a sharp decline in the immediate aftermarket of an IPO. For example, the full sample VPIN falls from an average level of 0.56 to 0.42, a reduction in the adverse selection risk by about 25%, by the time the 100th volume bucket get filled in the IPO aftermarket. Panel D of Table 6 shows the VPIN distribution for all possible volume buckets. In this graph, consistent with our hypothesis H1a, we observe that the VPIN values continue to decrease over time, although the rate of decline significantly drops down after first couple of days. Further, we also observe that the time series pattern of VPIN values exhibits a monotonically diminishing trend for hot IPOs as well as cold IPOs, which is consistent with our hypothesis H1b.

Finally, we conduct the Jonckheere-Terpstra (JT) trend analysis to test the null hypothesis that the VPIN values calculated over different horizons of aftermarket trading are equal, against the alternative hypothesis that they are highest at the beginning of the secondary market trading, and reduce monotonically as the time horizon is extended. Panel A in Table 7 reports the test results for hypothesis H1a. Jonckheere-Terpstra tests reject the null hypothesis, with a Jonckheere-Terpstra Z-statistic of 9.07. Average VPIN in the first hour of aftermarket trading is 52.38%, and declines to 45.45% at the end of the IPO listing day, 40.47% at the end of the first week of aftermarket trading, and 37.53% at the end of the first month of aftermarket trading.

Further, we conduct Jonckheere-Terpstra tests to examine the time series trend in the ex-post adverse selection for groups of firms partitioned on the basis of IPO underpricing. Panel B in Table 7 reports the test results for hypothesis H1b. Consistent with our hypothesis, we find that the adverse selection risk reduces monotonically for all groups of firms, even after partitioning them on the basis of the degree of IPO underpricing. For example, for the group of firms with lowest quartile of IPO underpricing, the mean probability of informed trading declines from 55.67% in the first hour of aftermarket trading to 46.61% at the end of the IPO listing day, and to 37.14% at the end of the first month of aftermarket trading. Jonckheere-Terpstra tests reject the null hypothesis, with a Jonckheere-Terpstra Z-statistic of 5.84. We find similar evidence of monotonically decreasing pattern of aftermarket adverse selection risk for group of firms in each quartile of IPO underpricing, confirming our hypothesis H1b.

In conclusion, our results provide insights into the evolution of ex-post adverse selection risk in the IPO aftermarket. The IPO microstructure literature suggests that information asymmetry problems should become increasingly less acute in the IPO aftermarket, as more information becomes public and the level of information asymmetry between the investors reduces over time. Consistent with this, we find that the order flow toxicity measure of ex-post adverse selection risk has a monotonically decreasing trend in the IPO aftermarket, and this time series pattern is observed for all types of IPOs, irrespective of the degree of IPO underpricing.

4.2 Determinants of Adverse Selection Risk in the IPO Aftermarket

We now investigate the determinants of ex-post adverse selection risk in the IPO aftermarket. We divide the group of variables influencing the order flow toxicity measure of adverse selection risk under three categories. First, we consider the impact of IPO characteristics such as IPO issue size and IPO syndicate size, on the ex-post adverse selection risk in the IPO aftermarket. Next, we

examine the explanatory power of firm characteristics such as firm size and post-IPO promoter holding in determining the ex-post adverse selection risk. Finally, we investigate the influence of liquidity characteristics such as turnover ratio on the evolution of adverse selection risk in the IPO aftermarket.

In our analysis in this section, we conduct univariate median tests between groups of firms partitioned on the basis of each of the control variables discussed above. For example, to examine the impact of IPO issue size on VPIN values, we divide our sample firms into two groups. The ‘High Group’ contains all the firms with above median IPO issue size, while the ‘Low Group’ contains the remaining firms with IPO issue size less than the median value. Finally, we conduct a non-parametric Wilcoxon signed rank test for the difference of median VPIN values calculated for these two groups of firms. We examine the effect of these variables on the ex-post adverse selection risk across different time horizons of IPO aftermarket trading.

4.2.1 Impact of IPO Characteristics on Adverse Selection Risk in the IPO Aftermarket

Table 8 presents the results of the univariate median tests for VPIN values calculated on the day of IPO listing (Panel A), as well as over a longer horizon in the IPO aftermarket (Panel B). We find that the VPIN value calculated on the day of IPO listing is significantly influenced by both IPO issue size and IPO syndicate size. For example, the median VPIN value in the first hour of IPO aftermarket trading (VPIN_1h) is 0.5927 for groups of firms with higher than average IPO size, which is significantly greater than the median VPIN value for firms with lower than average IPO size (0.5161). Similarly, the median value during the first hour of aftermarket trading is 0.6194 for firms with higher than average IPO syndicate size, which is significantly greater than the median VPIN value for firms with lower than average IPO syndicate size (0.5301). However, the difference in median VPIN values is not statistically significant in the IPO aftermarket over a longer horizon of one week or one month, as indicated by results shown in Panel B.

The results demonstrate that IPO characteristics such as IPO issue size and IPO syndicate size has a significantly positive relation with the ex-post adverse selection risk on the day of IPO listing, confirming both our hypothesis H2a and H2b. However, we note that the influence of these two variables on the adverse selection risk is weaker beyond the IPO listing day, as the difference in median VPIN values become statistically insignificant in the subsequent weeks of IPO aftermarket trading. Consistent with the literature, our findings suggest that larger sized IPOs and larger IPO syndicates can exacerbate the ex-post adverse selection risk on the day of IPO listing, although the effects are not likely to sustain in the subsequent trading days.

4.2.2 Impact of Firm Characteristics on Adverse Selection Risk in the IPO Aftermarket

The results of univariate median tests in Table 8 also show that the VPIN value calculated on the day of IPO listing is significantly influenced by firm characteristics such as post-IPO promoter stake. For example, the median VPIN value in the first hour of IPO aftermarket trading (VPIN_1h) is 0.5699 for groups of firms with higher than average post-IPO promoter holding, which is significantly greater than the median VPIN value for firms with lower than average post-IPO promoter holding (0.5231). The difference remains statistically significant even over the first week and first month of aftermarket trading. However, we do not find any statistically significant effect of firm size on the VPIN value, either on the day of listing or over the subsequent weeks.

The results suggest that firm characteristics such as post-IPO promoter holding has a significantly positive relation with the ex-post adverse selection risk in the IPO aftermarket, confirming our hypothesis H2d. However, we do not find any such evidence in support of our hypothesis H2c, and fail to observe any influence of firm size on the ex-post adverse selection risk in the univariate test results. Consistent with the IPO literature, our findings suggest that firms with higher post-IPO promoter holding are likely to face greater ex-post adverse selection risk in the IPO aftermarket.

4.2.3 Impact of Liquidity Characteristics on Adverse Selection Risk in the IPO Aftermarket

The results of the non-parametric median tests in Table 8 show that the liquidity characteristics of a security as measured by the average daily turnover ratio has a significantly negative relationship with the probability of informed trading in the IPO aftermarket. We find that in the first hour of IPO aftermarket trading, the median VPIN value ($VPIN_{1h}$) is 0.5141 for groups of firms with higher than average turnover ratio, which is significantly lower than the median VPIN value for firms with lower than average turnover ratio (0.5965). Additionally, this negative relationship is found to be robust over different horizons of VPIN calculation in the IPO aftermarket trading.

We infer from our results that liquidity characteristics as measured by average daily turnover ratio have a significantly positive relation with the ex-post adverse selection risk in the IPO aftermarket. This confirms our hypothesis H2e. Consistent with the microstructure literature, our findings suggest that IPO stocks which are actively traded in the IPO aftermarket face significantly lower adverse selection risks that may arise from informed trading.

In summary, we find that the ex-post adverse selection risk in the IPO aftermarket is determined by various IPO and firm characteristics, as well as the liquidity characteristics in the IPO aftermarket. In particular, we find that firms with higher IPO issue size, larger IPO syndicate and greater post-IPO promoter holding face significantly higher adverse selection risks in the IPO aftermarket. Finally, stocks that are highly liquid in the IPO aftermarket experience significantly lesser probability of informed trading, and hence face lower adverse selection risks in the aftermarket.

4.3 IPO Underpricing, Information Production and Adverse Selection Risk in the IPO Aftermarket

In the final part of this study, we examine whether the information production induced by the IPO underpricing mitigates the ex-post adverse selection problem in the IPO aftermarket. The literature on IPO book building and allocation suggests that underwriters deliberately underprice an IPO to induce informed, institutional investors to truthfully reveal their private information on the IPO

valuation (Beneviste and Spindt (1989), Loughran and Ritter (2002) and Ljungqvist and Wilhelm (2003)). In our paper, we conduct both univariate trend analysis and multivariate regression analysis to investigate the association between the IPO underpricing and ex-post adverse selection in the IPO aftermarket.

4.3.1 Univariate Trend Analysis

To capture the decreasing pattern of adverse selection risk with increasing level of IPO underpricing, we divide the firms in our sample into four groups, partitioned on the basis of the degree of IPO underpricing. Firms with an IPO underpricing less than the first quartile are put into the first group, those with an IPO underpricing ranging between the first quartile and the median underpricing are put into the second group, and so on. Panel B in Table 7 shows the mean value of various VPIN variables for each group of firms. We conduct the Jonckheere-Terpstra (JT) trend analysis to test the null hypothesis that the mean value of VPIN values calculated for each group of firms partitioned on the basis of degree of IPO underpricing are equal, against the alternative hypothesis that the VPIN values are highest for the group of firms with lowest IPO underpricing, and reduce monotonically in the subsequent groups as the average level of IPO underpricing increases.

We observe that the Jonckheere-Terpstra tests reject the null hypothesis for each of the VPIN values calculated on the day of IPO listing. For example, for the average VPIN value in the first hour of aftermarket trading, the null hypothesis is rejected with a Jonckheere-Terpstra Z-statistic of 2.21, as the probability of informed trading in the IPO aftermarket reduces from 55.6% in the least underpriced group to 42.83% in the highest underpriced group of firms. However, we do not observe any evidence of monotonic trend in the VPIN values over a longer horizon of aftermarket trading.

Overall, the univariate trend analysis provides evidence in support of our hypothesis H3. We find that the order flow toxicity measure of ex-post adverse selection risk is negatively related to the degree of IPO underpricing on the day of IPO listing, although the negative association becomes weaker in the subsequent trading days. As a robustness check, we follow up our investigation on the association

between IPO underpricing and ex-post adverse selection risk with a multivariate regression analysis, which controls for the effects of various other determinants of ex-post adverse selection risk in the IPO aftermarket.

4.3.2 Multivariate Regression Analysis

In this section, we examine the impact of IPO underpricing on ex-post adverse selection risk in the IPO aftermarket using a multiple linear regression model. Table 10 reports the results of the regression analysis. We use VPINs calculated at different time horizons in the IPO aftermarket as the dependent variable. Following our analysis on the determinants of ex-post adverse selection in the IPO aftermarket, we control for the effects of IPO characteristics such as IPO issue size and IPO syndicate size, firm characteristics such as firm size and post-IPO promoter holding, and liquidity characteristics such as average daily turnover ratio in our regression model.

Table 9 reports the cross-sectional pearson correlation coefficients for the set of variables used in our linear regression model for VPIN determinants. For ease of demonstration, we include only two proxies of VPIN measure (*vpin_1h* and *vpin_1d*) in our regression table. We find that these two proxies remain highly positively correlated (0.63), even at 1% level of statistical significance. We observe that all the signs of the correlation coefficient, except for firm size, are consistent with our proposed hypotheses. For example, the VPIN measures of ex-post adverse selection risk in the IPO aftermarket is positively correlated with IPO issue size, IPO syndicate size and post-IPO promoter holding. Similarly, consistent with our hypotheses, both the VPIN measures are negatively correlated with initial underpricing and average daily turnover ratio. However, contrary to our hypothesis H2c, we find that the VPIN measure is positively correlated with firm size. This might be due to the high correlation between IPO size and firm size (0.82). Our multivariate analysis controls for this effect, and finds evidence in support of our hypothesis H2c in the next section. We also note that the average daily turnover ratio exhibit relatively high correlation with all the other explanatory variables of VPIN in our regression

model. However, none of the correlations among the dependent variables are significant enough to cause any issues of multicollinearity, as evidenced by relatively low variance inflation factors ($VIF < 10$) in all our regression models.

The results in Table 10 show that IPO underpricing has a significantly negative effect on the ex-post adverse selection risk in the immediate aftermarket, on the same day of IPO listing. However, we do not find any evidence of significant impact of IPO underpricing on the adverse selection risk in the subsequent weeks of aftermarket trading. We observe that both firm size and turnover ratio have a strong, significantly negative relationship with the ex-post adverse selection risk in the IPO aftermarket. We also find that post-IPO promoter stake and IPO issue size have a significantly positive effect on the adverse selection risk in the IPO aftermarket. However, the effect of syndicate size on ex-post adverse selection risk is found to be statistically insignificant, although the regression coefficients carry the expected positive sign.

Overall, the regression results confirm our previous findings on the investigation of determinants of adverse selection risk. The results in Table 10 support our hypothesis in H3, as well as the hypotheses H2a – H2e which relate various firm characteristics, IPO characteristics and liquidity characteristics with the ex-post adverse election risk in the IPO aftermarket.

In conclusion, we find that the information production induced through IPO underpricing mitigates information asymmetry problem on the IPO listing day, and reduces the risk of informed trading in the IPO aftermarket. The results are consistent with the IPO book building literature, which suggest that information production is greater in IPOs which are more heavily underpriced. The results also confirm our hypothesis regarding the effect of various IPO characteristics, firm characteristics and liquidity characteristics on the ex-post adverse election risk in the IPO aftermarket.

5. Conclusion:

Using a sample of 70 Indian firms and a volume synchronized measure of probability of informed trading, we examine the evolution of ex-post adverse selection risk in the IPO aftermarket. We find that the adverse selection risk is highest at the beginning of the secondary market trading, and reduces monotonically in the subsequent IPO aftermarket. This is consistent with the IPO literature which suggests that the information asymmetry problems are most acute at the moment of IPO listing, and the information asymmetry between the traders reduces subsequently in the IPO aftermarket, as more and more information become public. We find that the monotonically decreasing pattern of adverse selection risk in the IPO aftermarket is robust, and consistently observed across different groups of firms with varying levels of IPO underpricing.

We investigate the determinants of ex-post adverse selection risk in the IPO aftermarket. Consistent with our hypotheses developed in this paper, we find that firms with larger IPO issue size, bigger IPO syndicates and greater post-IPO promoter holding are associated with higher ex-post adverse selection risk in the IPO aftermarket. Further, we also observe that larger firms and firms having more actively traded IPO stocks face relatively lower ex-post adverse selection risk in the IPO aftermarket.

Previous research on IPOs suggests that underwriters tend to extract truthful, private information from the informed, institutional investors during the IPO book building phase through the incentive of favorable allocation in more heavily underpriced IPOs. (Beneviste and Spindt (1989), Loughran and Ritter (2002) and Ljungqvist and Wilhelm (2003)). We extend this information production hypothesis from IPO book building literature to establish a link between the degree of IPO underpricing and the level of ex-post adverse selection risk in the IPO aftermarket. We find that IPOs that are more heavily underpriced tend to face lower risk of informed trading on the day of IPO listing.

The IPO literature has extensively documented the positive relationship between the ex-ante level of information asymmetry in an IPO and the expected IPO underpricing. However, the link between IPO underpricing and the ex-post level of information asymmetry have not been examined so far.

First, our results provide new insights on this literature gap in IPO research. Secondly, it extends the literature on IPO microstructure by studying the evolution of adverse selection risk in the IPO aftermarket, as measured by the volume synchronized probability of informed trading. Finally, this study investigates and establishes the relationship between the ex-post adverse selection risk in the IPO aftermarket and various firm, IPO and liquidity characteristics.

Table 1: Details of the Sample Data

Sample Period	May, 2010– November, 2011
Total number of IPOs	70
IPOs of firms affiliated to Indian business groups	7
IPOs of Public Sector Units	5
Book building issues	69
Fixed price issues	1
IPOs in year 2010	41
IPOs in year 2011	29

Table 2. Structure of the BSE Trade Data

The sample trade data contains information on all the transactions occurring in the Bombay Stock Exchange (BSE) for each IPO in our sample during the first 20 trading days from IPO listing. Each snapshot of the trade contains information on the company's BSE scrip code (a unique identifier, **Co_Code**), date of transaction (**Date**), time of transaction (**Time**), traded price in INR (**Price**), transaction volume in number of shares (**Volume**), and best outstanding bid (**Bid** and **Bid_Size**) and ask (**Ask** and **Ask_Size**) quotes at the time of transaction.

For example, the following is the snapshot of trade data on BSE of Ashoka Buildcon Limited (BSE Scrip Code 533271), at 09:15:00 hours, on 14th October, 2010, indicating the traded price and traded volume, along with the best outstanding bid and ask prices (in INR) and their corresponding order sizes (in number of shares) at the time of transaction. The BSE follows a strict price-time based trading priority system for its electronic order matching.

Obs	Co_Code	Date	Time	Price	Volume	Bid	Bid_Size	Ask	Ask_Size
1	533271	14Oct2010	09:15:00	325	10	325	400	325.5	31
2	533271	14Oct2010	09:15:01	325	50	325	590	325.5	31
3	533271	14Oct2010	09:15:01	325.05	100	325.05	400	325.5	531
4	533271	14Oct2010	09:15:02	325.6	110	325.2	700	325.6	254
5	533271	14Oct2010	09:15:02	325.5	50	325.5	793	325.55	100

Table 3. Definitions of Variables

This table lists down the acronyms, units and definitions of all the variables used in our analysis. The variables are calculated using the formulae as provided in the table below, from the information provided by the BSE trade level data, collected for a sample of 20 initial days of trading for 70 IPOs issued during the period of May, 2010 to November, 2011.

Variable	Unit	Definition
Trade Data		
Price	INR	Transaction price
Volume	# of shares	Volume of transaction, in number of shares traded
Bid	INR	Best bid price at the time of transaction, as per price-time trading priority rules
Bid_Size	# of shares	Order size of best bid at the time of transaction
Ask	INR	Best ask price at the time of transaction, as per price-time trading priority rules
Ask_Size	# of shares	Order size of best ask at the time of transaction
Firm Characteristics		
Pre-IPO Total Assets	INR	Total assets in the financial year, immediately preceding the IPO
Pre-IPO Sales	INR	Total sales in the financial year, immediately preceding the IPO
Pre-IPO PAT	INR	Total profit after tax in the financial year, immediately preceding the IPO
Debt-to-Equity Ratio	%	Ratio of book value of debt in the financial year immediately preceding the IPO, to the market value of the equity, calculated at the IPO offering price
Post-IPO Promoter Stake	%	Percentage ownership held by the promoters, after the IPO
Age	years	Age of the firm, calculated as the number of years between the date of incorporation and the date of IPO listing
IPO Characteristics		
Underpricing	%	Initial underpricing of IPOs, defined as (First day closing price – Offer price)/Offer price
Issue Size	INR	Size of the IPO, calculated as IPO offering price, multiplied by the number of shares issued in the IPO
Issue Volume	# of shares	Volume of the IPO, in terms of number of shares issued in the IPO
Issue Price	INR	IPO offering price
Average IPO Grade	#	Average IPO grading of the IPO issue
Syndicate Size	#	Number of syndicate members underwriting the IPO issue
Retail Oversubscription	x	Number of times the retail investor category of the IPO is oversubscribed
Institutional Oversubscription	x	Number of times the Qualified Institutional Buyer (QIB) category of the IPO is oversubscribed
Overall Oversubscription	x	Number of times the overall IPO is oversubscribed
Trading and Liquidity Characteristics		
Daily Volume	# of shares	Average daily traded volume, in number of shares traded
Daily Volatility	%	Average daily realized volatility, calculated as the standard deviation of intraday 1-minute interval returns
Daily Turnover	%	Average daily turnover ratio, calculated as the ratio of daily traded volume to the total number of shares outstanding after the IPO
Quoted Spread	INR	Average daily quoted spread, calculated as the difference between the best ask price and the best bid price at the time of transaction
Effective Spread	%	Average daily effective spread, calculated as the ratio of quoted spread to the bid-ask mid-point
VPIN Variables		
VPIN	%	Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012)
1 st hour VPIN (VPIN_1h)	%	Average VPIN value during the first hour of IPO aftermarket trading
2 hours VPIN (VPIN_2h)	%	Average VPIN value during the initial two hours of IPO aftermarket trading
3 hours VPIN (VPIN_3h)	%	Average VPIN value during the initial three hours of IPO aftermarket trading
4 hours VPIN (VPIN_4h)	%	Average VPIN value during the initial four hours of IPO aftermarket trading
5 hours VPIN (VPIN_5h)	%	Average VPIN value during the initial five hours of IPO aftermarket trading
1 st day VPIN (VPIN_1d)	%	Average VPIN value during the first day of IPO aftermarket trading
1 st week VPIN (VPIN_1w)	%	Average VPIN value during the first week of IPO aftermarket trading
1 st month VPIN (VPIN_1m)	%	Average VPIN value during the first month of IPO aftermarket trading

Table 4.1: Descriptive Statistics (Firm and IPO Characteristics). This table presents the summary statistics for a sample of 20 initial trading days of 70 IPO issues over the period of May, 2010 – November, 2011. **Panel A** describes the firm characteristics and **Panel B** describes the IPO characteristics. **Pre-IPO Total Assets** is the total asset of the firm in the financial year preceding the IPO, in INR millions. **Pre-IPO Sales** is the sales of the firm in the financial year preceding the IPO, in INR millions. **Pre-IPO PAT** is the profit after tax of the firm in the financial year preceding the IPO, in INR millions. **Debt-to-Equity Ratio** is the ratio of book value of debt in the financial year preceding the IPO to the market value of equity, calculated at the IPO offering price. **Post-IPO Promoter Stake** is the percentage ownership held by the promoters in the firm after the IPO. **Age** is the age of the firm at the time of IPO, calculated as number of years between the date of incorporation and the date of IPO listing. **Underpricing** denotes initial underpricing of IPOs, defined as (First day closing price – Offer price)/Offer price. **Issue Size** is the size of the IPO, in INR millions. **Issue Volume** is the volume of IPO, in millions of shares issued. **Issue Price** is the IPO offering price. **Average IPO Grade** is the average IPO grading of the issue. **Syndicate Size** is the size of the syndicate underwriting the IPO issue. **Retail Oversubscription** denotes the number of times the retail investor category of the IPO is oversubscribed. **Institutional Oversubscription** denotes the number of times the Qualified Institutional Investor (QIB) category of the IPO is oversubscribed. **Overall Oversubscription** denotes the number of times the overall IPO is oversubscribed. Definitions of variables are also provided in **Table 3**.

Panel A: Firm Characteristics	Units	Mean	Median	Std. Dev.	Min	Max
Pre-IPO Total Assets	INR mm	24,933	2,574	80,166	110	583,430
Pre-IPO Sales	INR mm	5,189	1,502	8,621	24	43,568
Pre-IPO PAT	INR mm	1,075	131	4,668	(2,872)	37,799
Debt-to-Equity Ratio	%	33	22	38	0	179
Post-IPO Promoter Stake	%	59	59	16	26	90
Age	years	17	15	17	3	103

Panel B: IPO Characteristics	Units	Mean	Median	Std. Dev.	Min	Max
Underpricing	%	15	7	39	(69)	154
Issue Size	INR mm	5,425	1,563	18,607	233	154,751
Issue Volume	mm shares	56	9	131	3	750
Issue Price	INR	170	114	206	10	1,310
Average IPO Grade	#	3	3	1	1	5
Syndicate Size	#	2	2	2	1	9
Retail Oversubscription	x	6.4	3.5	8.4	0.1	43.6
Institutional Oversubscription	x	7.8	1.5	12.6	0.0	49.8
Overall Oversubscription	x	8.8	3.1	12.2	0.9	56.2

Table 4.2: Descriptive Statistics (Post-Issue Trading Characteristics). This table presents the summary statistics of post-issue trading and liquidity characteristics for a sample of 20 initial trading days of 70 IPO issues over the period of May, 2010 – November, 2011. **VPIN** is the Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012). **vpin_1h** is the average VPIN value during the first hour of IPO aftermarket trading. **vpin_2h** is the average VPIN value during the initial two hours of IPO aftermarket trading. **vpin_3h** is the average VPIN value during the initial three hours of IPO aftermarket trading. **vpin_4h** is the average VPIN value during the initial four hours of IPO aftermarket trading. **vpin_5h** is the average VPIN value during the initial five hours of IPO aftermarket trading. **vpin_1d** is the average VPIN value during the first day of IPO aftermarket trading. **vpin_1w** is the average VPIN value during the first week of IPO aftermarket trading. **vpin_1m** is the average VPIN value during the first month of IPO aftermarket trading. **Daily Volume** is the average daily traded volume in thousands of shares. **Daily Volatility** is the average daily realized volatility, calculated as the standard deviation of intraday 1-minute interval returns. **Daily Turnover** is the average daily turnover ratio, calculated as the ratio of daily traded volume to the total number of shares outstanding after the IPO. Definitions of variables are also provided in **Table 3**.

Panel C: Post-Issue Trading Characteristics	Units	Mean	Median	Std. Dev.	Min	Max
1 st hour VPIN (<i>vpin_1h</i>)	#	0.52	0.55	0.14	0.07	0.77
2 hours VPIN (<i>vpin_2h</i>)	#	0.47	0.51	0.12	0.09	0.65
3 hours VPIN (<i>vpin_3h</i>)	#	0.45	0.48	0.11	0.19	0.62
4 hours VPIN (<i>vpin_4h</i>)	#	0.44	0.47	0.10	0.23	0.60
5 hours VPIN (<i>vpin_5h</i>)	#	0.45	0.46	0.09	0.22	0.64
1 st day VPIN (<i>vpin_1d</i>)	#	0.45	0.46	0.08	0.23	0.64
1 st week VPIN (<i>vpin_1w</i>)	#	0.40	0.41	0.07	0.19	0.56
1 st month VPIN (<i>vpin_1m</i>)	#	0.38	0.38	0.06	0.18	0.51
Daily Volume	'000s	3,000	508	8,785	0	191,881
Daily Volatility	%	0.20	0.17	0.12	0.04	0.60
Daily Turnover	%	11.5	5.3	13.9	0.1	69.1

Table 5: After-Market Trading and Liquidity Parameters. This table presents the summary statistics of post-issue trading and liquidity parameters for a sample of 20 initial trading days of 70 IPO issues over the period of May, 2010 – November, 2011. **Daily Trades** denote the average number of trades per trading day. **Daily Volume** denotes the average daily trading volume, in thousands of shares. **Daily Volatility** denotes the average daily volatility of a firm, calculated as the standard deviation of intraday 1-minute interval returns. **Daily Turnover** is the average daily turnover ratio, calculated as the ratio of daily traded volume to the total number of shares outstanding after the IPO. **Quoted Spread** is the average daily quoted spread, calculated as the difference between the best ask price and the best bid price at the time of transaction, in INR. **Effective Spread** is the average daily effective spread, calculated as the ratio of quoted spread to the bid-ask mid-point. **Horizon** indicates the duration over which the variable is averaged. Definitions of variables are also provided in **Table 3**.

Horizon	Trading Days	Daily Trades	Daily Volume	Daily Volatility	Daily Turnover	Quoted Spread	Effective Spread
	(#)	(#)	('000s)	(%)	(%)	(INR)	(%)
Day 1	1	25,167	27,345	0.83	91.71	0.14	0.12
Week 1	5	12,684	8,560	0.47	31.61	0.17	0.13
Week 2	5	5,374	1,766	0.31	8.02	0.21	0.17
Week 3	5	3,300	988	0.31	3.93	0.26	0.21
Week 4	5	2,521	667	0.33	2.59	0.31	0.25
Month 1	20	5,977	3,000	0.35	11.55	0.24	0.19

Table 6: Distribution of VPINs in the IPO Aftermarket. This table exhibits the distribution of VPINs over the initial 20 trading days for a sample of 70 IPOs which were listed on the BSE between May, 2010 and November, 2011. **Panel A** shows the variation in filling rates of volume buckets on the IPO listing day. **Panel B** shows the variation in filling rates of volume buckets over the first 20 trading days since IPO listing. **Panel C** shows the distribution of VPIN across the first 100 volume buckets, for all IPOs, hot IPOs and cold IPOs respectively. **Panel D** shows the distribution of VPIN across all possible volume buckets in the IPO aftermarket, for all IPOs, hot IPOs and cold IPOs respectively. **Bkt_fill** shows the numbers of volume buckets filled up. **Cum_bkt** shows the cumulative number of volume buckets filled up. **VPIN** is the Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012). **Hot IPOs** are those IPOs with above median level of underpricing in our sample. **Cold IPOs** are those IPOs with below median level of underpricing in our sample. We calculate **IPO underpricing** as (First day closing price – Offer price)/Offer price. Definitions of variables are also provided in **Table 3**.

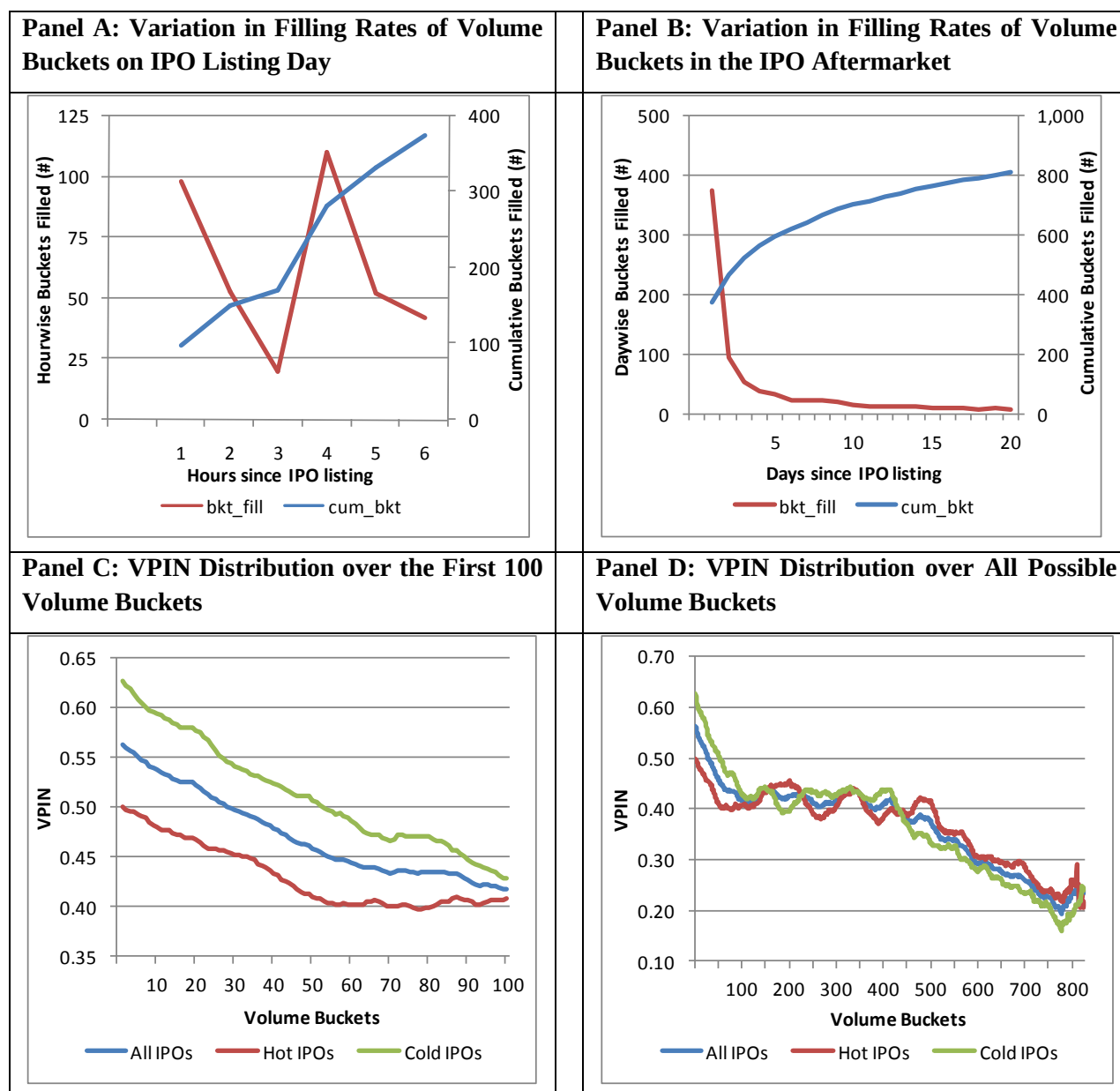


Table 7: Evolution of VPINs in the IPO Aftermarket (Jonckheere-Terpstra Test). In this table, **Panel A** provides the results of Jonckheere-Terpstra (JT) trend analysis to test the null hypothesis that the VPIN values are equal across different time intervals in the IPO aftermarket, against the alternative hypothesis that the VPIN values are larger initially and decline monotonically over time in the IPO aftermarket. **Panel B** provides the results of Jonckheere-Terpstra (JT) trend analysis to test the null hypothesis that the VPIN values are equal across IPOs grouped on the basis of level of underpricing, against the alternative hypothesis that the VPIN values are larger for groups of firms with lower IPO underpricing. In Panel B, the firms are divided into four sub-groups on the basis of the quartile values of IPO underpricing for our sample of 70 IPOs. **VPIN** is the Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012). **vpin_1h** is the average VPIN value during the first hour of IPO aftermarket trading. **vpin_2h** is the average VPIN value during the initial two hours of IPO aftermarket trading. **vpin_3h** is the average VPIN value during the initial three hours of IPO aftermarket trading. **vpin_4h** is the average VPIN value during the initial four hours of IPO aftermarket trading. **vpin_5h** is the average VPIN value during the initial five hours of IPO aftermarket trading. **vpin_1d** is the average VPIN value during the first day of IPO aftermarket trading. **vpin_1w** is the average VPIN value during the first week of IPO aftermarket trading. **vpin_1m** is the average VPIN value during the first month of IPO aftermarket trading. Definitions of variables are also provided in **Table 3**.

Panel A: Evolution of VPINs over time, for all IPOs

Time Horizon	VPIN variable	All firms
1 hour	<i>vpin_1h</i>	0.5238
2 hours	<i>vpin_2h</i>	0.4674
3 hours	<i>vpin_3h</i>	0.4466
4 hours	<i>vpin_4h</i>	0.4423
5 hours	<i>vpin_5h</i>	0.4466
1 day	<i>vpin_1d</i>	0.4545
1 week	<i>vpin_1w</i>	0.4047
1 month	<i>vpin_1m</i>	0.3753
JT Z-stat		(9.0741)
p-value		0.0000

Panel B: Evolution of VPINs over time, for IPOs grouped on the basis of level of underpricing

Groups based on Level of Underpricing							
Time Horizon	VPIN variable	Lowest	Low	High	Highest	JT Z-stat	p-value
		(<= p25)	(p25, p50)	(p50, p75)	(>=p75)		
1 hour	<i>vpin_1h</i>	0.5567	0.5337	0.5507	0.4283	(2.2059)	0.0137
2 hours	<i>vpin_2h</i>	0.4937	0.5007	0.4755	0.3872	(2.3228)	0.0101
3 hours	<i>vpin_3h</i>	0.4706	0.4835	0.4487	0.3803	(2.4398)	0.0073
4 hours	<i>vpin_4h</i>	0.4725	0.4561	0.4663	0.3779	(2.7601)	0.0029
5 hours	<i>vpin_5h</i>	0.4661	0.4413	0.4703	0.4111	(1.9045)	0.0284
1 day	<i>vpin_1d</i>	0.4675	0.4399	0.4776	0.4349	(1.1193)	0.1315
1 week	<i>vpin_1w</i>	0.4060	0.4028	0.4121	0.3973	(0.4459)	0.3278
1 month	<i>vpin_1m</i>	0.3714	0.3808	0.3906	0.3576	(0.7922)	0.2141
JT Z-stat		(5.8398)	(6.3727)	(4.5979)	(0.8542)		
p-value		0.0000	0.0000	0.0000	0.1965		

Table 8: Determinants of Adverse Selection Risk (Univariate Tests). This table reports the results of univariate median tests for comparison of VPIN values across firms partitioned on the basis of various IPO, firm and liquidity characteristics. **Panel A** provides the results of median tests over different durations of trading on the day of IPO listing. **Panel B** provides the results of median tests over different durations of trading during the first month of IPO aftermarket. The median tests are conducted for a sample of 70 IPO which were listed on the BSE between May, 2010 and November, 2011. **Issue Size** is the size of the IPO, in INR millions. **Total Assets** is the total asset of the firm in the financial year preceding the IPO, in INR millions. **Promoter Stake** is the percentage ownership held by the promoters in the firm after the IPO. **Syndicate Size** is the size of the syndicate underwriting the IPO issue. **Daily Turnover** is the average daily turnover ratio, calculated as the ratio of daily traded volume to the total number of shares outstanding after the IPO. **VPIN** is the Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012). **vpin_1h** is the average VPIN value during the first hour of IPO aftermarket trading. **vpin_2h** is the average VPIN value during the initial two hours of IPO aftermarket trading. **vpin_3h** is the average VPIN value during the initial three hours of IPO aftermarket trading. **vpin_4h** is the average VPIN value during the initial four hours of IPO aftermarket trading. **vpin_5h** is the average VPIN value during the initial five hours of IPO aftermarket trading. **vpin_1d** is the average VPIN value during the first day of IPO aftermarket trading. **vpin_1w** is the average VPIN value during the first week of IPO aftermarket trading. **vpin_1m** is the average VPIN value during the first month of IPO aftermarket trading. Definitions of variables are also provided in **Table 3**. The z-values for median comparison are calculated from two sample Wilcoxon rank-sum test. Statistical significance level of 10%, 5% and 1% is indicated by *, ** and ***, respectively.

Panel A: Univariate Median Tests on the day of IPO listing

Time horizon	First 1 hr of trading			First 2 hrs of trading			First 3 hrs of trading		
Variable	(VPIN_1h)			(VPIN_2h)			(VPIN_3h)		
Group	High Group	Low Group	Median Test	High Group	Low Group	Median Test	High Group	Low Group	Median Test
Issue Size	0.5927	0.5161	***	0.5291	0.4455	***	0.4978	0.4218	***
Total Assets	0.5770	0.5311		0.5196	0.4606		0.4797	0.4619	
Promoter Stake	0.5699	0.5231	*	0.5250	0.4472	**	0.4852	0.4314	*
Syndicate Size	0.6194	0.5301	***	0.5371	0.4489	***	0.5215	0.4372	***
Daily Turnover	0.5141	0.5965	***	0.4141	0.5265	***	0.3916	0.4898	***

Panel B: Univariate Median Tests over the horizon of 1 month following the IPO

Time horizon	First 1 day of trading			First 1 week of trading			First 1 month of trading		
Variable	(VPIN_1d)			(VPIN_1w)			(VPIN_1m)		
Group	High Group	Low Group	Median Test	High Group	Low Group	Median Test	High Group	Low Group	Median Test
Issue Size	0.4905	0.4440	*	0.4270	0.4017		0.3836	0.3637	*
Total Assets	0.4651	0.4488		0.4104	0.4157		0.3824	0.3835	
Promoter Stake	0.4777	0.4290	**	0.4307	0.3820	**	0.3892	0.3648	*
Syndicate Size	0.5018	0.4451	**	0.4292	0.4043		0.3836	0.3782	
Daily Turnover	0.4308	0.4962	***	0.3814	0.4321	**	0.3553	0.3894	***

Table 9: Correlation Table. This table reports the cross-sectional Pearson correlation coefficients for the set of variables used in the multiple linear regression model of VPIN determinants shown below. The correlation coefficients are estimated from our sample of 70 IPOs which were listed on the BSE between May, 2010 and November, 2011. **VPIN** is the Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012). The dependent variable **vpin_1h** is the average VPIN value during the first hour of IPO aftermarket trading. **vpin_1d** is the average VPIN value during the first day of IPO aftermarket trading. **Underpricing** denotes initial underpricing of IPOs, defined as (First day closing price – Offer price)/Offer price. **Log_pre_ipo_assets** is the natural logarithm of the total assets of the firm in the financial year preceding the IPO, in INR millions. **Post_IPO_promo_stake** is the percentage ownership held by the promoters in the firm after the IPO. **Synd** is the size of the syndicate underwriting the IPO issue. **Log_issue_size** is the natural logarithm of the size of the IPO, in INR millions. **Turnover** is the average daily turnover ratio, calculated as the ratio of daily traded volume to the total number of shares outstanding after the IPO. Definitions of variables are also provided in **Table 3**. Statistical significance level of 10%, 5% and 1% is indicated by *, **, and ***, respectively.

$$VPIN = \alpha_0 + \alpha_1 \text{underpricing} + \alpha_2 \log_pre_ipo_assets + \alpha_3 \text{post_ipo_promo_stake} \\ + \alpha_4 \text{synd} + \alpha_5 \log_issue_size + \alpha_6 \text{turnover}$$

Correlation Table for Variables in the VPIN Multiple Linear Regression

Variables	VPIN_1d	Underpricing	Log Pre IPO Assets	Post IPO Promo Stake	Synd	Log Issue Size	Turnover
VPIN_1h	0.63***	(0.44)***	0.26**	0.32**	0.43***	0.42***	(0.45)***
VPIN_1d		(0.17)	0.04	0.22*	0.19	0.22*	(0.31)**
Underpricing			(0.22)*	(0.04)	(0.23)*	(0.19)	0.42***
Log Pre IPO Assets				0.33***	0.73***	0.82***	(0.60)***
Post IPO Promo Stake					0.28***	0.33	(0.15)***
Synd						0.79***	(0.49)***
Log Issue Size							(0.62)***

Table 10: Determinants of Adverse Selection Risk (Multivariate Test). This table reports estimated coefficients of the parameters mentioned in the equation below. The models are estimated over a sample of 70 IPO which were listed on the BSE between May, 2010 and November, 2011. **VPIN** is the Volume-synchronized Probability of Informed Trading, calculated as per the model developed by Easley, Lopez de Prado and O'Hara (2012). The dependent variable **vpin_1h** (model 1) is the average VPIN value during the first hour of IPO aftermarket trading. **vpin_2h** (model 2) is the average VPIN value during the initial two hours of IPO aftermarket trading. **vpin_3h** (model 3) is the average VPIN value during the initial three hours of IPO aftermarket trading. **vpin_1d** (model 4) is the average VPIN value during the first day of IPO aftermarket trading. **vpin_1w** (model 5) is the average VPIN value during the first week of IPO aftermarket trading. **vpin_1m** (model 6) is the average VPIN value during the first month of IPO aftermarket trading. **Underpricing** denotes initial underpricing of IPOs, defined as (First day closing price – Offer price)/Offer price. **Log_pre_ipo_assets** is the natural logarithm of the total assets of the firm in the financial year preceding the IPO, in INR millions. **Post_IPO_promo_stake** is the percentage ownership held by the promoters in the firm after the IPO. **Synd** is the size of the syndicate underwriting the IPO issue. **Log_issue_size** is the natural logarithm of the size of the IPO, in INR millions. **Turnover** is the average daily turnover ratio, calculated as the ratio of daily traded volume to the total number of shares outstanding after the IPO. Definitions of variables are also provided in **Table 3**. The t-statistics are calculated based on White (1980) heteroskedasticity-consistent standard errors. Statistical significance level of 10%, 5% and 1% is indicated by *, ** and ***, respectively.

$$VPIN = \alpha_0 + \alpha_1 \text{underpricing} + \alpha_2 \log_pre_ipo_assets + \alpha_3 \text{post_ipo_promo_stake} + \alpha_4 \text{synd} + \alpha_5 \log_issue_size + \alpha_6 \text{turnover}$$

Dependent variable -> (Horizon)	VPIN_1h (1 hr)	VPIN_2h (2 hrs)	VPIN_3h (3 hrs)	VPIN_1d (1 day)	VPIN_1w (1 week)	VPIN_1m (1 month)
Intercept	0.4090**	0.3061*	0.3830***	0.5025***	0.4881***	0.4349***
underpricing	(0.0011)*	(0.0011)**	(0.0008)**	(0.0001)	0.0002	0.0001
log_pre_ipo_assets	(0.0347)***	(0.0237)***	(0.0206)***	(0.0237)**	(0.0195)***	(0.0145)**
post_ipo_promo_stake	0.1886**	0.2195***	0.1401**	0.1101*	0.1057*	0.0646
synd	0.0172	0.0119	0.0120*	0.0080	0.0067	0.0018
log_issue_size	0.0378**	0.0294*	0.0215	0.0146	0.0069	0.0078
turnover	(0.0031)	(0.0024)	(0.0028)**	(0.0021)***	(0.0023)***	(0.0024)***
Obs.(N)	56	59	62	65	70	70
Adj. R ²	0.3810	0.3989	0.3611	0.1584	0.1128	0.1652
F-value	0.0001	0.0001	0.0001	0.0125	0.0334	0.0072

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