รายงานฉบับสมบูรณ์

เรื่อง โครงสร้างจุลภาคของตลาดตราสารหนี้ไทย: หลักฐานเชิงประจักษ์จากการเปลี่ยนแปลงกฎระเบียบในตลาด

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Final Report

Market Microstructure :Empirical Evidence from Regulation Changes in the Thai Bond Market

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บทสรุปผู้บริหาร

โครงการวิจัยนี้ศึกษาประเด็นโครงสร้างจุลภาคของตลาดตราสารหนี้ไทย โดยมุ่งเน้นที่ผลกระทบจากการเปลี่ยนแปลงกฎระเบียบสองฉบับที่นำเสนอโดยสมาคมตลาดสารหนี้ไทย (ThaiBMA) ในปี พ.ศ. 2549 และ พ.ศ. 2552 ต่อความโปร่งใสและประสิทธิภาพของตลาดตราสารหนี้ไทย โดยศึกษาจากการเปลี่ยนแปลงของสภาพคล่อง ความผันผวนแบบก้าวกระโดด และความน่าจะเป็นของการซื้อขายโดยใช้ข้อมูลที่มีนัยสำคัญในตลาดตราสารหนี้ไทย เช่น พันธบัตรรัฐบาลไทย เป็นต้น ทั้งนี้ กฎระเบียบฉบับแรกที่ถูกบังคับใช้ในปี พ.ศ. 2549 สมาคมตลาดตราสารหนี้ไทย (ThaiBMA) ได้นำบทบัญญัติข้อ 2 ของประกาศสำนักงานคณะกรรมการกำกับหลักทรัพย์และตลาดหลักทรัพย์ฉบับที่ ส.ย. ที่ 37/2548 มากำหนดให้สมาชิกจัดส่งข้อมูลการซื้อขายให้ สมาคมตลาดตราสารหนี้ไทย (ThaiBMA) ภายใน 30 นาทีหลังจากการซื้อขายเพื่อเผยแพร่ต่อสาธารณะ กฎระเบียบฉบับที่สองบังคับใช้ ในปี พ.ศ. 2552 สมาคมตลาดตราสารหนี้ไทยออกบทลงโทษสำหรับธุรกรรมล่าช้า รายการผิดพลาด หรือธุรกรรมขาดหายไป เพื่อเสริมสร้างความโปร่งใสและประสิทธิภาพของตลาดตราสารหนี้ไทย การศึกษานี้ได้รับความอนุเคราะห์ข้อมูลดิบจากสมาคมตลาดตราสารหนี้ไทย (ThaiBMA) การวิจัยอาศัยชุดข้อมูลที่ครอบคลุมธุรกรรมพันธบัตรทั้งหมดตั้งแต่ปี พ.ศ. 2545 ถึง พ.ศ. 2562 โดยวิเคราะห์เฉพาะการซื้อขายพันธบัตรรัฐบาลเพื่อหลีกเลี่ยงปัจจัยด้านอื่นที่อาจจะกระทบการการวิเคราะห์ ผลการวิจัยคาดว่าจะให้ข้อมูลเชิงลึกที่มีค่าสำหรับนักลงทุนและหน่วยงานกำกับดูแล โดยเน้นที่ผลกระทบของกฎระเบียบความโปร่งใสต่อประสิทธิภาพของตลาด

จากการวิเคราะห์ข้อมูลการซื้อขายพันธบัตรรัฐบาลซึ่งมีจำนวนธุรกรรมที่เกิดขึ้นในช่วงเวลาที่ศึกษาทั้งสิ้น 745,911 รายการ โดยการศึกษามุ่งเน้นไปที่ระยะเวลาในการรายงานการซื้อขาย ความผันผวนของสภาพคล่อง และการกระโดดของตลาด ในแง่ของการรายงานธุรกรรม จากช่วงเวลาที่ทำการศึกษาพบว่ามีกรณีของความล่าช้าของการรายงานการซื้อขาย (delay) ที่มีค่าเป็นลบซึ่งแสดงว่ามีการรายงานก่อนเวลาในการซื้อขาย ซึ่งบ่งชี้ถึงความผิดพลาดจากการบันทึกข้อมูลโดยเจ้าหน้าที่หรือข้อผิดพลาดทางการพิมพ์ ซึ่งขณะนี้ถูกกำจัดโดยระบบการรายงานของ ThaiBMA ตั้งแต่ปี 2015 จึงทำให้ปัญหาความผิดพลาดดังกล่าวนี้หมดไปอย่างสิ้นเชิง ในอีกด้านหนึ่ง การศึกษาพบว่าธุรกรรมที่มีของความล่าช้าของการรายงานการซื้อขาย (delay) ที่มีค่าเป็นบวกแต่ต่ำกว่า 30 นาที มีถึง 85% ของธุรกรรมทั้งหมด แสดงให้เห็นว่า การปฏิบัติการรายงานตามมาตรฐานนั้นพบได้เป็นส่วนมากซึ่งสอดคล้องกับข้อกำหนดของกฎระเบียบของ ThaiBMA มีเพียงส่วนน้อยที่ไม่ปฏิบัติตามกฎระเบียบ สำหรับปัจจัยด้านสภาพคล่องซึ่งถูกวัดโดยใช้อัตราหมุนเวียน (Turnover Ratio) การวิเคราะห์แสดงให้เห็นความผันผวนของสภาพคล่องในช่วงหลายปีที่ผ่านมา โดยบางช่วงเวลามีปัญหาสภาพคล่องสูงซึ่งอาจจะเกิดจากสภาพของตลาดในช่วงเวลาหนึ่งๆ อย่างไรก็ตาม เราพบว่า

การบังคับใช้กฎระเบียบและบทลงโทษใหม่มีส่วนช่วยปรับปรุงสภาพคล่องและลดกรณีความล่าช้าในการรายงานธุรกรรมลงได้มาก เมื่อวิเคราะห์การกระโดด(Jump)ของตลาดโดยเฉพาะที่มีผลต่อสภาพคล่องรายวันพบว่ามีอิทธิพลสำคัญต่อสภาพคล่องเนื่องจากสภาพตลาดภายนอก โดยสรุป ผลการศึกษาจากงานวิจัยชิ้นนี้แสดงให้เห็นว่า ภายหลังจากที่มีการปรับเปลี่ยนเกณฑ์การรายงาน และบทลงโทษ ดังกล่าวข้างต้น ตลาดตราสารหนี้มีประสิทธิภาพยิ่งขึ้น และธุรกรรมส่วนใหญ่อยู่ในเกณฑ์การรายงานที่มาตรฐาน ดังนั้น กฎระเบียบที่ออกมามีความเหมาะสม การกำหนดเวลารายงาน 30 นาทียังคงเป็นระยะเวลาที่เหมาะสมในตลาดตราสารหนี้ไทย ผลการศึกษาแสดงให้เห็นว่า การกำกับดูแลกฎระเบียบในการรักษาเสถียรภาพและประสิทธิภาพของตลาดมีความเหมาะสม และยังอาจไม่มีความจำเป็นจะต้องปรับเวลาการรายงานให้ ช้าลงหรือเร็วขึ้น

Executive Summary

This research project investigates market microstructure issues in the Thai bond market, focusing on the impact of two regulatory changes introduced by the Thai Bond Market Association (ThaiBMA) in 2006 and 2009. The regulation in 2006 mandated that trading information be submitted to ThaiBMA within 30 minutes post-execution for public dissemination, aiming to enhance market transparency. The 2009 regulation introduced penalties for late, erroneous, or missing transaction reports, further reinforcing market transparency and efficiency. The study aims to evaluate the effectiveness of these regulations by examining changes in liquidity, volatility, and the probability of informed trading in the Thai bond market. The research utilizes a comprehensive dataset covering all bond transactions from 2002 to 2019, focusing on government bonds to avoid confounding factors. The findings are expected to provide valuable insights for investors and regulators, highlighting the impact of transparency regulations on market efficiency.

An analysis is dedicated to Government Bonds, with 745,911 transactions over the study period. The study identifies notable patterns in trading delays, liquidity fluctuations, and market jumps. In term of transaction reporting, we find instances of negative time gaps where report times precede trade times, indicating potential human or typographical errors. This is currently eliminated by ThaiBMA reporting system. In addition, the positive time gaps, indicating standard reporting practices, are more common, with 85% of total transactions reported within 30 minutes, adhering to regulatory requirements. Liquidity is measured using the turnover ratio. The analysis shows fluctuations in liquidity over the years, with certain periods exhibiting heightened liquidity issues. The implementation of new regulations and penalties has contributed to improved liquidity and reduced delay instances. Market jumps, particularly those affecting daily liquidity, were analyzed, showing significant influence on liquidity due to external market conditions. These findings indicate that reporting regulation has improved and underscore the importance of timely reporting and regulatory oversight in maintaining market stability and efficiency.

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Market Microstructure :Empirical Evidence from Thai bond market

1. Project Summary

This project focuses on market microstructure issues in the Thai bond market. Specifically, we utilize two regulations introduced by the Thai Bond Market Association (ThaiBMA) in 2008 and 2012 as exogenous events to explore market transparency and efficiency in the Thai bond market. These two regulations are as follows. First, in 2008, the ThaiBMA introduced the provisions of Clause 2 of the Notification of the Office of Securities and Exchange Commission, No. Sor.Yor. 37/2005, requiring trading information to be submitted to ThaiBMA within 30 minutes after execution for public dissemination. Second, in 2012, under Clause 20 (2) and Clause 68 of the Articles of Association of the Thai Bond Market Association, the Board of Directors of the Thai Bond Market Association issued regulations enforcing the penalty for Late Transaction, Error Transaction, or Missing Transaction. We investigate whether these introduced regulations improve market transparency and efficiency by exploring the changes in liquidity, volatility and probability of informed trading in the Thai bond market. Our expected findings will provide investors as well as regulators with valuable insights regarding the effectiveness of regulations.

2. Motivation and objective

In recent years, there has been a growing focus on the structure of the bond market. Researchers in this field have placed great emphasis on improving market transparency. A survey of European capital markets revealed that nearly all participants were in favour of greater transparency in post-trade transactions[1]. Those surveyed believed that the transparency

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[1] A survey in the annual MarketAxess and Trax European Capital Markets Forum, Andaz Hotel, Liverpool Street, London, on Thursday, 11 May 2017.

requirements of MiFID II[2] would benefit the European fixed income markets. The survey results also indicated that enhanced transparency under MiFID II would have a considerable impact on fixed income market liquidity.

Market transparency refers to the information that is accessible to market participants regarding the trading process. This includes pre-trade transparency, which concerns the details of the trade inputs and helps investors trade at the most favourable price, and post-trade transparency, which refers to recently completed transactions and enables investors to evaluate the execution quality by using this information. This definition is based on the work of O'Hara in 1995, and the idea was further developed by Foucault, Pagano, and Roell in 2013. Post-trade transparency with appropriate length of delay time will give more information on actual market activity. Several papers have investigated the impact of transparency on market liquidity using price dispersion, trading volume and other liquidity measured as proxies. Most regulators believe that greater transparency leads to the liquidity improvement in the market. It can improve the efficiency in securities and encourage investors to participate more in the market.

The market efficiency hypothesis, introduced by Fama (1963) states that financial markets are "efficient" in processing all available information to set prices for assets. Specifically, the hypothesis asserts that: i) all available information is already reflected in market prices and ii) it is impossible to consistently achieve above-average returns by using publicly available information because any potential excess returns are quickly reflected in market prices. Three forms of market efficiency hypothesis are weak, semi-strong and strong forms. The weak-form market efficiency is based on the idea of the "random walk," which is

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[2] Financial Instruments Directive (MiFID II) reporting requirements aim to boost investor protection by strengthening the transparency framework for the regulation of markets in financial instruments, including OTC markets. Under MiFID II, post-trade data must publish as close to real time as is technically possible (15 min. limit).

the concept that stock prices move randomly and independently of one another, making it impossible to consistently predict their movements based on historical data. Next, the semi-strong form efficiency suggests that price reflects all publicly available information. Finally, the strong form efficiency implies that price reflects all private information. The market efficiency hypothesis has important implications for investors and financial professionals. If markets are indeed efficient, it suggests that investors cannot consistently earn excess returns by picking undervalued securities or timing the market. Instead, the most efficient strategy would be to hold a diversified portfolio of assets that matches the investor's risk preferences.

Generally, trading cost is often used as a measure to assess the impact of increased transparency on market liquidity. When a market is more transparent, liquidity providers can offer lower trading costs, which are typically measured by the effective bid-offer spread, to uninformed traders. Additionally, enhancing transparency can decrease the price that market makers charge for exchanging securities (Pagano & Roell, 1996). Further, Naik, Neuberger, and Viswanathan (1999) argue that increased transparency can lower dealers' holding costs, which in turn can reduce trading costs in a dealer market. Such transparency can also encourage more traders to participate, giving them an advantage over dealers and ultimately reducing trading costs (Chen & Zhong, 2012). Theoretical studies suggest that spreads decline in transparent markets (Edwards, Harris, & Piwowar, 2007; Goldstein, Hotchkiss, & Sirri, 2007). Additionally, increased transparency also leads to improvement in market efficiency with lower volatility, less frequent jump and less informed traders. However, empirical findings show that the effects of increasing transparency and efficiency depend on the market structure and securities being traded.

Regulations regarding transparency differ across countries worldwide. As an illustration, in Europe, the Markets in Financial Instruments Directive II (MiFID II) mandates that trades in government bonds must be disclosed within 15 minutes and with certain limits.

In the initial years of the Trade Reporting and Compliance Engine (TRACE), another regulatory change resulted in a shorter reporting window for dealers. This change led to a decrease in execution costs for large insurance companies that utilized TRACE for transaction reporting. In general, an increase in transparency tends to improve market liquidity and eventually market efficiency. For Thailand, two related regulations regarding the post-trade transparency were introduced in 2008 and 2012 by the ThaiBMA as follows. First, in January 2008, the ThaiBMA introduced the provisions of Clause 2 of the Notification of the Office of Securities and Exchange Commission, No. Sor.Yor. 37/2005, requiring trading information to be submitted to ThaiBMA within 30 minutes after execution for public dissemination. However, the penalty for not following this requirement was not made explicit until the second event. In 2012 and revision on 21 Jan 2014, under Clause 20 (2) and Clause 68 of the Articles of Association of the Thai Bond Market Association, the Board of Directors of the Thai Bond Market Association issued regulations enforcing the penalty for Late Transaction, Error Transaction, or Missing Transaction. Dealers who report later than one working day, or do not report transactions within the next working day, or report information trading without correction and cancelation of missing or error transaction shall be fined or subject to additional penalty from the ThaiBMA. The latest announcement on 1 September 2022 maintains the reporting rule within 30 minutes. This motivates us to evaluate the effectiveness of such regulations on market transparency and efficiency.

Specifically, this project has the following objectives. First, we aim to empirically explore changes in market liquidity, pre- and post-regulations. Second, we aim to empirically explore market efficiency, proxied by probability of informed trading (PIN), introduced by Easely et al. (1996). Third, we aim to empirically employ jump based on Barndorff-Nielsen and Shephard (2004) as an alternative way to explore market efficiency. Finally, this project investigates the effect of delayed trade-reporting on market liquidity, volatility and PIN.

3. Review of related literature

3.1. The effect of transparency on market liquidity

The effect of transparency on market liquidity is a complex and multifaceted relationship that can vary depending on the context, market structure, and the specific measures of transparency being considered. The key effects and mechanisms through which transparency can impact market liquidity are as follows. Transparency could potentially improve liquidity by reducing bid-ask spread, information asymmetry, price impact, increasing market depth and trading volume. However, over-transparency could have an adverse effect as market participants could be overwhelmed by too much available information and unable to make an informed decision, leading to market instability. In line with this argument, existing studies explore the effect of transparency on market liquidity providing mixed evidence of both positive and negative effects. Studies finding positive effect of transparency on market liquidity include Pagano and Roell (1996), Flood, Huisman, Koedijk, and Mahieu (1999), Chen and Zhong (2012), Bessembinder, Maxwell, and Venkataraman (2006), Edwards et al. (2007), Goldstein et al. (2007). For example, Pagano & Roell (1996) suggest that transparency increases market liquidity and reduces market making cost as liquidity providers tend to narrow spreads, resulting in lower trading costs to uninformed traders in a more transparent market. Similarly, Flood, Huisman, Koedijk, and Mahieu (1999) document that pre-trade transparency improves market liquidity with lower bid-ask spread. Relying on Hong and Warga (2000) and Chakravarty and Sarkar (2003), Chen and Zhong (2012) estimate the average effective spread of pre-trade transparent bonds and find increased pre-trade transparency leads to market liquidity enhancement, inducing more traders to enter the bond market.

On the contrary, a negative effect of transparency on market liquidity is reported by various researchers (Bloomfield & O'Hara, 1999; Porter & Weaver, 1998; Holmstrom, 2015; Dang et al., 2015; Balakrisshnan et al., 2020). For instance, Bloomfield and O'Hara (1999) document an increase in opening bid-ask spread when transparency rises. Similarly, Porter and Weaver (1998) explore the Toronto Stock Exchange (TSE) and estimate effective spreads and the percentage bid-offer spread by using four levels of best bid and offer and its depth. They document that spreads are widened after the introduction of the available trading information up to four levels, and suggest that a decrease in liquidity is associated with transparency. Holmstrom (2015), Dang et al. (2015) and Balakrisshnan et al. (2020) suggest that disclosing detailed and complex information in a debt market appears to have an adverse rather than positive effect on trading mechanisms.

3.2. The effect of transparency on market efficiency

Transparency in market microstructure studies refers to the degree to which information about financial assets, trading activities, and market participants is readily available to all market participants. The effect of transparency on market efficiency in market microstructure studies is a complex and widely debated topic. Market efficiency is a concept that describes how well financial markets incorporate available information into asset prices. Fama (1970) proposes three main forms of market efficiency: weak, semi-strong and strong efficiency. While increased transparency can generally improve market efficiency by reducing information asymmetry and facilitating price discovery, there can also be negative consequences, particularly when transparency reaches excessive levels or when market participants engage in herding or manipulative behaviours. The optimal level of transparency may vary depending on the specific characteristics of a given market and the goals of market regulators.

Transparency plays a crucial role in the efficiency of financial markets. Market efficiency refers to the extent to which asset prices in a financial market incorporate all available information accurately and quickly. The level of transparency in a market can have a significant impact on its efficiency. Transparency ensures that relevant information, including financial statements, company news, economic data, and trading activity is readily available to all market participants. When information is easily accessible and widely disseminated, it helps to level the playing field and reduces information asymmetry among investors. This, in turn, contributes to market efficiency by allowing prices to reflect all available information more accurately. In such markets, asset prices are less likely to deviate significantly from their intrinsic values because investors have access to the same information and can make more informed investment decisions. This reduces the occurrence of mispricing and speculative bubbles. Additionally, transparency can deter market manipulation and promote a fair and efficient market environment. However, excessive transparency can lead to market noise and increased volatility as traders react quickly to minor fluctuations in information, potentially destabilizing the market. In some cases, high transparency can make it easier for manipulative trading strategies to occur, as market participants may exploit vulnerabilities in market rules and regulations. Increased transparency may also lead to herding behaviour, where traders all react to the same information simultaneously, amplifying market movements. Existing studies on the effect of transparency on market efficiency include Bloomfield and O'Hara (1999), Brandao-Marques et al. (2013), Zhang et al. (2023). For instance, Bloomfield and O'Hara (1999) document that transparency induces informational efficiency in price. Brandao-Marques et al. (2013) also argue that transparency matters and reduces herding behaviour, investor overactions and trading by sentiment. Lin (2016) explores the Taiwanese stock market and documents that increased transparency reduces market information asymmetry after opening. Chen and Lu (2016) find the positive effect of mandatory post-trade market transparency on pricing efficiency in the corporate bond market. However, Zhang and Li (2013) document that higher transparency of open call auction decreases price discovery efficiency. Zhang et al. (2023) suggest that not all traders have the same analytical skills to analyse transparent information during the trading process and that this inabillity, rather than lack of transparency drives market inefficiencies. Kakhbod and Song (2020) document that post-trade transparency hinders the price discovery process. Similarly, Barnerjee et al. (2017) suggest that transparency decreases price informativeness resulting in an informational inefficiency.

3.3. Measuring market liquidity

Measuring market liquidity is a critical component of financial analysis and risk management. The concept of liquidity encompasses the ease with which an asset can be bought or sold in the market without significantly affecting its price. Accurate measurement of market liquidity is essential for investors, traders, policymakers, and financial institutions, as it provides valuable insights into market dynamics, risk assessment, and investment strategies. It is crucial to recognize that liquidity measurement is not one-size-fits-all. Different asset classes, such as equities, bonds, currencies, and commodities, may require tailored liquidity metrics. Additionally, liquidity can vary across markets, with emerging markets often exhibiting lower liquidity compared to established ones. One commonly used liquidity measure is the bid-ask spread which is a widely recognized measure of liquidity and is often used as an initial gauge of market conditions (Easley et al., 2018). The bid-ask spread represents the cost of executing a trade immediately, with a narrower spread suggesting higher liquidity and lower transaction costs. A wider spread suggests lower liquidity, as traders incur higher transaction costs. A number of studies uses bid-ask spread such as Fleming (2003), Bessembinder, Maxwell, and Venkataraman (2006). While this metric provides a basic understanding of liquidity, it may not account for the complexities of market dynamics, such as hidden liquidity (Biais et al., 2011).

The bid-ask spread alone does not provide a comprehensive view of liquidity, as it may not reflect the depth of the market or the ability to trade large volumes without substantial price impact. The thickness of trading as measured by trading volume and value are fundamental metrics in liquidity measurement. Higher trading volumes and values typically indicate more liquid markets, as there are more participants actively trading the asset. This metric is particularly important for assessing the liquidity of publicly traded stocks and bonds. Higher trading volumes are generally associated with more liquid markets (Hasbrouck, 2009). The turnover ratio measures the proportion of total market capitalization that is traded within a specific time frame. A higher turnover ratio implies more frequent trading and can signal higher liquidity, while a lower ratio may indicate illiquidity. Empirical research has shown that trading volume can influence asset pricing, reflecting its significance in liquidity measurement (Amihud, 2002). This notion is further supported by the findings of Chordia et al. (2001), who explored the relationship between liquidity and trading activity in U.S. equity markets, emphasizing that illiquid stocks are associated with lower trading activity and higher trading costs. Moreover, Pastor and Stambaugh (2003) delved into the concept of liquidity risk and its implications for expected stock returns, highlighting that investors demand a premium for bearing liquidity risk, which is particularly pronounced in the case of illiquid assets.

Market Depth, however, assesses the number of buyers and sellers at different price levels. A deep market indicates higher liquidity, as there is a greater supply of orders waiting to be executed. A deeper market suggests a higher degree of liquidity, as there is a more extensive pool of potential buyers and sellers (O'Hara, 1995). Conversely, a shallow market may be susceptible to price fluctuations when larger orders are executed. However, depths are not appropriate for the OTC markets as there is no market information provided.

In the bond market, Bao, Pan, and Wang (2011) propose several measures of illiquidity in the U.S. bond markets. Negative covariance of price changes by trade-to-trade or daily data, gamma, is extended version of Roll’s spread measure to estimate the bid ask spread from the daily stock markets. Hameed, Helwege, Li and Packer (2019) show that corporate bond issuance increases in the liquid market. However, the illiquid bond markets in Malaysia deter the development of debt financing of the economy. Lin, Wang, and Wu (2011) examine the relationship of Amihud’s illiquidity on the bond market. They find the positive relationship between the expected corporate bond market returns and liquidity risk. Liquidity risk spread accounts for a significant portion of corporate bond risk premium. Results strongly suggest that liquidity risk is an important determinant of expected corporate bond returns.

3.4. Measuring probability of informed trading (PIN)

Before the emergance of the empirical measure of the adverse selection problem in the trading exchange, the models of trading behaviour in the first generation were designed in the dynamic manner (Kyle, 1985; Glosten & Milgrom, 1985; Easley & O’Hara, 1987; Easley, Kiefer, O’Hara, & Paperman, 1996). The common theme for the analyzes in these papers is the discrete time setup under asymmetric information. This poses the effects of the sequential equilibrium bid and ask price of the asset since the asymmetric information posits the deviation from the efficient price. Also, the bid-ask spread does exist for several reasons, but one of the reasons is the adverse selection problem when the trader and market maker are exposed to the risk that the other side of trading may have some informational advantage in priori.

Easley, Kiefer, O’Hara, and Paperman (1996) not only introduced a sequential trade model in the discrete homogenous time setup under the asymmetric information, but also proposed the probability of informed trading (PIN). This measure gauged the probability the traders and market makers faced the order from the informed traders, yielding risk of loss in trading. The PIN has a natural estimator based on the Maximum Likelihood Estimation (MLE) method since the sequential trade model here assumes that presence of the informed and uninformed traders in each trading day follows the independent Poisson processes.

A valid and reliable measure of informed trading is critical for empirical studies in market microstructure in finance. A pioneering work by Easley, Kiefer, O'Hara, and Paperman (1996), and Easley, Kiefer, and O'Hara (1997) offers a reliable proxy of information asymmetry, based on the assumption that informed traders play an important part in the observed order imbalance. This proxy is known as the probability of informed trading (PIN). To estimate the likelihood that a trading order is based on private information, Easley et al. (1996, 1997) propose a statistical framework, known as the Probability of Informed Trading (PIN) model. The PIN model relies on various market data, including order flow, price changes, and order book data. The assumption behind the PIN model is the diverse trading behaviour between informed and uninformed traders. The PIN model also assumes that price changes in response to incoming orders. By trading on private information, informed traders are more likely to place orders that move prices in their favor. The estimated probability of a particular order or set of orders being informed trading is the PIN value. A higher PIN indicates a higher likelihood of informed trading, while a lower PIN suggests that most trading is likely due to uninformed traders. PIN is a valuable tool for understanding the informativeness of trading activity in financial markets and can be useful in areas such as market microstructure analysis and regulatory oversight.

Since the introduction of PIN, numerous works have utilized this measure as proxy for information asymmetry. For example, in the study conducted by Cruces and Kawamura in 2005, they calculated the static PIN for seven stock markets in Latin America and observed a correlation between the quality of corporate governance and the average PIN across these countries. Furthermore, two recent research papers, namely Barbedo et al. (2010) and Martins et al. (2013), utilized PIN as an indicator of informed trading in the context of

Brazil. Additionally, Villarraga, Giraldo, and Agudelo (2012) examined the distribution of dynamic PIN within the same group of six emerging markets, focusing on its relationship with trading activity, market size, and day-of-the-week effects. Two other notable studies in this area include Lesmond's (2005) comprehensive investigation of liquidity in 31 emerging markets on a quarterly basis and Bekaert, Harvey, and Lundblad's (2007) examination of whether liquidity is a priced factor in a selection of 19 emerging markets, with both studies utilizing proxies for liquidity.

The probability of informed trading (PIN) measure has been increasingly used in empirical research in finance. However, there is a growing debate as to whether PIN measures information-based or liquidity-based trading and numerous studies offer alternative varieties of the static PIN as a measure of information asymmetry, for example Easley, Hvidkjaer, and O'Hara (2002), Chung, Li, and McInish (2005), Vega (2006), and more recently, Chung, Elder, and Kim (2010), Chen and Zhao (2012), Lin, Lee, and Wang (2013), Sankaraguruswamy, Shen, and Yamada (2013) and Chang and Lin (2015).

3.5. Measuring jumps

Stochastic diffusion processes have been used in the finance literature to model interest rate movements (for example, Cox et al., 1985; Ahn & Thomson, 1988). Behaviour of interest rates has long been the subject of study due to their significance in the pricing of various financial assets in the economy and its impact on macroeconomic activities as a whole. Stochastic processes allow interest rates to follow a random time series process, with the movement over time allowed to be dynamic and exhibit random movements. The random movements allowed for by the stochastic processes can be relatively small and moves proportional through time, as captured by the Brownian motion; can be autoregressive in nature, as allowed for by a complex drift component; or can be more extreme movements that occur infrequently, as captured by stochastic jump processes.

In early literature of stochastic processes involving jumps, parametric assumptions are assumed, and identified via any deviation of the data observations from the usual continuous processes. With the jump events occurring rather infrequently and unobserved, or latent, the econometric techniques involved in estimating such component is complex. Sophisticated Bayesian computation is often required for inference of such complex models, for example, Eraker, Johannes and Polson (2003), Eraker (2004), and Maneesoonthorn, Forbes and Martin (2017).

Even though stochastic jump components occur infrequently and are notoriously difficult when it comes to inference, they are an important part of the stochastic process because they contribute to the extremal risks associated with the process. In modeling interest rates, there has been growing interest in the early 2000s to account for these extreme tail behaviours. Notably, Das (2002) develops a Poisson-Gaussian jump model to explain the surprise effects in the US Federal Fund rates and found that their proposed jump model has better statistical fit properties than pure diffusion models. Johannes (2004) developed a test for jump-induced model misspecification and found jumps to play a role in a model for Treasury bill rates, with jumps coinciding with unexpected macroeconomic news.

With the availability of high-frequency data from the financial market, there has been increasing interest in the academic literature in studying the behaviour of the stochastic processes that drive financial asset prices. Of particular interest is the study of the dynamics of the variation of the price process, including any variations that may come from the extreme jump movements. Earlier work that touched on high-frequency observations include Andersen and Bollerslev (1997, 1998), along with Madhavan (2000).

The development of methodology for high-frequency financial prices exploded in the early 2000s, with the development of econometric methods that allow for high-frequency data to be used to construct various direct measures of the stochastic price process, including direct measures of volatility and jump variation. In particular, the seminal works of Barndorff-Nielsen and Shepard (2002, 2004, 2006) establish the statistical properties of such direct measures, which allow for measures of variation to be studied and explored. In addition, measures of price jump variation can be constructed directly without the need to specify a parametric model, with the statistical properties of the various measures of variation used to conduct statistical tests for jump events.

This makes studies related to the discrete jump processes much more convenient, as researchers can now avoid the inferential procedure of models with many latent variables, which is often required when working with the stochastic modeling approach. Direct measures of total volatility can now be separated into the diffusive volatility and volatility that comes from discrete and extreme jump components. Statistical tests can also be conducted based on the volatility measures constructed from high-frequency to identify jump events over a particular time horizon under question. The key advantage of this approach is the avoidance of parametric assumptions on the jump distribution, which can lead to misleading conclusions if mis-specified.

Measures of jump events are constructed by taking the difference between the total variation measure, also known as realized volatility (Barndorff-Nielsen & Shepard, 2002) and a measure of the integrated volatility that excludes variations from discrete and extreme jump events. See, for example, Barndorff-Nielsen and Shepard (2004) and Andersen, Dobrev and Schaumburn (2012) for alternative measures of integrated volatility. The so-called jump variation measures and their respective in-fill asymptotic properties can also be used to conduct a statistical test to assess if there is statistical evidence of jumps over a particular trade interval. Barndorff-Nielsen and Shepard (2006) pioneered the literature in this direction, with many subsequent studies developing alternative tests, see Huang and Tauchen (2011), Andersen, Dobrev and Schaumburn (2012), amongst others.

A review of the performance of these alternative tests is also conducted in Dimitru and Urga (2012) and more recently, with greater coverage, by Maneesoonthorn, Martin, and Forbes (2020). Both studies found that the performance of the price jump tests can be sensitive to the presence of microstructure noise present in the financial market, with robustness in test performance found to be best in methods that are specifically designed to smooth out these effects. In addition, Maneesoonthorn, Martin, and Forbes (2020) found that the presence of volatility jumps can also impact the price jump test performance, with the testing procedure proposed by Andersen, Dobrev, and Schaumburn (2012) performing best in the presence of volatility jumps. These recent findings suggest that even though the jump test based on the bipower variation of Barndorff-Nielsen and Shepard (2004 and 2006) is most commonly used in the literature, it may not perform best in emerging markets, where microstructure noise is a normal occurrence.

There is an abundance of empirical studies that investigate the behaviour of jumps in financial asset prices. Jumps in the stock market are found to certainly be present and are important contributors to the predictive return distribution (Andersen, Bollerslev, and Diebold, 2007; Maneesoonthorn, Forbes, and Martin, 2017). Jumps are also contributors to the derivative market, with the option implied volatility suggesting that extreme jump components are priced in derivative assets (Bates, 1996; Duffie, Pan, and Singleton, 2000; Busch, Christensen, and Nielsen, 2011). This implies that investors certainly factor in risks associated with the extreme tail events in their expectation of the future, and jump components should not be overlooked in the context of market efficiency in processing information flow.

More recently, the financial econometric literature has found that jumps play a key role in predicting future return volatilities, and that that jumps exhibit time series dynamics. Patton and Sheppard (2015) proposed a model that incorporates signed jumps in predicting future volatility, and found negative jumps to be associated with higher future volatility. See also Clements and Liao (2017) and Ma, Liao, Zhang, and Cao (2019) for similar conclusions, even when applied to different financial markets, including that of the energy prices.

Note that the aforementioned studies focus on the use of jump variation in forming future predictions of total return volatility. There is also another branch of the literature that directly models the jump process as a discrete time event, and finds that the jump event itself is dynamic and predictable. Maheu and McCurdy (2004) is one of the earliest works on this front, proposing a conditionally deterministic type structure on jump arrival on a GARCH model. More recently, there are advances on the development of stochastic volatility models that incorporate dynamic jumps using the Hawkes (1971) Poisson process. These include Ait-Sahalia, Cacho-Diaz, and Laeven (2015) who studied the impact of contagion on the extreme tail co-movements between financial markets using the Hawkes process; Fulop, Li, and Yu (2015), who proposed a stochastic volatility with Hawkes price jump, with negative price jump driving the stochastic volatility to also jump; and most recently Maneesoonthorn, Forbes, and Martin (2017), who propose a stochastic volatility model with self-exciting jumps in both the price and volatility processes. The use of the Hawkes process in the finance context has also been reviewed by its creator, see Hawkes (2018).

With the revelation of behaviour of jumps, its dynamic structure and its relationship with the predictive distribution of financial asset prices, there has also been growing interest in studying the behaviour of jumps and its relationship with the financial market efficiency and information flow in various financial market settings. For example, Lee (2012) investigated the predictability of macroeconomic information on jump arrivals for the US stock markets, and found that both macroeconomic information and firm-specific information play a role in the predictability of jump arrivals. Chan, Powell, and Treepongkaruna (2014) established that jumps in the currency market of emerging markets are more severe in magnitude compared to developed markets, linking this feature to the lower degree of market efficiency in the emerging markets. Miao, Ramchander, and Zumwalt (2014) confirmed the relationship between macroeconomic news and jumps in the futures markets, while Elder, Miao, and Ramchander (2013) found strong relationship between economic news and crude oil price jumps in the energy market.

Specific to the secondary bonds market, jumps are often linked to information flow, particularly to macroeconomic news announcements. Lahaye, Laurent, and Neely (2011) study the jumps that are common to stock index futures, bond futures and exchange rates, with their empirical analysis revealing that bond price jumps react strongly to new information that enters the market compared to the other two asset classes. Jiang, Lo, and Verdelhan (2011) reveal that US Treasury bond price jumps react strongly to liquidity shocks, with measures of such shocks having significant predictive power even when controlling for information flow factors.

Studies on the behaviour of volatility of bond markets in the context of emerging and Asian markets are few and far between. The two studies that explore this are Nowak, Andritzky, Jobst, and Tamirisa (2011), who examine how bond market volatility in emerging markets responds to macroeconomic news; and Kim, Kumar, Mallick, and Park (2021), who assess the effect of uncertainty shocks on the Asian bond economies during the COVID-19 pandemic. As far as we are aware, there is no study to date that investigates the impact of information flow on the extreme price jump events in the Asian bond market context. We aim to exploit this gap in the literature to study the impact of information flow on the predictability of bond price jumps. In particular, we assess the impact of the information disclosure regulation on such relationship to assist in the assessment of the effectiveness of the regulation.

3.6. The impact of delayed time on market liquidity and market efficiency

With the Efficient Market Hypothesis (EMH), market is expected to be informationally efficient. Delay can cause information asymmetry. Some market participants possess information that is not yet reflected in asset prices. This can lead to adverse selection issues, where traders with superior information exploit those with delayed or less information (Easley et al., 2018). In the stock market, Hou and Moskowitz (2005) argue that investors require more premium on firms with delayed price response to information. Order submission can be riskier as prices may change rapidly before an order is filled. This can result in higher transaction costs and increased price impact, particularly in illiquid assets (Kyle, 1985). Delayed time can also affect the depth of the market, as traders may hesitate to provide liquidity if they are uncertain about the most recent market information. This can lead to shallower markets, making it harder to execute large trades without significantly affecting prices (O'Hara, 1995). Information delay can cause a lag between when an event occurs and when it is fully reflected in asset prices. This lag may create opportunities for arbitrage and trading strategies based on exploiting the delay (Lo, 2004). Delayed time can make markets more susceptible to flash crashes and sudden price movements, as there may be a sudden rush of trading when delayed information is finally released (Biais et al., 2018).

Similarly in the bond market, Frino, Galati, and Gerace (2022) examine the reporting delays in the off-market trades of the futures market. They find that reporting delay, which is believed to reduce information efficiency may, in fact, attract informed traders to trade on their private information and make the price more efficient. As Grossman and Stiglitz (1980) propose, the market prices need to be sufficiently noisy to allow for the cost of information searches to be recovered.

On the contrary, whether price information in real time is necessary or not is also debatable. The rise of high-frequency trading has amplified the effects of delayed time on market liquidity and efficiency. High Frequency Trading (HFT) firms use advanced algorithms to capitalize on market information with minimal latency. This has raised concerns about the potential for increased market fragmentation and the impact of HFT on traditional market participants (Hendershott et al., 2011). Cochrane (2013) argues that the price discovery process does not occur in the millisecond as well as new information arrival, especially in decision on the corporate investment, risk sharing and hedging. Chordia and Miao (2019) study the low latency trading activites to both the pre-scheduled (i.e., earnings announcements) and unscheduled announcements (i.e., Merger & Acquisition (M&A) announcements, insider filing). They find that fast trading decreases the price drift and improves price efficiency.

As for the bond markets, they seem to have a similar mandate across countries. Bessembinder and Maxwell (2008) summarize the studies on U.S. corporate bond markets as the introduction of the Transaction Reporting and Compliance Engine (TRACE) that was put in place in 2002. Bond dealers were required to report all trades to the public. Brugler, Forde, and Martin (2022) study the effects of market transparency and corporate bond issuing costs in the US market. They find that yield spreads of the corporate bond reduced by 14 bps, down from 144 bps. With the transparent trading environment, bonds tend to trade at higher prices, and as a result, it’s less costly to the bond issuer. It also lowers price crash risk in the stock market as well (Guan, Kim, Liu, and Xin, 2023). Empirical studies have shown that reducing delays in information dissemination can improve market quality, reduce information asymmetry, and enhance market efficiency (Hasbrouck and Saar, 2013).

3.7. Thai Bond Market Association

3.7.1. Evolution of the Thai Bond Market

Over the past two decades, the Thai government has consistently issued bonds to finance annual budget deficits, support economic development, and restructure public debt. This strategy has transformed the bond market into a crucial funding source for both government and corporate sectors, while also serving as a key instrument for the central bank's monetary policy management.

The growth of the bond market has significantly contributed to balancing Thailand's financial landscape, which encompasses bank loans, the stock market, and the bond market. Since 1997, the proportion of bank loans to GDP has decreased from 131% to 112% (as of September 2021), while the bond market has expanded from 12% to 94% of GDP. The corporate bond market has experienced remarkable growth, with outstanding bonds increasing from 3% to 27% of GDP. Concurrently, stock market capitalization has risen from 24% to 117% of GDP.

3.7.2. The Role of the Thai Bond Market Association (ThaiBMA)

The Thai Bond Market Association (ThaiBMA) has played a pivotal role in the market's development. Initially established as the Bond Dealers Club (BDC) in November 1994, it evolved into the Thai Bond Dealing Centre (ThaiBDC) in April 1998. A major reform in December 2004, initiated by the Minister of Finance, centralized the trading platform at the Stock Exchange of Thailand (SET) and expanded ThaiBDC's functions, leading to its rebranding as ThaiBMA.

ThaiBMA oversees the registration of nearly all bonds issued in Thailand, with exceptions for a limited number of private placements (PP10) and short-term commercial paper. The registration process, mandated by the Securities and Exchange Commission (SEC), requires issuers to provide bond information for public disclosure. This is a prerequisite for offering corporate bonds in the primary market. Government bonds, Bank of Thailand (BOT) bonds, and State-Owned Enterprise (SOE) bonds are automatically registered with ThaiBMA at no cost. For corporate bonds, the registration process is integrated with the SEC filing process through the IPOS system. Upon SEC approval, bond information is electronically transmitted to ThaiBMA's registration database and published on its website, facilitating the calculation of mark-to-market prices for mutual, pension, and provident funds.

3.7.3. Regulation of ThaiBMA and Trading Mechanism

Bond trading in Thailand operates on an Over-the-Counter (OTC) basis, primarily conducted through telephone negotiations or voice brokers. Dealers, who are SEC-licensed financial institutions, must report all bond transactions to ThaiBMA within a specified timeframe. The prices disseminated by ThaiBMA serve as crucial market references for mark-to-market (MTM) valuations, ensuring transparency and efficiency in the Thai bond market.

The Notification of The Thai Bond Market Association Re: Terms, Conditions and Procedure concerning Reporting of Debt Instrument Trading [3]requires information of transaction report and control post-trade deferred publication. This notification came into force on and from January 2006. Based on this regulation, dealers are required to report all required trading information to ThaiBMA within 30 minutes after execution for public dissemination. This includes:

[3] Under virtue of the provisions of Clause 2 of the Notification of the Office of Securities and Exchange Commission, No. Sor.Yor. 37/2005, concerning the reporting on the trading of securities, and Clause 15(3) of the Regulations of Thai Bond Market Association, file:///G:/2.5_Notification_Terms,%20Conditions%20and%20Procedure%20concerning_Jan%2008.pdf

(1) Trade date

(2) Issue symbol

(3) Type of transaction (buy or sell)

(4) Purpose of the transaction

(5) Price

(6) Volume in units

(7) Time of execution (Trade Time)

(8) Settlement date

(9) Trader ID

(10) Counterparty

Later in 2009, another regulation was imposed. The Notification of the Board of Directors of the Thai Bond Market Association Re: Administrative Sanctions concerning Reporting of Debt Instrument Trading[4] is the penalty for Late Transaction, Error Transaction, or Missing Transaction.

Unlike stock markets, the bond market is the OTC market, where the transactions are conducted through the dealers. Therefore, the transaction could be performed between the dealers (e.g., dealer A sells to dealer B, and dealer B buys from dealer A), or the transaction between the dealer and its investor, (dealer A sells to investor C, and investor C buys from dealer A). In this case, the investor can be banks, mutual funds, insurance companies, corporations, and so on. According to the regulations, all dealers must report their transactions to ThaiBMA. Thus, both transactions that occur between two dealers must be reported

[4] Under virtue of Clause 20 (2) and Clause 68 of the Articles of Association of the Thai Bond Market Association, the Board of Directors of the Thai Bond Market Association, http://www.thaibma.or.th/pdf/sro/announce/announce40_jan2014.pdf

separately. However, the transaction between the dealer and investor will be reported only once by the dealer.

In addition, the regulation from ThaiBMA requires that every transaction occurring before 15:30 must be reported to ThaiBMA within the same day, while the transaction after 15:30 must be reported by before 9:30 of the following business day. Thus, the dealer who does not conform with the requirements or reports the information without correction and cancelation of missing or error transaction shall be fined with varying amounts.

Member may get disciplinary actions as follows[5];

(1) Warning;

(2) Probation;

(3) Fine (The maximum level of the fine in each case shall not exceed 300,000 THB.)

Besides the fine penalty, if dealers are found to have intention not to report according to the Terms, Conditions, and Procedure concerning reporting of Debt Instrument Trading (the notification in 2008), a disciplinary committee shall apply penalty with the other disciplinary procedures. Dealer members will be barred from any member rights and terminated from membership.

3.8. Hypotheses Development

The above motivations and objectives, along with the existing literature lead us to develop the following hypotheses :

3.8.1. Effect of Regulations

According to Ewing et al. (2018), the MiFID II/R implementation does not improve European market transparency. However, regulations in different countries may lead to

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[5] under Article 68 and 101 of the Securities and Exchange Act, B.E. 2535(A.D. 1992), http://www.thaibma.or.th/pdf/sro/announce/Codified2555.pdf

different effects. If regulations introduced by ThaiBMA are effective, then it should improve transparency .Hence, we propose the following hypotheses .

Hypothesis 1 :The announcement of Notification of Board of Directors of ThaiBMA leads to smaller delay time.

Hypothesis 1a :The announcement of reporting trading transactions notification leads to smaller delay time.

Hypothesis 1b :The announcement of penalty for late reporting trading transactions leads to smaller delay time.

3.8.2. Market Liquidity

According to Edward, Harris, and Piwowar (2007), there exists the association between decrease in investors' trading costs in corporate bonds with the initiation of transaction reporting .We propose the following hypotheses related to bond market liquidity as follows:

Hypothesis 2a :Increased transparency leads to higher turnover.

Hypothesis 2b :Turnover increases with the smaller delay in the reporting of trades in transparent market.

3.8.3. Probability of Informed Trading (PIN)

According to Easely et al. (1996), probability of informed trading is lower when liquidity is improved. This leads us to the following hypotheses.

Hypothesis 3a : Increased transparency leads to lower PIN.

Hypothesis 3b :PIN decreases with the smaller delay in the reporting of trades in transparent market.

3.8.4. Jumps

According to Chan, Powell, and Treepongkaruna (2014), emerging market currency jumps are considerably more severe than those of developed markets. This implies jumps are associated with less market efficiency .This leads us to the following hypotheses.

Hypothesis 4a :Increased transparency leads to fewer and/or smaller jumps.

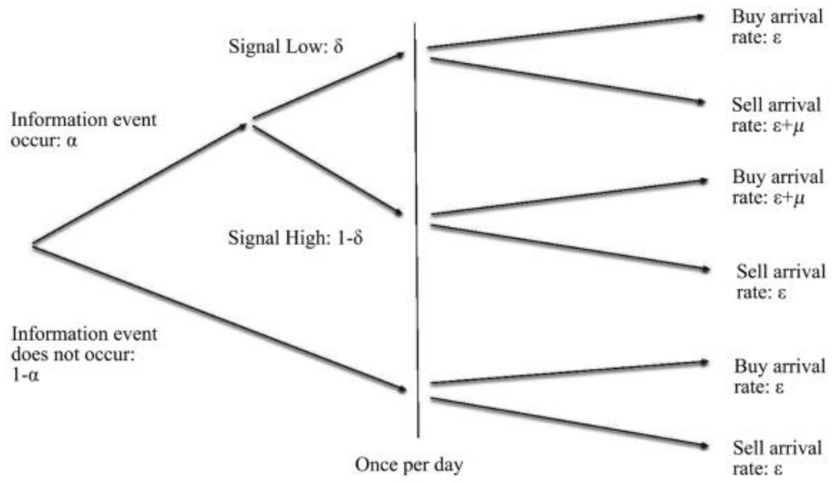
Hypothesis 4b :Jump frequency and magnitude decrease with the smaller delay in the reporting of trades in transparent market.

4. Methodology

4.1. Probability of Informed Trading

We utilize the Probability of Informed Trading (PIN) model from Easley, O'Hara, and Pepperman (1995). The model can be explained through the tree diagram in Figure 1. Before the start of a trading day, it is determined by nature whether an information event will occur in the market. These events occur independently and with a probability denoted by α. An information event can be categorized as either good news (signal high or $1 - \delta$) or bad news (signal low - δ). At the beginning of the trading day, the true value of an asset is unknown. By the end of the day, the full information about the asset is revealed. Informed traders are expected to act based on the information events. On a bad information day (signal low), informed traders would sell, while uninformed traders might randomly trade (buy or sell) with equal probability. Conversely, on a good news day (signal high), informed traders would buy, while uninformed traders might randomly trade (buy or sell) with equal probability. Each trading day, the arrival of informed and uninformed traders is modeled by Poisson processes with intensities ε and μ, respectively. Traders exchange a single risky asset with a market maker over trading periods. Let's define Pt = [P(n), P(b), P(g)] as the market maker's prior belief about the event sets as "no news," "bad news," and "good news" at time t. The value of the asset, conditional on no information, good news, and bad news, is V* , V^, and $\underline{V}$, respectively.

Figure 1. Tree diagram on the information event and the probability of informed trades.



Assume at the time t, a market maker observes a sell order arrival, he set the bid price given the information set S_t, as follows:

$b_t = E(V_t \mid t, St)$.

This can be rewritten as

$$b_t = E(V_t \sim t,\ S_t, n)P_t(n \sim S_t) + E(V_t \sim t,\ S_t, g)P_t(g \sim S_t) + E(V_t \sim t,\ S_t, b)P_t(b \sim S_t)$$

$$b_t = V^* P_t(n \sim S_t) + \overline{V} P_t(g \sim S_t) + \underline{V} P_t(b \sim S_t)$$

Each component of the bid is the conditional probability of set value. We can show that the first component can be calculated using the Bayes rule as follows:

$$P_t(n \sim S_t) = \frac{P_t(S_t \sim n)P_t(n)}{P_t(S_t)}$$

The term P(St ~ n) represents the probability at time t that a market maker observes a sell order arrival on a no news day. According to Easley et al. (2012), we can establish the bid and ask prices based on this probability.

$$b_t = \frac{P_t(n)\varepsilon V^{\cdot} + P_t(b)(\varepsilon + \mu)\underline{V} + P_t(g)\varepsilon\overline{V}}{\varepsilon + P_t(g)\mu}$$

$$a_t = \frac{P_t(n)\varepsilon V^{\cdot} + P_t(b)\varepsilon \underline{V} + P_t(g)(\varepsilon + \mu)\overline{V}}{\varepsilon + P_t(g)\mu}$$

So the spread can be computed as

$$a_t - b_t = \frac{\mu\big(1 - P_t(n)\big)}{2\varepsilon + (1 - P_n)\mu}\big(\overline{V} - \underline{V}\big)$$

We assume that the probability of news information is constant, Pt(n) = P(n) = 1 - α, therefore, we obtain the probability of informed trading as

$$PIN = \frac{\mu\alpha}{2\varepsilon + \mu\alpha}$$

Easley et al (1995) suggested using the log-likelihood model to estimate the set of parameters required from the set of known variables, the number of buys and sells. Thus,

$$L[\,(B,S)\sim\theta] \;= (1-\alpha)e^{-\varepsilon_b}\frac{(\varepsilon_b)^B}{B!}e^{-\varepsilon_s}\frac{(\varepsilon_s)^S}{S!}$$

$$+(\alpha\delta)e^{-\varepsilon_b}\frac{(\varepsilon_b)^B}{B!}e^{-(\varepsilon_s+\mu)}\frac{(\varepsilon_s+\mu)^S}{S!}$$

$$+\alpha(1-\delta)e^{-(\varepsilon_b+\mu)}\frac{(\varepsilon_b+\mu)^B}{B!}e^{-\varepsilon_s}\frac{(\varepsilon_s)^S}{S!}$$

Where B and S represents the total number of buys and sells for a trading period and $\theta = [\alpha, \delta, \mu, \varepsilon]$ which is the set of parameters vector.

4.2. Barndorff-Nielsen and Shephard (BNS) jump detection technique

In this study, we adopt the jump detection technique of Barndorff-Nielsen and Shephard (2004). It is well documented that volatility can be measured using realised volatility (see Jones et al., 1994; Andersen and Bollerslev, 1998; Chan and Fong, 2006) and defined as the sum of the corresponding 1/Δ high-frequency intra-daily squared returns as:

$$RV_t(\Delta) = \sum_{j=1}^{1/\Delta} r_{t+j\Delta,\Delta}^2 \qquad (1)$$

where $r_{t,\Delta} \equiv p(t) - p(t-\Delta)$ is the discretely sampled Δ-period return (5 minute return in our case) and $1/\Delta$ is the number of intradaily periods.

However, based on the theory of quadratic variation, Andersen and Bollerslev (1998) suggest that as the sampling frequency of the underlying returns increases, the realized variation converges uniformly in probability to the increment of the quadratic variation process as follows:

$$RV_t(\Delta) \to \int_{t-1}^{t} \sigma^2(s)ds + \sum_{j=1}^{N_t} \kappa_{t,j}^2 \quad (2)$$

$$RV_t(\Delta) \to \text{Integrated Variance} + \text{Jumps} \quad (3)$$

for $\Delta \to 0$, where N_t is the number of jumps on day t and $\kappa_{t,j}$ is the *j*-th jump size on that day.

That is, realised volatility includes the dynamics of both the continuous sample path and the jump process. However, when jump exists, it appears that realized volatility does not consistently estimate integrated volatility as it does not distinguish continuous and discontinuous components of volatility. To overcome this drawback, Barndorff-Nielsen and Shephard (2004) propose the use of bi-power variation, allowing for separation of the two components of the quadratic variation process. BNS defines the Bi-power variation, BV as the summation of the product of adjacent absolute intradaily returns standardised by a constant as follows:

$$BV_t(\Delta) \equiv \mu_1^{-2} \sum_{j=2}^{1/\Delta} | r_{t+j\Delta,\Delta}^2 || r_{t+(j-1)\Delta,\Delta}^2 | \quad (4)$$

where $\mu_1 \equiv \sqrt{2/\pi}$

In the presence of discontinuous jumps:

$$BV_t(\Delta) \to \int_{t-1}^{t} \sigma^2 \,(s)ds \quad (5)$$

Hence, by taking the difference between the realized variation and the bi-power variation, one can consistently estimate the jump contribution of the quadratic variation process as:

$$RV_t(\Delta) - BV_t(\Delta) \rightarrow \sum_{j=1}^{N_t} \kappa_{t,j}^2 \text{, when } \Delta \rightarrow 0 \qquad (6)$$

In setting threshold for significant jump, Andersen, Bollerslev, and Diebold (2007) suggest that small jumps should be treated as measurement errors or part of the continuous sample path process and large jumps as the 'significant' jump component. In this study, we follow Huang and Tauchen (2005) and Andersen et al. (2007) by computing the *Z* statistic for jumps as:

$$Z_t(\Delta) \equiv \Delta^{-1/2} \frac{[RV_t(\Delta) - BV_t(\Delta)]RV_t(\Delta)^{-1}}{[(\mu_1^{-4} + 2\mu_1^{-2} - 5)\max\{1, TQ_t(\Delta)BV_t(\Delta)^{-2}\}]^{1/2}} \qquad (7)$$

where

$$TQ_t(\Delta) \equiv \Delta^{-1}\mu_{4/3}^{-3} \sum_{j=3}^{1/\Delta} |\, r_{t+j\Delta,\Delta}^2|^{4/3} |r_{t+(j-1)\Delta,\Delta}^2|^{4/3} |r_{t+(j-2)\Delta,\Delta}^2|^{4/3} \qquad (8)$$

and $\mu_{4/3} = 2^{2/3}\Gamma(7/6)\Gamma(1/2)^{-1}$, $TQ_t(\Delta)$ is the integrated quarticity.

BNS demonstrates that the integrated quarticity may be consistently estimated using equation (8). Under the null hypothesis of no jumps, $Z_t(\Delta)$ is approximately normally distributed. To detect significant jumps, we compare the test statistics to a standard normal distribution with our chosen significance level α and create an indicator variable, $I_{t,\alpha}(\Delta) \equiv I[Z_t(\Delta) > \Phi_\alpha]$. [6] The jump component is as follows:

$$J_{t,\alpha}(\Delta) = I_{t,\alpha}(\Delta)[RV_t(\Delta) - BV_t(\Delta)] \qquad (9)$$

To overcome microstructure noise causing high-frequency returns to be autocorrelated, Andersen et al. (2007) use the 'staggered' versions of the bi-power variation and the integrated quarticity measures. This integrated variance allows the summation of the jump component and the continuous component equal to realized volatility as follows:

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[6] The smaller the significant level α, the lesser and larger (in magnitude) jumps we have.

$$C_{t,\alpha}(\Delta) = \left[1 - I_{t,\alpha}(\Delta)\right] RV_t(\Delta) + I_{t,\alpha}(\Delta) BV_t(\Delta) \quad (10)$$

Next, we follow Andersen et al. (2010a), and Tauchen and Zhou (2011) to obtain the sign of significant jumps by assuming that there is at most one jump during trading day *t*. We define the sign for significant jumps as:

$$\sqrt{J_{sign,t,\alpha}(\Delta)}\text{=Ind(max|r(t,j=1, ….}\Delta) \quad (11)$$

where the sign indicator Ind(.) is equal to 1 or –1 depending upon the sign of the argument. In addition, we also compute the jump intensity (λ, the proportion of days with significant jumps), the jump mean (γ) and the jump standard deviation (δ) of $\sqrt{J_{sign,t,\alpha}(\Delta)}$ on days with significant jumps. Finally, to evaluate realised jumps over the sample period, we also compute the corresponding mean γ* and standard deviation δ* of the absolute jump size (i.e., $\left|\sqrt{J_{sign,t,\alpha}(\Delta)}\right|$) on days with significant jumps.

4.3. Regression Analyses

To test Hypothesis 1, we estimate the following regression model:

$$\overline{delay}_{i,T} = \beta_0 + \beta_1 Event1_T + \beta_2 Event2_T + \sum_j \beta_j Control_{j,T} + \varepsilon_{i,T} \quad (12)$$

where, $\overline{delay}_{i,T}$ is the average delayed time (minutes) of bond i on day T. Delayed time is defined as difference between trade time and report time for each trade of bond i on day T. $Event_T$ is year 2008 and 2012, respectively. Control variables include bond characteristics such as time-to-maturity, issue size, issue term and coupon rate, respectively.

Additionally, we also estimate the following model:

$$delay15_{i,T,t} = \beta_0 + \beta_1 Event1_T + \beta_2 Event2_T + \sum_j \beta_j Control_{j,T} + \varepsilon_{i,T} \quad (13)$$

where, $delay15_{i,T}$ is a dummy setting to 1 if transaction is reported within 15 minutes and zero otherwise.

To test remaining Hypotheses, we estimate the following regression model:

$$Y_{i,T} = \beta_0 + \beta_1 \overline{delay}_{i,T} + \sum_{j=1}^{2} \beta_j Event_{j,T} + \sum_{k=1}^{2} \beta_k Event_{k,T} * \overline{delay}_{i,T} + \sum_m \beta_m Control_{m,T} + \sum_n \beta_n InvestorType_{n,T} + \varepsilon_{i,T} \quad (14)$$

where $Y_{i,T}$ is daily liquidity proxy and BNS jump, defined as above.

5. Empirical Results

5.1. Data Source and Descriptive Statistics

Three primary tables of data are provided by ThaiBMA covering the study period from January 2002 to December 2019. The first primary data source is the table containing all transaction data, trade details including buyer and seller identities, security symbols, prices, volumes, yields, and other pertinent information. The most important information relevant to this study are the timestamps indicating both the occurrence and reporting times of transactions. Furthermore, the dataset includes information on the buyers and sellers involved in each transaction, enabling the identification of whether they are dealers or investors. However, it does not reveal the identity of participants who buy or sell bonds in the transaction. The identities are concealed by the code number. Nevertheless, the dataset categorizes participants as either dealers or investors, offering insight into the composition of market activity. The second table presents bond characteristics such as issuer details, size, outstanding amount, coupon rate, and time to maturity. The third table is the bond indicative spread showing the average daily indicative quoted spread provided by the bond dealer. Both tables contain the control variables in the regression analysis, enabling an examination of the relationship between various factors in the market.

We first examine the transaction data, encompassing all bond issues within the market. These include Government bonds (GB), Treasury Bills (TB), State Agency Bonds (SA), State-Owned Enterprise Bonds (SOE), Corporate Bonds (COR), Commercial Papers (CP), Foreign Bonds (FB), and USD Bonds (USD). Notably, each bond category exhibits varying transaction frequencies. Table 1 presents a summary of the transactions conducted throughout the study period. The total number of transactions is 2.7 million rows. State Agency Bonds emerge as the most actively traded securities, totaling 1.3 million transactions. Following are Government bonds, with close to a million transactions, while Corporate bonds have almost a quarter of a million transactions. Other categories experience significantly lower transaction volumes over our sample period.

Table 1 Number of transactions during 2002 to 2019.

Bond Type	Number of Transaction
Government bond (GB)	978,771
Treasury Bills (TB)	108,972
State Agency Bond (SA)	1,347,535
State Owned Enterprise (SOE)	27,628
Corporate Bond (COR)	225,135
Commercial Paper (CP)	21,524
Foreign Bond (FB)	4,944
USD Bond (USD)	7
All	**2,714,516**

In this study, we focus only on the Government bond (GB) to avoid other risk factors that may confound the results. We combine the transaction data with the bond characteristics and spread information. This results in our final dataset including 745,911 transactions covering about/almost 2 decades of bond trading.

5.2. Dealer and Investor Code

As previously described, transactions can occur between dealers or between dealers and investors, with participant identities anonymized through code representation. Table 2 provides a comprehensive roster of participants from both sides. Panel A presents the list of dealer codes, indicating the involvement of 54 dealers throughout the study duration. Panel B delineates the counterparties involved in transactions, comprising 53 dealers and 36 investors.

Table 2 Participant roster during the study period 2002 to 2019.

List of Dealers

Dealer1	Dealer140	Dealer159	Dealer408	Dealer82
Dealer10	Dealer141	Dealer170	Dealer5	Dealer84
Dealer12	Dealer143	Dealer171	Dealer59	Dealer88
Dealer13	Dealer149	Dealer172	Dealer630	Dealer9
Dealer134	Dealer150	Dealer177	Dealer68	Dealer90
Dealer135	Dealer151	Dealer196	Dealer71	Dealer91
Dealer136	Dealer152	Dealer2	Dealer73	Dealer93
Dealer137	Dealer154	Dealer256	Dealer74	Dealer937
Dealer138	Dealer155	Dealer258	Dealer75	Dealer94
Dealer139	Dealer157	Dealer349	Dealer76	Dealer950
Dealer14	Dealer158	Dealer4	Dealer8	

List of Counter Parties

Dealer1	Dealer157	Dealer73	Investor12	Investor53
Dealer10	Dealer159	Dealer74	Investor13	Investor58
Dealer12	Dealer170	Dealer75	Investor14	Investor61
Dealer13	Dealer172	Dealer76	Investor15	Investor69
Dealer135	Dealer177	Dealer8	Investor16	Investor70
Dealer136	Dealer196	Dealer82	Investor17	Investor71
Dealer137	Dealer2	Dealer84	Investor18	Investor73
Dealer138	Dealer256	Dealer88	Investor19	Investor74
Dealer139	Dealer258	Dealer9	Investor2	Investor75
Dealer14	Dealer349	Dealer90	Investor27	Investor76
Dealer140	Dealer4	Dealer91	Investor32	Investor82

Dealer141	Dealer408	Dealer93	Investor35	Investor9
Dealer143	Dealer5	Dealer937	Investor36	Investor91
Dealer149	Dealer59	Dealer94	Investor37	Investor92
Dealer150	Dealer630	Dealer950	Investor38	Investor93
Dealer151	Dealer68	Investor1	Investor4	
Dealer152	Dealer691	Investor10	Investor51	
Dealer155	Dealer71	Investor11	Investor52	

5.3. Delay Analysis and Distribution

We compute the time intervals by subtracting the trade time from the report time for each transaction. A negative time gap indicates instances where report times precede trade times, while a positive time gap indicates standard reporting practices. Table 3 illustrates the distribution of these time gaps. On the left side of the table are transactions exhibiting negative time gaps, totaling 5,598 instances. Notably, most of these discrepancies, accounting for 3,334 out of 5,598 observations, occur within an hour. Such inconsistencies may stem from human or typographical errors.

Conversely, the right side of Table 3 showcases transactions with positive time gaps. The first and second rows denote instances where transactions are reported within 15 and 30 minutes, respectively. We observe 583,566 and 58,000 occurrences out of 745,911 total observations, indicating that the majority of reporting transactions adhere to the regulatory requirement of within 30 minutes.

Transactions beyond the 30-minute mark are considered delayed. Notably, the majority of these delayed reports, totaling 33,014, 34,113 and 13,390 transactions, respectively, occur within 3 hours. It is worth noting that delayed reports may stem from transactions occurring both before and after 15:30, with regulations requiring reporting within 30 minutes on the same day or before 9:30 on the following business day, respectively.

Table 3 Time gap between the trade time and report time in minutes.

Report Time Gap	Freq	%	Report Time Gap	Freq	
< Neg 6 Hrs	257	0.034%	**0:00 Hrs**	**11,931**	1.600%
Neg 6:00 Hrs	191	0.026%	**0:15 Hrs**	**571,635**	76.636%
Neg 5:00 Hrs	353	0.047%	**0:30 Hrs**	**58,000**	7.776%
Neg 4:00 Hrs	435	0.058%	1:00 Hrs	33,014	4.426%
Neg 3:00 Hrs	505	0.068%	2:00 Hrs	34,113	4.573%
Neg 2:00 Hrs	523	0.070%	3:00 Hrs	13,390	1.795%
Neg 1:00 Hrs	3,334	0.447%	4:00 Hrs	5,863	0.786%
			5:00 Hrs	3,726	0.500%
			6:00 Hrs	1,764	0.236%
			> 6:00 Hrs	6,877	0.922%
Total	5,598	0.750%	Total	740,313	99.250%

Table 4 presents the number of negative delay reports recorded each year along with their total value in billion Baht. Panel A shows the results by year. Panel B shows the results by trade type which are either buy or sell transactions. The data reveals significant fluctuations in the number of reports and their corresponding values. The total number of negative delay reports varied widely from 2002 to 2015, peaking at 3,093 in 2002 and reaching a low of 5 in 2004. Notable are the occurrences 2004 to 2006, 2009, and 2012 when the regulation has been implemented. The findings indicate periodic increases in negative delay reports both in frequency and financial impact, suggesting that certain years experienced heightened issues that warranted closer scrutiny. Most importantly we notice that the negative delay disappeared after 2015. This is due to the implementation of the recording system of ThaiBMA which disabled the manual records and ensures the correct timestamp. Panel B categorizes the negative delay reports into buy and sell transactions, along with their total values. We find that there are 2,568 buy transactions with a total value of 69 billion Baht, and 3,030 sell transactions with a total value of 107 billion Baht.

Table 4 Statistics of Negative Delay Report

Panel A. Number of observations with negative delay reports and value of transaction by year.

Year	Negative Report	Value (Billion Baht)
2002	3,093	65.419
2003	97	2.407
2004	5	0.392
2005	12	0.378
2006	16	0.661
2007	451	29.485
2008	209	9.567
2009	35	1.806
2010	509	10.329
2011	782	14.679
2012	39	3.607
2013	122	9.190
2014	197	24.462
2015	31	3.157

Panel B. Number of observations with negative delay reports and value of transaction categorized by type of trades.

Trade Type	Negative Report	Value (Billion Baht)
Buy	2,568	68.822
Sell	3,030	106.718

Table 5 presents the number of long delay reports recorded each year along with their total value in billion Baht. In the regular cases, when the transaction is completed and reported subsequently, the delay is positive. However, to be in line with table 3, we use the 6 hour threshold in this table. Panel A shows the results by year and panel B shows the results by trade type which are buy or sell transaction. Similar to the negative delay reports, the occurrence of positive delay reports was high at the beginning in 2002 and 2003, peaking at 2,367 in 2002 and 1,004 in 2003. Notably the occurrences dropped significantly when the regulation was implemented and penalty was enforced. However, our findings indicate periodic increases in long delay reports both in frequency and amount. Panel B categorizes the positive delay reports. We find that there are 3,283 buy transactions with a total value of 127 billion Baht, and 3,572 sell transactions with a total value of 149 billion Baht.

Table 5. Statistics of Long Delay Reports

Panel A. Number of observations with long delay reports and value of transactions by year.

Year	Delayed Report (>6:00Hrs)	Value (Billion Baht)
2002	2,367	55.433
2003	1,004	22.770
2004	491	15.563
2005	475	15.033
2006	319	13.506
2007	554	27.839
2008	128	7.349
2009	89	4.426
2010	198	11.714
2011	130	13.126
2012	110	11.725
2013	205	18.268
2014	145	12.623
2015	166	9.736
2016	112	11.676
2017	102	5.758
2018	129	8.360
2019	131	10.672

Panel B. Number of observations with long delay reports and value of transactions categorized by type of trades

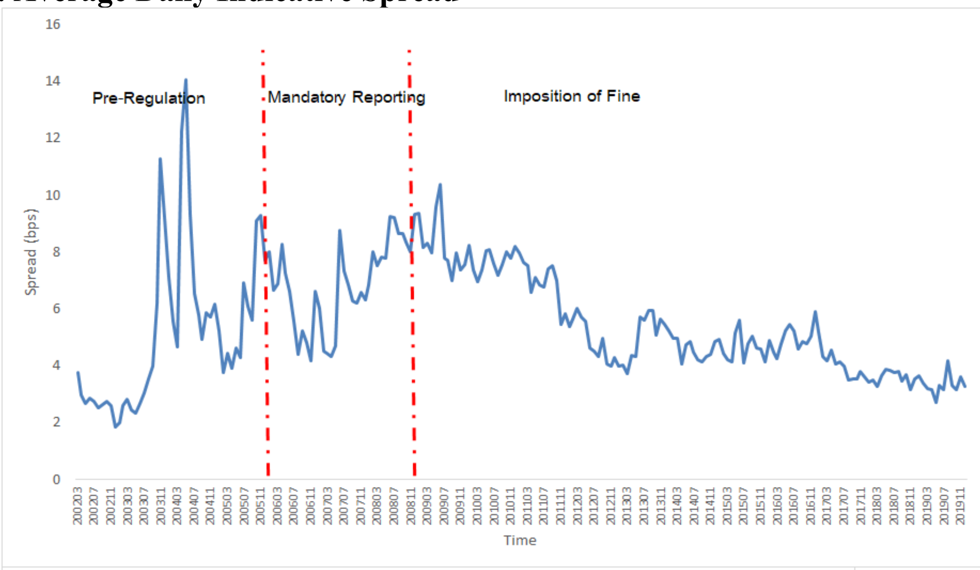
Trade Type	Delayed Report (>6:00Hrs)	Value (Billion Baht)
B	3,283	127.006
S	3,572	148.569

5.4. Liquidity Evolution of Bond Trading

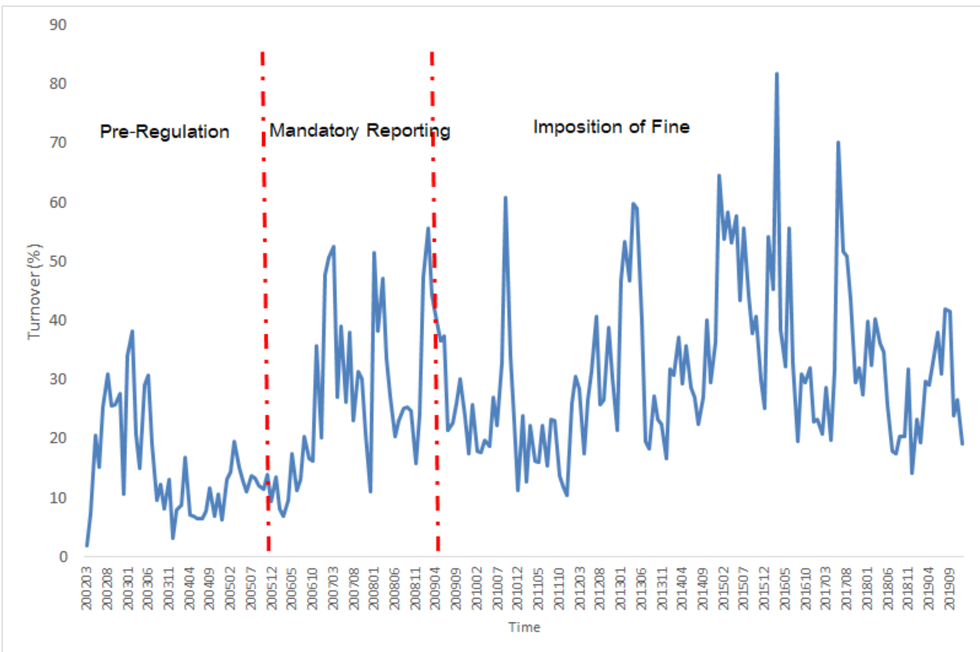
We further examine the liquidity of trading activity over years. We use the indicative spread and turnover to proxy for liquidity. Unlike the stock market, in which the traders post the bid and ask price to indicate their demand and supply, the bond market uses the bid and ask quoted by dealers. Thus the limitation of using indicative spread is that it does not directly convey the liquidity of trading in the bond market. We also use the turnover calculated from the transaction volume divided by the outstanding amount of bonds. The turnover represents the relative value of the actual transaction of a bond, which can be a better proxy for liquidity. Figure 2 depicts the evolution of the indicative spread in panel A and turnover ratio in panel B of bonds traded from January 2002 to December 2019. Each graph includes two vertical red dotted lines indicating key regulatory enforcement dates: January 1, 2006, when trade reporting was mandated, and January 1, 2009, when penalties for non-compliance were introduced. In panel A, the spread fluctuates significantly in the early years, reaching peaks around 2003 and 2004. Following the first regulatory enforcement in January 2006, there is a notable decline in spread volatility and a general downward trend. It is worth noting that, if the large spikes during the periods are disregarded, the overall spreads in pre-2006 are relatively smaller than the period of 2006 to 2009. After a sharp drop in early 2006, the remaining period shows an increasing trend until 2009. We also observe brief spikes around 2008-2009, likely influenced by the global financial crisis. Post-2009, following the introduction of penalties, the spread stabilizes and continues to decrease gradually until 2019, indicating improved market efficiency and transparency. In panel B, Turnover ratios show an increasing trend over time, with high volatility throughout the period. Pre-2006 there are frequent and pronounced fluctuations, while after the introduction of trade reporting in 2006 turnover ratios show increased volatility but also demonstrate a higher value on average, suggesting greater market activity and liquidity. After penalties are enforced in 2009, the turnover ratio continues to rise and remains volatile indicating sustained market activity. We can conclude that the liquidity of the bond market was initially volatile, however it evolved over time. The improvement can be observed from the reduction in spread and increase in turnover ratio over the last 10 years of our study period.

Figure 2. Average daily indicative spread and turnover ratio of bond trading from 2002 to 2019.

Panel A. Average Daily Indicative Spread



Panel B. Average Daily Turnover



5.5. Regression analysis of delay

Table 6, panel A, presents a regression analysis of the regulation's effect on daily reporting as shown in equation 12. We regressed the average delay of each bond on dummy variables and control variables, excluding observations with negative delays or delays longer than 6 hours due to their small sample size (less than 1% each), which could cause confounding effects. The delay variables are calculated as the average delay in seconds for transactions of the same bond on the same day. Dummy Event 1 represents the "Pre-Regulation" period which are the transactions occurring before December 31, 2005. Dummy Event 2 represents the "Mandatory Reporting" which are the transactions occurring from January 1, 2006, to December 31, 2008, and Event 2 represents the "Imposition of Fine" which are transactions from January 1, 2009, onward. TTM is the time to maturity in years of a bond, Issue Size is the bond issue value in million Baht, Coupon is the percentage rate of coupon payment on the bond's face value, and Issue Term is the bond's term in years. Overall, our hypothesis 1 is supported, with the coefficients for Event 1 and Event 2 showing significant negative results at the 1% level. This indicates that, compared to the pre-2006 period, delays decreased by 46 seconds and 55 seconds during 2006 to 2009, respectively, reflecting effective regulation by the ThaiBMA.

In panels B and C, we replace the daily delay average with transaction-by-transaction delays, finding similar significant negative results for the event dummy variables. Longer times to maturity and higher coupon rates are associated with longer delays, while long-term bonds have shorter reporting times. Further analysis reveals that some dealer groups exhibit different reporting behaviours, with Dealer 1 (BankF) showing longer delays and Dealer 2 (NDL) showing shorter delays compared to the control group (SEC). Transactions occurring on Wednesdays and Thursdays are more likely to be delayed than those on Mondays, possibly due to the day-of-the-week effect on reporting. Additionally, transactions involving a dealer and its client tend to have shorter reporting delays, as the dealer is responsible for reporting to the ThaiBMA.

Panel D of Table 6 provides a regression analysis focusing on the likelihood of reporting delays within 15 minutes, considering the influence of the same set of control variables. The coefficients for Event 1 and Event 2 are both positively significant at the 1% level, suggesting that the introduction of mandatory reporting and subsequent imposition of fines markedly increase the probability of reporting within 15 minutes compared to the pre-2006 period. Specifically, the implementation of regulations after January 1, 2006, is associated with a higher likelihood of reporting compliance, highlighting the effectiveness of these regulatory measures in enhancing prompt reporting practices. In addition to control variables, dealer behaviour varies significantly, with Dealer BankL, BankF, and NDL exhibiting substantially lower likelihoods of reporting within 15 minutes compared to the control group. This variation underscores the differences in reporting efficiency across different dealer groups. Additionally, the analysis of day-of-the-week effects reveals that transactions reported on Wednesdays, Thursdays, and Fridays are less likely to meet the 15-minute reporting requirement, indicating potential mid-to-late-week delays. Transactions involving a dealer and its client (Dummy D2C) show a positive and significant coefficient, suggesting that such transactions are more likely to comply with the 15-minute reporting rule. Overall, the results reinforce the conclusion that regulatory interventions have substantially improved reporting timeliness, aligning with international standards and enhancing market transparency.

Table 6. The effect of regulation on reporting delay

Panel A. Daily Regression

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	61.016***	2.0124	30.3198	0.0000
Event1	-46.019***	1.3556	-33.9470	0.0000
Event2	-55.755***	0.9513	-58.6070	0.0000
TTM	0.297***	0.0970	3.0555	0.0030
Issue Size	0.001	0.0001	0.4524	0.6522
Coupon	1.162***	0.3622	3.2078	0.0019
Issue Term	-0.345***	0.1016	-3.3924	0.0011

Panel B. Trade by Trade Regression

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	60.7126***	2.3872	25.4326	0.0000
Event1	-46.9582***	2.1466	-21.8759	0.0000
Event2	-56.4811***	0.8098	-69.7457	0.0000
TTM	0.3894***	0.0890	4.3751	0.0000
Issue Size	0.0001	0.0000	-0.1025	0.9186
Coupon	1.4792***	0.4249	3.4813	0.0008
Issue Term	-0.4144***	0.0829	-4.9963	0.0000

Panel C. Trade by Trade Regression with Control Variables

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	62.0601***	2.4732	25.0931	0.0000
Event1	-49.5760***	2.1804	-22.7370	0.0000
Event2	-59.2590***	0.8398	-70.5627	0.0000
TTM	0.4243***	0.0859	4.9374	0.0000
Issue Size	0.0001	0.0000	-0.4123	0.6812
Coupon	1.4411***	0.4069	3.5415	0.0007
Issue Term	-0.4772***	0.0766	-6.2303	0.0000
Dealer BankL	0.2064	1.2551	0.1645	0.8698
Dealer BankF	5.8511***	1.4435	4.0535	0.0001
Dealer NDL	-24.2625***	1.8997	-12.7719	0.0000
Tue	-0.0228	0.2544	-0.0898	0.9287
Wed	0.5366***	0.1999	2.6842	0.0088
Thu	0.6699***	0.2181	3.0713	0.0029
Fri	0.3740	0.2923	1.2797	0.2043
Dummy D2C	-1.7314*	0.9530	-1.8168	0.0729

Panel D. Trade by Trade Regression on 15-minute Report with Control Variables

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	0.532***	0.032	16.512	0.000
Event1	0.421***	0.031	13.740	0.000
Event2	0.594***	0.011	54.049	0.000
TTM	-0.005***	0.001	-3.893	0.000
Issue Size	0.000	0.000	1.600	0.113
Coupon	-0.013*	0.005	-2.491	0.015
Issue Term	0.006***	0.001	4.977	0.000
Dealer BankL	-0.182***	0.014	-13.373	0.000
Dealer BankF	-0.256***	0.013	-19.348	0.000
Dealer NDL	-0.185***	0.019	-9.712	0.000
Tue	-0.002	0.002	-0.711	0.479
Wed	-0.009***	0.002	-4.322	0.000
Thu	-0.008***	0.002	-3.922	0.000
Fri	-0.008***	0.003	-3.063	0.003
Dummy D2C	0.019**	0.008	2.476	0.015

5.6. The Effect of Regulation and Reporting Delay on Liquidity.

To further examine the effect of regulation on liquidity in the government bond market, we fit a model in Equation 14, where the dependent variable is the turnover ratio of government bonds. To save space, we report results based only on the transaction regression, as shown in Table 7. Overall, we find that reporting delay is positively related to turnover: the longer the delay, the more liquidity in the bond market. Interestingly, regulation appears to have an adverse effect on market liquidity. Specifically, Event 1 is positively significant with a 48 basis point turnover ratio, while Event 2, the period after 2009 when penalties were imposed, shows no significant difference from the pre-2006 period. This result may be due to the high volatility of the turnover ratio over the periods. In panel B, we include the same set of control variables, and the positive relationship between liquidity and delay, as well as the event dummies, remains. We speculate that higher turnover may indicate greater participation from large traders, which could attract other market participants. Dealers involved in such transactions may delay reporting to the market.

Table 7. The Effect of Regulation and reporting delay on liquidity.

Panel A. Trade by Trade Regression

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	0.0064	0.0069	0.9264	0.3573
Delay	0.0001**	0.0000	-2.1479	0.0350
Event1	0.0048**	0.0020	2.4102	0.0185
Event2	0.0003	0.0025	0.1021	0.9190
TTM	-0.0016 * * *	0.0005	-3.6189	0.0005
Issue Size	0.0000 *	0.0000	-1.7207	0.0895
Coupon	0.0012	0.0014	0.8385	0.4045
Issue Term	0.0015 * * *	0.0005	3.1866	0.0021

Panel B. Trade by Trade Regression with Control Variables

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	0.0047	0.0071	0.6657	0.5077
Delay	0.0001**	0.0000	-2.2910	0.0248
Event1	0.0046**	0.0020	2.2828	0.0254
Event2	0.0001	0.0025	0.0173	0.9862
TTM	-0.0016***	0.0005	-3.6007	0.0006
IssueSize	0.0000*	0.0000	-1.7267	0.0884
Coupon	0.0011	0.0014	0.8225	0.4134
Issue Term	0.0015***	0.0005	3.1443	0.0024
Dealer BankL	0.0009*	0.0005	1.8820	0.0638
Dealer BankF	0.0006	0.0005	1.2598	0.2117
Dealer NDL	-0.0007	0.0008	-0.9070	0.3674
Tue	0.0003*	0.0002	1.8793	0.0642
Wed	0.0022***	0.0004	5.3971	0.0000
Thu	0.0008***	0.0002	3.5407	0.0007
Fri	0.0009***	0.0003	3.2926	0.0015
Dummy D2C	0.0013*	0.0006	1.9646	0.0533

5.7 The Evolution of Market Liquidity

We further investigate whether market liquidity has evolved over time by replacing the event dummy variables with a time trend variable. This time trend is intended to capture the evolution of liquidity as measured by the turnover ratio. If liquidity has simply increased over time, the time trend should be significantly related to the liquidity proxy. Other variables remain the same as in the previous section. In panel A, the time trend variables are not significant, nor is the delay, indicating that other factors besides time may influence the evolution of liquidity. Panel B shows similar results, with liquidity related to time-to-maturity, issue size, and issue term. The day-of-the-week effects remain consistent, with non-Mondays tending to show higher liquidity than other days. Liquidity is driven by transactions with clients

Table 8. The Evolution of Reporting Delay and Liquidity.

Panel A. Trade by Trade Regression with Time Trend

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	0.0027	0.0107	0.2501	0.8032
Delay	-0.0001	0.0000	-1.1903	0.2378
Time Trend	0.0002	0.0004	0.4399	0.6613
TTM	-0.0013 * * *	0.0005	-2.7113	0.0084
Issue Size	-0.0001 *	0.0000	-1.7388	0.0863
Coupon	0.0023	0.0022	1.0456	0.2992
Issue Term	0.0011 *	0.0006	1.7820	0.0789

Panel B. Trade by Trade Regression with Time Trend and Control Variables

Parameter	Estimate	StdErr	t-Value	Prob
Intercept	0.0011	0.0111	0.0984	0.9219
Delay	0.0000	0.0000	-1.0996	0.2751
Time Trend	0.0002	0.0004	0.3886	0.6987
TTM	-0.0013***	0.0005	-2.7539	0.0074
Issue Size	0.0001*	0.0000	-1.7422	0.0857
Coupon	0.0022	0.0022	1.0058	0.3178
Issue Term	0.0011*	0.0006	1.8111	0.0742
Dealer BankL	0.0010*	0.0005	1.9529	0.0547
Dealer BankF	0.0006	0.0005	1.3208	0.1907
Dealer NDL	-0.0014	0.0014	-1.0249	0.3088
Tue	0.0003*	0.0002	1.9239	0.0583
Wed	0.0021***	0.0004	5.3944	0.0000
Thu	0.0008***	0.0002	3.5541	0.0007
Fri	0.0009***	0.0003	3.4048	0.0011
Dummy D2C	0.0013**	0.0006	2.1513	0.0348

5.8. Probability of informed trades.

Table 9 reports the results of the PIN estimation on the overall sample. Since some dealers have insufficient trading information to fit the model, we require at least the PIN results in two periods for comparison purposes. The first row presents the PIN estimates from the overall sample. We find that the value of PIN in all three periods is relatively stable at 0.2528 to 0.2649. This may indicate, regardless of the delay or liquidity change, relatively stable proportions of the market participants between the informed and uninformed traders in the bond over time. However, from the regulator perspective, being the informed or uninformed traders could be less relevant to the market development or efficiency, therefore we examine the jump property of the bond trading in the next section.

Table 9. Probability of Informed Trading Results

	Pre Regulation	Mandatory Reporting	Imposition of Fine
PIN	0.2615	0.2649	0.2528
p-value	0.0000	0.0000	0.0000

5.9. Jumps in bond price movements

For the evaluation of our hypotheses related to jumps, we construct the realized measures from high-frequency data for a small subset of government bonds. With the use of high-frequency data playing a key role in the accuracy of these measures, we select bonds that adequately cover the pre-regulation period, the threat period (where regulation is in place with no fine), and the period where fines were introduced. The bonds that were selected are actively traded bonds, with at least 40 trades per day on average. The government bonds that were used in this analysis are summarized in Table 10. For all four bonds under consideration, we analyze the behaviour of jumps before any reporting regulation (prior to January 2006), the period in which only the imposition of mandatory reporting is implemented (between January 2006 and December 2008), and the period from which late fine is imposed (from January 2009 onward).

Table 10: The list of government bonds used to conduct jump activity analysis

Bond	Number of Trading Days	Start	End
LB11NA	1280	12/03/2002	16/11/2011
LB104A	929	6/03/2002	24/03/2010
LB12NA	781	13/11/2002	16/10/2012
LB113A	820	6/03/2002	16/02/2011

We construct the realized volatility and bipower variation in order to conduct the price jump test, with the 1% significance level used in all cases. Plots of the weekly percentage change in bond prices, realized variation, jump variation, and the detected price jumps for each of the four bonds are depicted in Figures 3-6 below. On each panel, the vertical red dotted lines represent the two events of regulatory introduction: the introduction of mandatory reporting and the imposition of the fine, respectively. Since the four bonds were traded over different periods, the positions of these lines differ for each Figure. From the visualization, we observe one striking phenomenon: that there is only one detected weekly jump across all four bonds after the introduction of mandatory reporting. The jump variation (JV) also appear to reduce in magnitude for the bonds being investigated here.

Figure 3: Returns, RV, JV and Detected Jumps for LB11NA

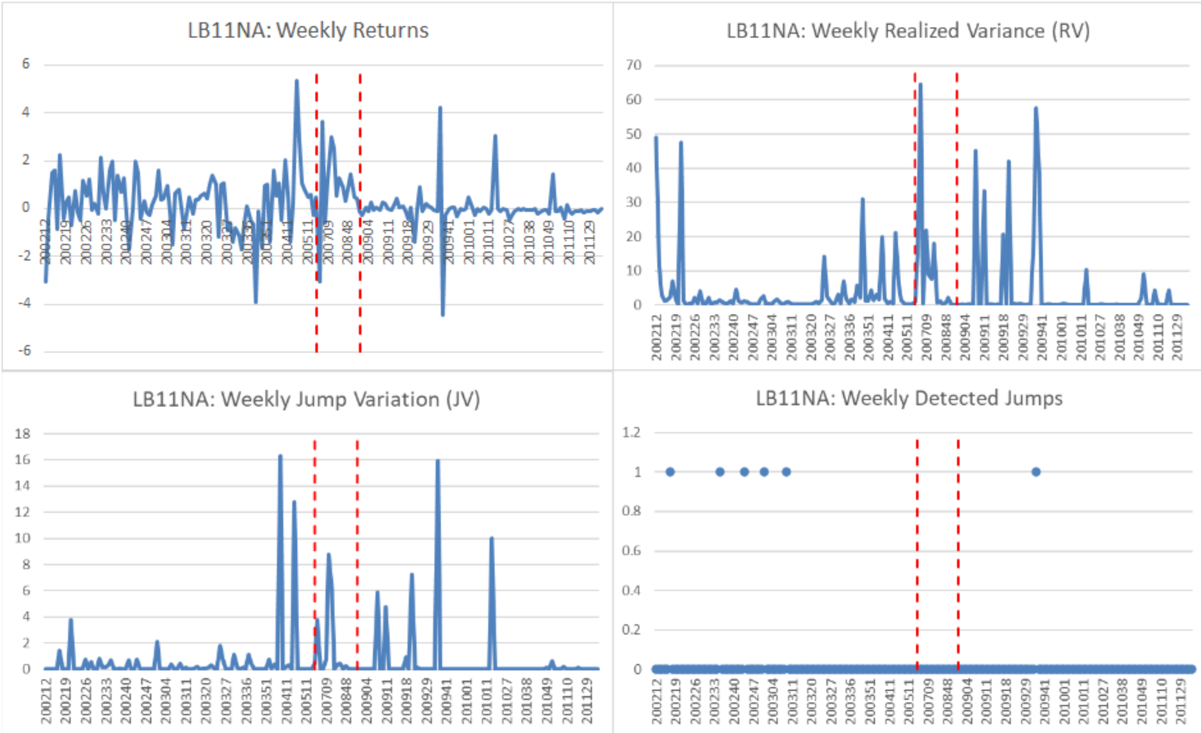


Figure 4: Returns, RV, JV and Detected Jumps for LB104A

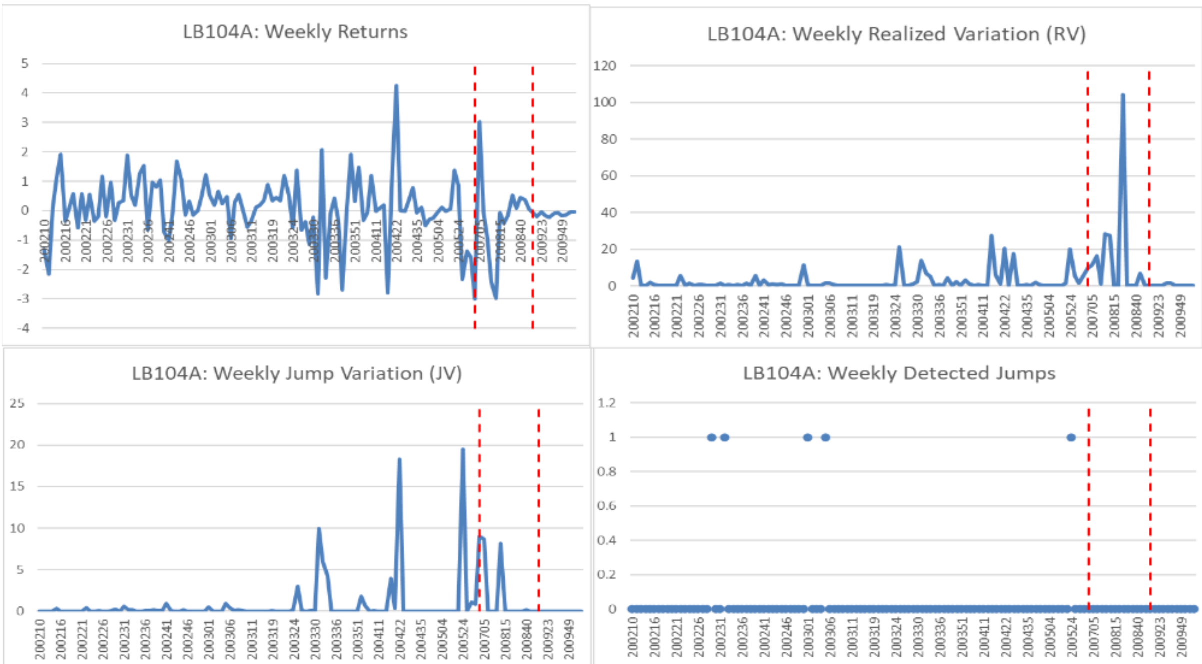


Figure 5: Returns, RV, JV and Detected Jumps for LB12NA

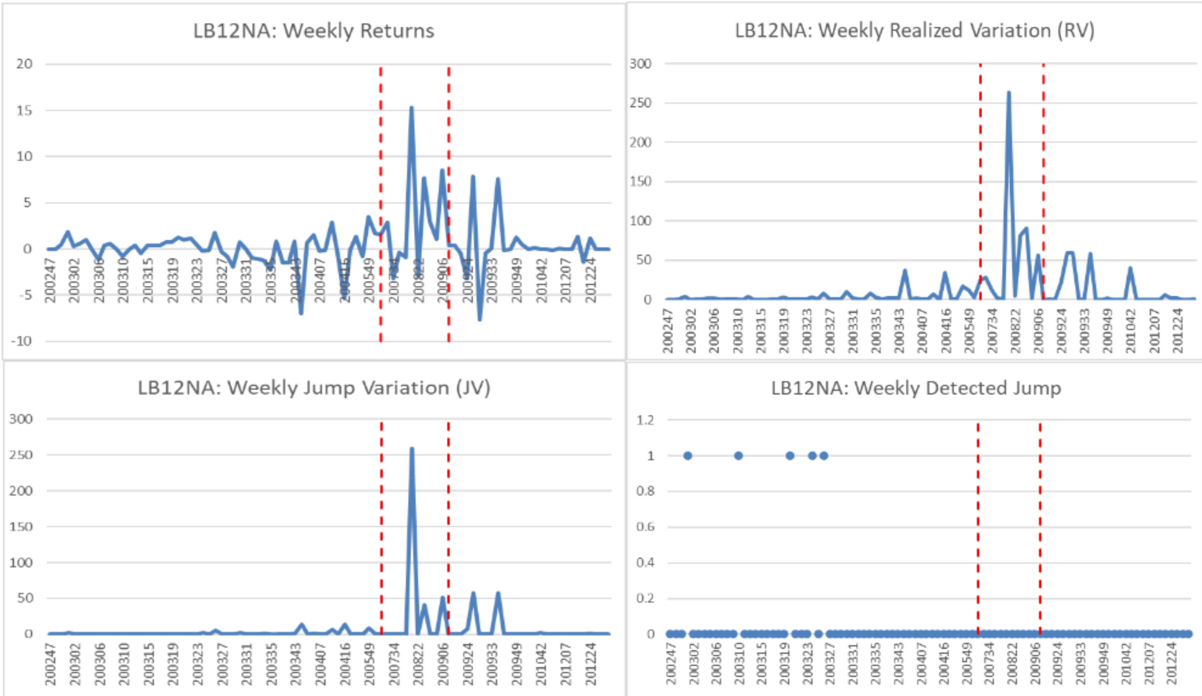
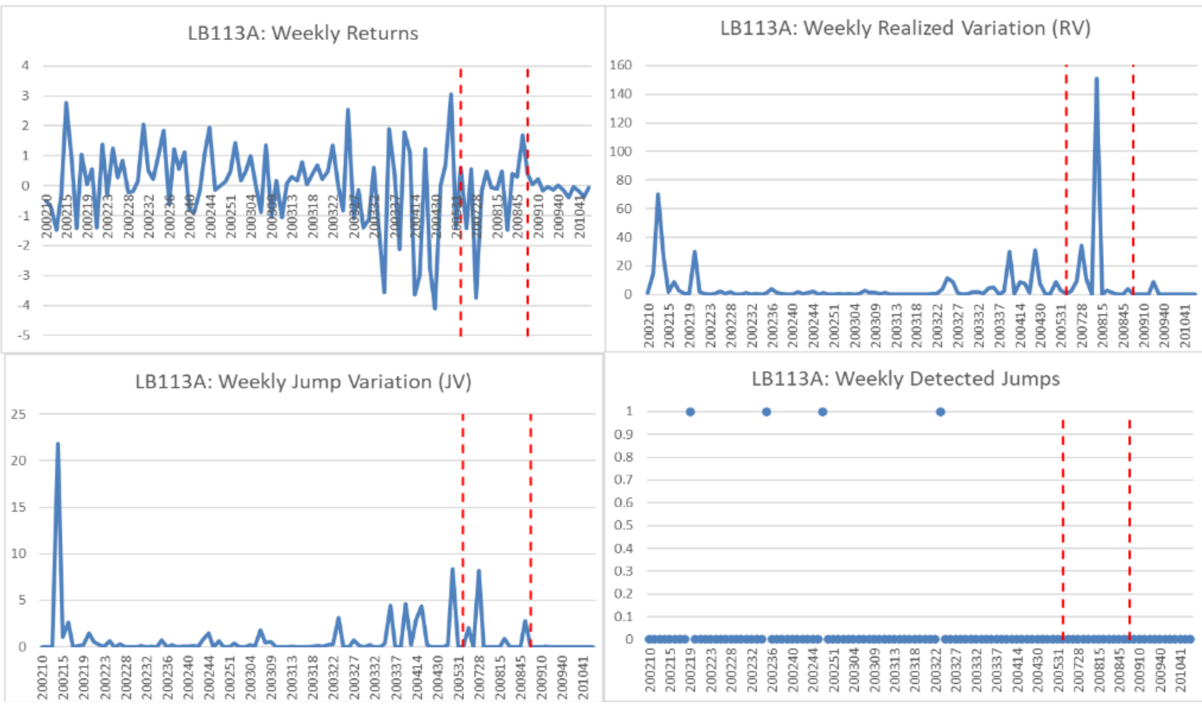


Figure 6: Returns, RV, JV and Detected Jumps for LB113A



The jump frequency implied by the BNS jump test is then summarized and reported alongside its confidence interval, constructed using the blocked bootstrap to retain any dependency of jump occurrences over time. Likewise, we also report the resulting variation attributed to jumps for the corresponding bonds and period, with the mean jump variation reported alongside the bootstrap confidence interval. Both jump frequency and jump variation statistics are reported in Table 11.

Table 11: Summary of jump frequency and jump variation for the three phases of the regulation. We report the 95% bootstrapped confidence interval along with the sample mean of each quantity.

	Bond	Pre-Regulation	Mandatory Reporting	Imposition of Fine
Jump Frequency	LB11NA	0.0532	0.0000	0.0118
		(0.0213,0.0957)	(0,0)	(0,0.0353)
	LB104A	-0.0481	0.0000	0.0000
		(0.0096,0.0962)	(0,0)	(0,0)
	LB12NA	0.0943	0.0000	0.0000
		(0.0377,0.1698)	(0,0)	(0,0)
	LB113A	0.0494	0.0000	0.0000
		(0.0123, 0.0864)	(0,0)	(0,0)
Jump Variation	LB11NA	0.5347	1.3899	0.5412
		(0.2008, 1.0764)	(0.3713,2.4085)	(0.1594,0.9868)
	LB104A	0.7297	1.8610	0.0010
		(0.1788,1.3169)	(0.5940,3.1280)	(0.0004,0.0017)
	LB12NA	1.1900	27.3366	6.3865
		(0.3780,2.1798)	(3.7413,50.9318)	(0.2961,12.6427)
	LB113A	0.8281	0.9233	0.1980
		(0.2823,1.5101)	(0.2371, 1.6093)	(0.0006,0.3954)

From Table 11, it is clear that the jump frequency reduces significantly after introduction of mandatory reporting of trade in 2006. For three out of the four bonds considered here, no jumps were detected after 2006, indicating that the presence of unexpected price movements subsides after the introduction of the mandatory reporting. This continues to be the case after the imposition of late reporting fine. Turning our attention to the analysis of jump variation, it is clear that the variation due to jump, constructed from the difference between RV and BV, generally reduces after the introduction of the reporting regulation, with the exception of one bond (LB12NA). From our analysis of jump activities, we can conclude that the regulation certainly has impact on the extreme movements of the bond prices. There is clear consensus of the impact on the frequency of extreme price movements, with our confidence intervals suggesting that extreme and unexpected bond price movements reduce significantly after the introduction of the mandatory reporting regulation. There is also evidence that the degreeof such extreme movements is reduced, based on the analysis of difference alone.

In addition to the analysis of the mean differences of the jump variation, we also conduct a regression analysis that controls for the key covariate of time to maturity of the bond. We consider the regression

$$\log(JV_t) = \beta_0 + \beta_1 \, Event_{1t} + \beta_2 \, Event_{2t} + \beta_3 TTM_t + \varepsilon_t$$

For each case, $Event_{1t}$ denotes the indicator variable that equates to 1 between January 2006 and December 2008, when mandatory reporting is in place, while $Event_{2t}$ denotes the indicator variable that equates to 1 from January 2009 onwards, when fine for late reporting is imposed. The only covariate that changes through time and is feasible to use as a control covariate in this case is the time to maturity of each bond. Table 12 reports the result from the regression, with the coefficient estimate reported along with the associated p-values in parenthesis. For three out of the four bonds investigated, the slope coefficients of the $Event_{2t}$ indicator are statistically significant, while none of the slope coefficients for the $Event_{1t}$ indicator showed any statistical significance. From this analysis with controlled covariates, we observe that the degree of jump variation is impacted by the introduction of the fine for only one out of the four bonds considered. No significant impact was observed on jump variation with the mandate of the reporting without penalty.

Table 12: Regression results for assessment of the impact of the introduction of the regulations and fine on the magnitude of jump variation, controlling for the time to maturity of the bond. Asterisk (*) denotes the coefficient that is statistically significant from zero at the 10% significance level.

Bond Symbol	Coefficients			
	Intercept	Event1	Event2	TTM (years)
LB11NA	-4.9670*	3.5470*	1.4827	0.3756
	0.0833	*0.0460*	*0.5277*	*0.2513*
LB104A	1.2742	-1.3839	-6.4699*	-0.4221
	0.6480	*0.5253*	*0.0517*	*0.2881*
LB12NA	-0.1213	3.0198	-0.7898	-0.0476
	0.9830	*0.4009*	*0.8530*	*0.9380*
LB113A	1.1076	0.8819	-2.3614	-0.3035
	0.7478	*0.7022*	*0.4403*	*0.4754*

6. Conclusions

The study concludes that the regulations introduced by the ThaiBMA have positively impacted market transparency and efficiency in the Thai bond market. It reveals that these regulations led to a significant decrease in negative and long delay reports. For instance, the total number of negative delay reports dropped from 3,093 in 2002 to just 31 in 2015, showcasing the effectiveness of the regulatory framework in mitigating delays. Similarly, long delay reports, which initially peaked at 2,367 in 2002, also saw a substantial decline following the enforcement of stricter penalties and reporting requirements. This reduction in delays indicates a notable improvement in the efficiency of the Thai bond market, contributing to a more transparent and reliable trading environment. The regulatory implications of these findings are profound. The success of the ThaiBMA's regulations underscores the importance of timely and accurate trade reporting in enhancing market transparency. Regulators can draw lessons from this study, highlighting the need for stringent enforcement mechanisms to ensure compliance with reporting standards. The imposition of penalties for late, erroneous, or missing transaction reports proved effective in promoting adherence to the regulations, thereby fostering an accountability among market participants

The findings from this research highlight significant patterns and implications for regulatory practices within the Thai bond market. Analyzing the delay in transaction reporting, it was observed that most transactions adhered to the regulatory requirement of being reported within 30 minutes. Specifically, 85% of total transactions were reported within 30 minutes, with 76% reported within 15 minutes which is the global standard, indicating a high level of compliance. However, a notable portion of transactions, totaling 33,014, 34,113, and 13,390, were reported with delays extending beyond the 30-minute threshold but within three hours, suggesting areas where reporting efficiency could be improved.

The regression analyzes provided deeper insights into the factors influencing reporting delays. It was found that certain bond characteristics, such as time-to-maturity and issue size, significantly affected the likelihood of delayed reporting. Also, implementing stricter regulations and enhanced reporting systems after 2015 led to a noticeable decrease in negative and long delay reports. This indicates that regulatory interventions, coupled with technological advancements in reporting systems, can effectively mitigate reporting delays and enhance market transparency. The analysis of Probability of Informed Trading (PIN) and significant jumps in trading further elucidates the market dynamics. PIN, which measures the price impact of trades, and the detection of significant jumps, which indicate large price movements, both suggest heightened market activity and potential liquidity issues during certain periods. The observed correlation between these factors and reporting delays underscores the need for continuous monitoring and adjustment of regulatory frameworks to accommodate the evolving market conditions and ensure robust market functioning.

In conclusion, the liquidity and efficiency of trading as well as compliance in the Thai bond market has been improving over time. We also recommend several regulatory and operational enhancements to improve the timeliness and accuracy of transaction reporting in the Thai bond market. Additionally, incorporating advanced analytics to monitor and address significant market movements can further enhance market stability. By implementing these measures, regulatory bodies can ensure a more transparent, efficient, and resilient bond market. Moving forward, it is recommended that ongoing monitoring and periodic reviews of the regulatory framework be conducted to adapt to evolving market conditions. Further, the integration of advanced technological solutions, such as automated reporting systems, can enhance the accuracy and efficiency of trade reporting. Continuous dialogue between regulators and market participants will be crucial in identifying and addressing emerging challenges, ensuring that the Thai bond market remains robust, transparent, and efficient in the face of future developments

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8. Appendix

Appendix A1: A Snapshot of Bond Trading Transaction

The table illustrates a snapshot of bond transaction data reported to ThaiBMA. The columns purpose and sub_purpose indicate the intention of trading and its subcategory. The columns dealer and counter_party are the masked identifiers of the dealers involved. Issue_type1 indicates the category of the issuer, while Issue_type2 specifies the type of security issued by each issuer. Trade date and trade time represent the date and time when the transaction occurred. Settlement date and settlement time denote when the payment for the security was made and the security was delivered. Report date and report time indicate when the transaction was reported into the system. Yield represents the yield to maturity of the transaction. Volume_Unit and price_gross_baht refer to the number of units traded and the gross price of the bond in baht. Price_clean is shown as a percentage value based on the clean price of the bond, excluding accrued interest. Par_at_settlement indicates the par value per unit of the bond.

purpose	sub-purpose	trade_type	dealer	symbol	counter_party	issue_type1	issue_type2	d2d_d2c	dealer_group	counterparty_group	match_id_text	transaction_id_text	trade_date	settlement_date	report_date	match_date	trade_time	settlement_time	report_time	match_time	yield	yield_type	volume_unit	price_gross_Baht	value_mb	price_clean	par_at_settlement
OUT	OUT	S	Dealer155	LB08DA	Investor17	GB	LB	D2C	NDL	NDL	0	214	3/5/2002	3/7/2002	3/6/2002		12:28:00	00:00:00	08:59:00		4.5	YTM	100000	1251.500852	125.1500852	123.077482	1000
OUT	OUT	S	Dealer138	LB08DA	Investor17	GB	LB	D2C	BANKL	NDL	0	227	3/5/2002	3/7/2002	3/6/2002		14:30:00	00:00:00	09:03:00		4.47	YTM	20000	1253.468619	25.06937238	123.274259	1000
OUT	OUT	S	Dealer157	LB03OA	Investor18	GB	LB	D2C	BANKF	AMC	0	14	3/5/2002	3/8/2002	3/6/2002		15:20:00	00:00:00	07:28:00		2.335	YTM	20000	1125.291649	22.50583298	109.251768	1000
OUT	OUT	S	Dealer157	LB03OA	Investor18	GB	LB	D2C	BANKF	AMC	0	17	3/5/2002	3/8/2002	3/6/2002		15:20:00	00:00:00	07:29:00		2.335	YTM	80000	1125.291649	90.02333192	109.251768	1000
OUT	OUT	B	Dealer74	LB046A	Investor18	GB	LB	D2C	BANKF	AMC	0	220	3/5/2002	3/7/2002	3/6/2002		15:45:00	00:00:00	09:00:00		2.6	YTM	35000	1094.166506	38.29582771	108.012541	1000
OUT	OUT	S	Dealer2	LB077A	Investor18	GB	LB	D2C	BANKL	AMC	0	2	3/5/2002	3/7/2002	3/6/2002		16:00:00	00:00:00	07:17:00		4.065	YTM	50000	1082.169777	54.10848885	107.311773	1000
OUT	OUT	B	Dealer71	LB046A	Investor18	GB	LB	D2C	BANKF	AMC	0	85	3/5/2002	3/7/2002	3/6/2002		16:01:00	00:00:00	07:52:00		2.605	YTM	20000	1094.051266	21.88102531	108.001017	1000
OUT	OUT	S	Dealer71	LB046A	Investor17	GB	LB	D2C	BANKF	NDL	0	82	3/5/2002	3/7/2002	3/6/2002		16:01:00	00:00:00	07:51:00		2.6	YTM	20000	1094.166506	21.88333012	108.012541	1000
OUT	OUT	S	Dealer12	LB104A	Investor17	GB	LB	D2C	BANKL	NDL	0	105	3/5/2002	3/7/2002	3/6/2002		16:01:00	00:00:00	08:03:00		5	YTM	10000	1006.441225	10.06441225	98.68467	1000
OUT	OUT	B	Dealer74	LB08DA	Investor18	GB	LB	D2C	BANKF	AMC	0	433	3/5/2002	3/7/2002	3/6/2002		16:03:00	00:00:00	09:00:00		4.49	YTM	30000	1252.156345	37.56469035	123.143031	1000
OUT	OUT	B	Dealer74	LB08DA	Investor18	GB	LB	D2C	BANKF	AMC	0	434	3/5/2002	3/7/2002	3/6/2002		16:03:00	00:00:00	09:00:00		4.49	YTM	30000	1252.156345	37.56469035	123.143031	1000
OUT	OUT	B	Dealer12	LB113A	Investor18	GB	LB	D2C	BANKL	AMC	0	107	3/5/2002	3/7/2002	3/6/2002		16:06:00	00:00:00	08:04:00		5.1	YTM	10000	1171.580979	11.71580979	117.117002	1000
OUT	OUT	B	Dealer12	LB077A	Dealer74	GB	LB	D2D	BANKL	BANKF	427	110	3/5/2002	3/7/2002	3/6/2002	3/6/2002	16:10:00	00:00:00	08:04:00	8:04	4.08	YTM	20000	1081.426717	21.62853434	107.237467	1000
OUT	OUT	B	Dealer157	LB05OA	Investor18	GB	LB	D2C	BANKF	AMC	0	20	3/5/2002	3/7/2002	3/6/2002		16:10:00	00:00:00	07:30:00		3.155	YTM	2320	1214.343896	2.81727783	118.080965	1000
OUT	OUT	B	Dealer157	LB05OA	Investor18	GB	LB	D2C	BANKF	AMC	0	27	3/5/2002	3/7/2002	3/6/2002		16:10:00	00:00:00	07:32:00		3.155	YTM	21810	1214.343896	26.48484037	118.080965	1000
OUT	OUT	B	Dealer157	LB05OA	Investor18	GB	LB	D2C	BANKF	AMC	0	24	3/5/2002	3/7/2002	3/6/2002		16:10:00	00:00:00	07:31:00		3.155	YTM	25870	1214.343896	31.41507658	118.080965	1000
OUT	OUT	S	Dealer74	LB077A	Dealer12	GB	LB	D2D	BANKF	BANKL	110	245	3/5/2002	3/7/2002	3/6/2002	3/6/2002	16:12:00	00:00:00	09:09:00	8:04	4.08	YTM	20000	1081.426717	21.62853434	107.237467	1000
OUT	OUT	B	Dealer74	LB08DA	Investor18	GB	LB	D2C	BANKF	AMC	0	435	3/5/2002	3/7/2002	3/6/2002		16:40:00	00:00:00	09:00:00		4.49	YTM	20000	1252.156345	25.0431269	123.143031	1000
OUT	OUT	S	Dealer82	LB08DA	Investor75	GB	LB	D2C	SEC	BANKF	0	34	3/6/2002	3/8/2002	3/6/2002		07:34:00	00:00:00	07:35:00		4.56	YTM	50000	1247.731012	62.3865506	122.677211	1000
OUT	OUT	B	Dealer9	LB08DA	Dealer74	GB	LB	D2D	BANKL	BANKF	234	69	3/6/2002	3/7/2002	3/6/2002	3/6/2002	07:45:00	00:00:00	07:46:00	7:46	4.475	YTM	20000	1253.140389	25.06280777	123.241436	1000
OUT	OUT	B	Dealer73	LB06DA	Investor74	GB	LB	D2C	BANKF	BANKF	0	181	3/6/2002	3/7/2002	3/6/2002		09:20:00	00:00:00	08:41:00		3.755	YTM	10000	1202.805357	12.02805357	118.329851	1000
OUT	OUT	S	Dealer138	LB082A	Investor17	GB	LB	D2C	BANKL	NDL	0	339	3/6/2002	3/8/2002	3/6/2002		09:34:00	00:00:00	09:35:00		4.41	YTM	20000	988.124842	19.76249683	98.541251	1000
OUT	OUT	S	Dealer1	LB06DA	Dealer12	GB	LB	D2D	BANKL	BANKL	121	311	3/6/2002	3/8/2002	3/6/2002	3/6/2002	09:58:00	00:00:00	09:27:00	8:07	3.78	YTM	10000	1201.734307	12.01734306	118.200828	1000
OUT	OUT	B	Dealer73	LB077A	Dealer74	GB	LB	D2D	BANKF	BANKF	286	201	3/6/2002	3/8/2002	3/6/2002	3/6/2002	10:00:00	00:00:00	08:53:00	8:53	4.11	YTM	10000	1080.062805	10.80062805	107.085732	1000
OUT	OUT	B	Dealer71	LB06DA	Dealer138	GB	LB	D2D	BANKF	BANKL	337	140	3/6/2002	3/8/2002	3/6/2002	3/6/2002	10:00:00	00:00:00	08:15:00	8:15	3.8	YTM	10000	1200.780438	12.00780438	118.105441	1000
OUT	OUT	B	Dealer1	LB06DA	Dealer13	GB	LB	D2D	BANKL	BANKL	10	9	3/6/2002	3/8/2002	3/6/2002	3/6/2002	10:00:00	00:00:00	07:25:00	7:25	3.81	YTM	10000	1200.303854	12.00303854	118.057782	1000
OUT	OUT	S	Dealer138	LB06DA	Dealer71	GB	LB	D2D	BANKL	BANKF	128	332	3/6/2002	3/8/2002	3/6/2002	3/6/2002	10:00:00	00:00:00	09:34:00	8:10	3.8	YTM	10000	1200.780438	12.00780438	118.105441	1000
OUT	OUT	B	Dealer73	LB06DA	Dealer9	GB	LB	D2D	BANKF	BANKL	421	420	3/6/2002	3/8/2002	3/6/2002	3/6/2002	10:00:00	00:00:00	10:00:00	10:00	3.78	YTM	10000	1201.734307	12.01734306	118.200828	1000

Appendix A2: A Snapshot of Bond Characteristics

This table illustrates a snapshot of bond characteristics registered with ThaiBMA. The symbol indicates the trading symbol of each bond, which will be used to match the transaction data. The issuer and sector columns identify the bond issuers and their respective sectors or industries. Bond structure indicates whether the bond is a straightforward fixed-income instrument or has an exotic feature attached. Coupon_pct represents the coupon rate. Issue_Term_yr indicates the total maturity period for each bond. Please note that not all columns are displayed or spelled out in full to save space, and some columns are not relevant to our analysis.

Symbol	ISIN	Issuer	Sector	BondType	PrincipalPayment	BondStructure	SecuredType	Coupon_Payment	Frequency	Claim_Type	Distribution	Registrar	IssuerName	ListedStatus	Issue_Date	Maturity_Date	Registered_Date	Coupon_Pct	Issue_Term_yr
LB024A	TH062303C407	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	12-Apr-99	12-Apr-02	12-Apr-99	6.125	3
LB026A	TH062303C605	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	15-Jun-99	15-Jun-02	16-Jun-99	4.75	3
LB033A	TH062303D306	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	5-Mar-99	5-Mar-03	14-May-99	5.25	4
LB038A	TH062303D801	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	31-Aug-98	31-Aug-03	14-Sep-98	10	5
LB03OA	TH062303DA05	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	14-Oct-98	14-Oct-03	27-Oct-98	8.25	5
LB046A	TH062303E601	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	15-Jun-99	15-Jun-04	16-Jun-99	6.25	5.01
LB04NA	TH0623K3EB08	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	30-Nov-01	30-Nov-04	30-Nov-01	3.5	3
LB053A	TH062303F301	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	5-Mar-99	5-Mar-05	10-Sep-99	6	6.01
LB05OA	TH062303FA03	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	14-Oct-98	14-Oct-05	27-Oct-98	8.5	7.01
LB061A	TH062303G101	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	24-Jan-03	24-Jan-06	24-Jan-03	2	3
LB06DA	TH062303GC00	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	8-Dec-98	8-Dec-06	29-Jan-99	8	8.01
LB077A	TH062303H703	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	7-Jul-00	7-Jul-07	7-Jul-00	5.6	7
LB082A	TH062303I206	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	12-Feb-01	12-Feb-08	12-Feb-01	4.125	7
LB085A	TH062303I503	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	14-May-04	14-May-08	14-May-04	2.75	4
LB088A	TH062303I800	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	5-Aug-05	5-Aug-08	5-Aug-05	3.875	3
LB08DA	TH062303IC08	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	8-Dec-98	8-Dec-08	18-Dec-98	8.5	10.01
LB095C	TH062303J501	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	15-May-06	15-May-09	15-May-06	5.375	3
LB096A	TH062303J600	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	21-Jun-02	21-Jun-09	21-Jun-02	4.625	7.01
LB09NC	TH062303JB08	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	19-Nov-04	19-Nov-09	19-Nov-04	4.125	5
LB104A	TH062303K400	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	9-Apr-01	9-Apr-10	9-Apr-01	4.8	9.01
LB108A	TH062303K806	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	13-Aug-04	13-Aug-10	13-Aug-04	4.25	6
LB111A	TH062303L184	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	9-Jan-04	9-Jan-11	9-Jan-04	3.875	7.01
LB113A	TH062303L309	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	5-Mar-99	5-Mar-11	10-May-99	7.5	12.01
LB116A	TH0623A3L607	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	6-Mar-09	17-Jun-11	6-Mar-09	1.75	2.28
LB11NA	TH062303LB04	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	30-Nov-01	30-Nov-11	30-Nov-01	5.375	10.01
LB123A	TH062303M307	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	11-Mar-05	11-Mar-12	11-Mar-05	4.5	7.01
LB12NA	TH062303MB03	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	1-Nov-02	1-Nov-12	1-Nov-02	4.125	10.01
LB133A	TH062303N305	MOF	MOF	GB	Bullet Issue	Plain Vanilla Issue	Unsecured	Fixed Coupon	Semi-annually	Senior	PG	BOT	MINISTRY OF FINANCE	Non-listed	13-Jul-07	13-Mar-13	13-Jul-07	4.25	5.67

Appendix A3: A Snapshot of Bond Indicative Spread

This table illustrates a snapshot of the spread of registered bonds from dealers. The column asof indicates the trading date on which the spread is reported. Maturity represents the maturity date of the corresponding bond. Bid denotes the average bid yield of the participating dealers, reported as a percentage. Change_bp indicates the change in spread from the prior trading day to the current day, also reported as a percentage. Spread_bp is the difference between the bid and ask yields of the participating dealers, reported in basis points. Note that the ask yield and the spread can be directly obtained by subtracting the bid from spread_bp. TTM represents the time to maturity, reported in years.

symbol	asof	Maturity	Bid	Change_bp	Spread_bp	TTM
LB033A	1/2/2002	3/5/2003	2.498571	-5.2858	4.4285	1.169863014
LB038A	1/2/2002	8/31/2003	2.602857	-5	5.1428	1.660273973
LB03OA	1/2/2002	10/14/2003	2.607143	-5	5.4286	1.780821918
LB046A	1/2/2002	6/15/2004	2.692857	-4.4286	5	2.452054795
LB04NA	1/2/2002	11/30/2004	2.74	-2.4286	3.2857	2.912328767
LB053A	1/2/2002	3/5/2005	2.784286	-6.4285	4.1429	3.17260274
LB05OA	1/2/2002	10/14/2005	2.887143	-7.5714	4.8572	3.783561644
LB06DA	1/2/2002	12/8/2006	3.262857	-8.7143	3.2857	4.934246575
LB077A	1/2/2002	7/7/2007	3.462857	-8.1429	3.2857	5.512328767
LB082A	1/2/2002	2/12/2008	3.778571	-7.3572	5.8571	6.115068493
LB08DA	1/2/2002	12/8/2008	3.862857	-8.7143	2.7143	6.936986301
LB104A	1/2/2002	4/9/2010	4.351429	-9.1428	3.5715	8.271232877
LB113A	1/2/2002	3/5/2011	4.46	-8.2857	4	9.175342466
LB11NA	1/2/2002	11/30/2011	4.73	-10	2.9286	9.915068493
LB143A	1/2/2002	3/5/2014	5.101429	-5	5.8572	12.17808219
LB157A	1/2/2002	7/7/2015	5.264286	-5.1428	4.1429	13.51780822
LB214A	1/2/2002	4/9/2021	5.988571	-2.1429	8	19.27945205
LB033A	1/3/2002	3/5/2003	2.49	-0.8571	3.8333	1.167123288
LB038A	1/3/2002	8/31/2003	2.596667	-0.619	4.5	1.657534247
LB03OA	1/3/2002	10/14/2003	2.603333	-0.381	3.8333	1.778082192
LB046A	1/3/2002	6/15/2004	2.7	0.7143	3.5	2.449315069
LB04NA	1/3/2002	11/30/2004	2.75	1	3.5	2.909589041

Appendix A4. SAS Code for Bond Trading Analysis

```
*********************************
Read Bond Characteristics
*********************************;
%let path= C:\_Research\CMDF;
libname output "&path\data";
data output.BondChar;
      length IssueSize_txt $15 Outstanding_txt $15 Issue_Term_txt
$10 TTM_txt $10;
      length Symbol $15 ISIN $20 IssueNameThai  $100  Issuer $20
Rate_and_Agency $20
                Sector  $20  BondType $20 PrincipalPayment $30
BondStructure $30
                DebtType $20 SecuredType $20  Securedby  $20;
      length Coupon_Payment $20  Frequency  $20
                Embedded_Option $30 Claim_Type $30  Distribution $30
Duration $30 Registrar $30
                Underwriter $30  Representative $30 IssuerName $30
                Sustainability_Goal $30  ListedStatus $30
Distribution_type $30;
      informat Issue_Date Maturity_Date Registered_Date Payment_Date
XI_Date  Reset_Date Date9.;
      informat CurrentPar_THB comma15.2;
        format Issue_Date Maturity_Date Registered_Date Payment_Date
XI_Date  Reset_Date Date10.;

      infile "&path\Data\BondChar.csv" dsd dlm="," firstobs=2
truncover missover;
      input Symbol $ ISIN $ IssueNameThai $ Issuer $ Rate_and_Agency
$ Sector $ BondType $
                PrincipalPayment $  BondStructure $  DebtType $
SecuredType $  Securedby $
                Guarantor $  TRIS $ Fitch $ Moody $ SNP $ Fitch $
RNI $  CurrentPar_THB
                IssueSize_txt $ Outstanding_txt $ Issue_Term_txt $
TTM_txt $ Issue_Date Maturity_Date Registered_Date
                Coupon_Payment $  Payment_Date  XI_Date $
Reset_Date   Frequency $ Coupon_Pct
                Embedded_Option $ Claim_Type $  Distribution $
Duration $ Registrar $  Underwriter $  Representative $ IssuerName $
                Sustainability_Goal $  ListedStatus $
Distribution_type $;

      IssueSize_mln = input(IssueSize_txt,comma10.2);
      Outstanding_mln = input(Outstanding_txt,comma10.2);
      Issue_Term_yr = input(Issue_Term_txt,10.);
      TTM_yr = TTM_txt *1;
      drop IssueNameThai IssueSize_txt Outstanding_txt
Issue_Term_txt  TTM_txt;
run;

data output.Spread;
      length asof_txt $20  symbol $20  Maturity_txt  $20;
      format asof Maturity yymmdd10.;
```

```
	infile "&path\Data\BidAskSpread.csv" dsd dlm=',' firstobs=2
truncover missover;
	input asof_txt $ symbol  Bid Change_bp  Spread_bp
Maturity_txt $  TTM ;
	asof = input(scan(asof_txt,1," "),yymmdd10.);
	Maturity = input(scan(Maturity_txt,1," "),yymmdd10.);
	drop asof_txt Maturity_txt;

	ask = bid-spread_bp/100;
run;
************************************************************
Read Trade Transaction
***********************************************************;
%macro lp;
data read;
	length trade_datetxt $19 settlement_datetxt $19 report_datetxt
$29  match_datetxt $29;
	length purpose $8 subpurpose $8 trade_type $1 dealer $10
symbol $15 counter_party $10
			issue_type1 $8 issue_type2 $8 d2d_d2c $3
dealer_group $5 counterparty_group $5
			match_datetxt $29 match_id_text $18
transaction_id_text $18;
	format  trade_date settlement_date report_date match_date
yymmdd10.
			trade_time settlement_time report_time match_time
time15.5;

	infile  "&path\Data\transaction_&yy..csv" dlm=',' dsd missover
truncover firstobs=2;
	input trade_datetxt $ settlement_datetxt $ report_datetxt $
			purpose $ subpurpose $ trade_type $ dealer $ symbol
$ counter_party $
			yield  yield_type $ volume_unit  price_gross_Baht
			issue_type1 $ issue_type2 $ d2d_d2c $ dealer_group $
counterparty_group $ value_mb  price_clean
			match_datetxt $ match_id_text $ transaction_id_text
$ par_at_settlement  financing_rate  financing_term;

	trade_date = input(scan(trade_datetxt,1," "),yymmdd10.);
	trade_time = input(scan(trade_datetxt,2," "),time10.);

	settlement_date = input(scan(settlement_datetxt, 1,"
"),yymmdd10.);
	settlement_time = input(scan(settlement_datetxt, 2,"
"),time10.);

	report_date = input(scan(report_datetxt,1," "),yymmdd10.);
	report_time = input(scan(report_datetxt,2," "),time25.10);

	match_date = input(scan(match_datetxt,1," "),yymmdd10.);
	match_time = input(scan(match_datetxt,2," "),time25.10);

	drop trade_datetxt settlement_datetxt report_datetxt
match_datetxt;
run;
```

```
data all;
      set all read;
run;
%mend lp;
%let yy=2001-2012; %lp
%let yy=2013; %lp
%let yy=2014; %lp
%let yy=2015; %lp
%let yy=2016; %lp
%let yy=2017; %lp
%let yy=2018; %lp
%let yy=2019; %lp

data all;
      set output.all;
run;
proc import datafile="&path\Data\ListAllDate.xlsx"
      dbms=xlsx replace     out=alldate;
run;
proc sort data=output.combine_hol5 out=holiday;
      by newdate holiday2;
data holiday; set holiday; date=newdate; keep date; run;

data dayoff;
      merge alldate (in=a) holiday (in=b);
            by date;
      if a&b or weekday(date)=1 or weekday(date)=7 then off=1;
      else off=0;
      if year(date)>2000;
run;
proc sort data=dayoff; by descending date; run;
data dayoff2;
      retain countday chk;
      set dayoff;
      if (lag(off)=1) then do; countday+1; end;
      else do; countday=0; chk+1; end;
run;

data output.dayoff2;
      set dayoff2;
      drop off chk;
run;
data dayoff2;
      set output.dayoff2;
run;

proc sort data=output.all out=allbondnew; by symbol trade_date
transaction_id_text;
proc sql;
      create table allbondnew2 as
      select *
      from allbondnew as a, dayoff2 as b
      where a.trade_date=b.date;
quit;
** Use to check trade before holiday *;
proc sort data=allbondnew2;
```

```
     by symbol purpose subpurpose trade_date match_date
match_time  trade_time  report_time
           settlement_date  transaction_id_text volume_unit yield
dealer counter_party;
run;

data allbondnew3;
     set allbondnew2;
           by symbol purpose subpurpose trade_date match_date
match_time   trade_time  report_time
                 settlement_date transaction_id_text volume_unit
yield dealer counter_party;
     if match_date=lag(match_date) and abs(match_time-
lag(match_time)<0.1) and match_time^=. and
           match_id_text=lag(transaction_id_text) and
lag(match_id_text) = transaction_id_text and
           dealer = lag(counter_party) and counter_party=lag(dealer)
then do;
           faster=0;
     end;
run;
proc sort data=allbondnew3;
     by symbol purpose subpurpose trade_date match_date descending
match_time descending trade_time  descending report_time
           settlement_date transaction_id_text volume_unit yield
dealer counter_party;
run;
data allbondnew3;
     set allbondnew3;by symbol purpose subpurpose trade_date
match_date descending match_time descending trade_time descending
report_time
           settlement_date transaction_id_text volume_unit yield
dealer counter_party;

     lag_match_date =lag(match_date);
     lag_match_time =lag(match_time);
     lag_transaction_id_text = lag(transaction_id_text);
     lag_match_id_text = lag(match_id_text);
     lag_counter_party     =lag(counter_party);
     lag_dealer                 =lag(dealer);
     if match_date=lag_match_date and abs(match_time-
lag_match_time<0.1) and match_time^=. and
           match_id_text=lag_transaction_id_text and
transaction_id_text = lag_match_id_text and
           dealer = lag_counter_party and counter_party=lag_dealer
then do;
           faster=1;
     end;
     drop lag_match_date        lag_match_time
     lag_transaction_id_text          lag_match_id_text
     lag_counter_party     lag_dealer ;
run;
proc sort data=allbondnew3;
     by symbol purpose subpurpose trade_date match_date match_time
trade_time report_time
```

```
          settlement_date  transaction_id_text volume_unit yield
dealer counter_party;
run;
data allbondnew4;
     set allbondnew3;
     trade_datetime = dhms(trade_date, 0,0,trade_time);
     report_datetime = dhms(report_date, 0,0,report_time);
     lagtrade_datetime  = lag(trade_datetime);
     lag_faster      = lag(faster);
     lag_trade_date = lag(trade_date);
     lag_trade_time = lag(trade_time);
     lag_transaction_id_text = lag(transaction_id_text);
     lag_match_id_text = lag(match_id_text);
     lag_counter_party     =lag(counter_party);
     lag_dealer                 =lag(dealer);

     if (faster=0 or faster=1) and (lag_faster=1 or lag_faster=0)
and
          match_id_text         = lag_transaction_id_text and
          transaction_id_text = lag_match_id_text and
          dealer                          = lag_counter_party and
          counter_party         = lag_dealer         then do;
          if trade_datetime > lagtrade_datetime   then do;
               trade_datetime =lagtrade_datetime;
               trade_time = lag_trade_time;
               trade_date = lag_trade_date;
          end;
     end;
     drop lagtrade_datetime lag_faster lag_trade_date
lag_trade_time;
run;
proc sort data=allbondnew4;
     by symbol purpose subpurpose trade_date match_date trade_time
match_time report_time
          settlement_date  transaction_id_text volume_unit yield
dealer counter_party;
run;
data allbondnew4;
     set allbondnew4;
     trade_datetime = dhms(trade_date, 0,0,trade_time);
     report_datetime = dhms(report_date, 0,0,report_time);
     lagtrade_datetime  = lag(trade_datetime);
     lag_faster      = lag(faster);
     lag_trade_date = lag(trade_date);
     lag_trade_time = lag(trade_time);
     lag_transaction_id_text = lag(transaction_id_text);
     lag_match_id_text = lag(match_id_text);
     lag_counter_party     =lag(counter_party);
     lag_dealer                 =lag(dealer);
     if (faster=0 or faster=1) and (lag_faster=1 or lag_faster=0)
and
          match_id_text         = lag_transaction_id_text and
          transaction_id_text = lag_match_id_text and
          dealer                          = lag_counter_party and
          counter_party         = lag_dealer         then do;
          if trade_datetime > lagtrade_datetime   then do;
```

```
                  trade_datetime =lagtrade_datetime;
                  trade_time = lag_trade_time;
                  trade_date = lag_trade_date;
            end;
      end;
      drop lagtrade_datetime lag_faster lag_trade_date
lag_trade_time lag_transaction_id_text
            lag_counter_party     lag_dealer  lag_match_id_text;
run;
** Main Part is Here **;
data allbondnew5;
      format tmptrade_datetime tmpreport_datetime  datetime14.;
      set allbondnew4;
      tradedayofweek = weekday(trade_date);
      if    (report_date = trade_date) then do;
            if report_time >= trade_time then do;
                  cat = "00";
                  tmptrade_datetime = dhms(trade_date,
0,0,trade_time);
                  tmpreport_datetime = dhms(report_date,
0,0,report_time);
                  newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime); format newdelay time10.;
            end;
            else do;
                  cat = "09";
                  tmptrade_datetime = dhms(trade_date,
0,0,trade_time);   ** cannot use normal time gap between day **;
                  tmpreport_datetime = dhms(report_date,
0,0,report_time);
                  newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime); format newdelay time10.;
            end;
      end;
      else if    (report_date = trade_date+1) then do;
            if trade_time >= "15:30"t then do;
                  if report_time<="9:30"t then do;
                        cat = "10";
                        tmptrade_datetime = dhms(trade_date,
0,0,trade_time);
                        tmpreport_datetime = dhms(report_date,
0,0,report_time);
                        newdelay = "0:00"t; format newdelay time10.;
                  end;
                  else do;
                        cat = "11";
                        tmptrade_datetime = dhms(trade_date+1,
0,0,"9:30"t);   ** as if trade start 9:30 **;
                        tmpreport_datetime = dhms(report_date,
0,0,report_time);
                        newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime)+"0:30"t; format newdelay time10.;
                  end;
            end;
            if trade_time < "15:30"t then do;
                  cat = "15";
```

```
                tmptrade_datetime = dhms(trade_date,
0,0,trade_time);  ** fixed according to email **;
                tmpreport_datetime = dhms(report_date,
0,0,report_time);
                newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime); format newdelay time10.;
            end;
      end;
      else if    (report_date = trade_date+countday+1) then do;
            if trade_time >= "15:30"t then do;
                if report_time<="9:30"t then do;
                      cat = "20";
                      tmptrade_datetime = dhms(trade_date,
0,0,trade_time);
                      tmpreport_datetime = dhms(report_date,
0,0,report_time);
                      newdelay = "0:00"t; format newdelay time10.;
                end;
                else do;
                      cat = "29";
                      tmptrade_datetime =
dhms(trade_date+countday+1, 0,0,"9:30"t);   ** as if trade start
9:30 **;
                      tmpreport_datetime = dhms(report_date,
0,0,report_time);
                      newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime)+"0:30"t; format newdelay time10.;
                end;
            end;
            else if trade_time < "15:30"t then do;
                cat = "25";
                tmptrade_datetime = dhms(trade_date,
0,0,trade_time);
                tmpreport_datetime = dhms(report_date,
0,0,report_time);
                newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime)-countday*"0:24:00"t; format newdelay time10.;
            end;
      end;
      else if    (report_date > trade_date+countday+1) then do;
            if trade_time >= "15:30"t then do;
                      cat = "99";
                      tmptrade_datetime =
dhms(trade_date+countday+1, 0,0,"9:30"t);   ** as if trade start
9:30 **;
                      tmpreport_datetime = dhms(report_date,
0,0,report_time);
                      newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime)+"0:30"t; format newdelay time10.;
            end;
            else if trade_time < "15:30"t then do;
                cat = "95";
                tmptrade_datetime = dhms(trade_date,
0,0,trade_time);
                tmpreport_datetime = dhms(report_date,
0,0,report_time);
```

```
                newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime)-countday*"0:24:00"t; format newdelay time10.;
           end;

      end;
      else if (report_date < trade_date+countday+1) then do;
           cat = "XX";
           tmptrade_datetime = dhms(trade_date, 0,0,trade_time);
** cannot use normal time gap between day **;
           tmpreport_datetime = dhms(report_date, 0,0,report_time);
           newdelay = intck("minute",tmptrade_datetime,
tmpreport_datetime); format newdelay time10.;
      end;
run;
proc sql;
      create table count_issue_type as
      select issue_type1, n(issue_type1) as count
      from allbondtrade
      where issue_type1 not eq ''
      group by issue_type1;
      create table count_issue_type_all as
      select "ALL" as issue_type1, n(issue_type1) as count
      from allbondtrade
      where issue_type1 not eq '';
quit;
data T01_count_issue_type_stack;
      set count_issue_type_all  count_issue_type;
run;
data bondtrd;
      set allbondtrade;
      if issue_type1="GB";
      if purpose="OUT";
      yr = year(datepart(trade_datetime)); format yr z4.;
      mo = month(datepart(trade_datetime)); format mo z2.;
      dd = day(datepart(trade_datetime)); format dd z2.;
      yrmo = compress(yr)||'_'||compress(mo);
      tradedate = datepart(trade_datetime); format tradedate
yymmdd10.;
      time = timepart(trade_datetime); format time time.;
      hh = hour(timepart(trade_datetime));
      mm = minute(timepart(trade_datetime));
            if 0<=newdelay<="0:00:15"t then do; delay15=1;
dum_delay15=1; dum_delay30=1; dum_delay99=0; end;
      else if "0:00:15"t<newdelay<"0:00:30"t then do; delay15=0;
dum_delay15=0; dum_delay30=1; dum_delay99=0; end;
      else                                    do; delay15=0;
dum_delay15=0; dum_delay30=0; dum_delay99=1; end;
run;
proc sort data=bondtrd; by symbol settlement_date trade_datetime
report_datetime;run;
proc sort data=output.BondChar  out=BondChar ; by Symbol;
proc sort data=output.Spread     out=Spread;  by maturity Symbol ;
run;
**************************************
Match Char + Transaction + Spread
**************************************;
```

```
data bondtrd2;
      merge bondtrd (in=b) bondchar (in=c); by symbol;
      if b&c;
run;
*** Spread has only GB issue_type ***;
proc sql;
      create table bondtrd3 as
      select *
      from bondtrd2 as b, spread as s
      where b.symbol=s.symbol and b.tradedate=s.asof
      order by b.symbol, b.tradedate, b.time;
quit;
proc sort data=bondtrd3;
      by symbol purpose subpurpose trade_date match_date match_time
trade_time report_time
            settlement_date  transaction_id_text volume_unit yield
dealer counter_party;
run;
proc sql;
      create table bondtrd4 as
      select *
      from bondtrd3 as a, policy as b
      where a.trade_date=b.Dates;
quit;
** drop black columns **;
data bondtrd4;
      set bondtrd4;
      format trade_datetime report_datetime  datetime.;
      drop Distribution_type Payment_Date XI_Date Reset_Date
CurrentPar_THB Guarantor
            TRIS Fitch Moody SNP RNI Rate_and_Agency
Sustainability_Goal ListedStatus;
      drop financing_rate  financing_term
              settlement_time  Underwriter Representative IssuerName;
      drop ISIN issuer sector bondtype PrincipalPayment
BondStructure SecuredType Securedby
            Coupon_Payment Frequency Embedded_Option Claim_Type
Distribution Duration Registrar;
run;
proc sql;
      create table final_sample as
      select issue_type1, freq(issue_type1) as count
      from bondtrd4
      where issue_type1="GB"
      group by issue_type1;
quit;
data T01_final_sample;
      set final_sample;
run;
********************************
Sample Descriptive Stat
*******************************;
proc sql;
      create table symbol_year as
      select yr, n(distinct symbol) as nsym
      from bondtrd4
```

```
      group by yr;

      create table symbol_year_all as
      select 0000 as yr, n(distinct symbol) as nsym
      from bondtrd4;
quit;
data T02_symbol_year_stack;
      set symbol_year_all symbol_year ;
run;
proc sql;
      create table chk_dealer as
      select distinct dealer
      from bondtrd4
      ORDER BY DEALER;
quit;
proc sql;
      create table chk_counter_party as
      select distinct counter_party
      from bondtrd4
      ORDER BY counter_party;
quit;
*******************************************************************
********
4 dealer group = BANKF,BANKL, NDL, SC
10 counterparty group = AMC, BANKF, BANKL, DCO, FCO, IND, INS, NDL,
OTH, SEC
*******************************************************************
********;
proc sql;
      create table chk_dealer_party_group as
      select dealer_group, counterparty_group, count(counter_party)
as nn
      from bondtrd4
      group by dealer_group, counterparty_group
      order by counterparty_group, dealer_group;
quit;
proc transpose data=chk_dealer_party_group
out=chk_dealer_party_group2;
      var nn;
      by counterparty_group;
      id dealer_group;
run;
*******************************************
Filter by Dealer Number (individual dealer)
*****************************************;
proc sql;
      create table dealer_ntrd as
      select dealer, yr,mo, freq(dealer) as ntrd
      from bondtrd4
      group by dealer, yr,mo;
quit;
proc sort data=dealer_ntrd; by yr mo;
proc transpose data=dealer_ntrd  out=dealer_ntrd2;
      by yr mo;
      var ntrd;
      id dealer;
```

```
run;
*** Dealer with less than 100 months ***;
proc sql;
      create table dealer_ntrd_mth as
      select dealer, n(dealer) as ntrd_mth
      from dealer_ntrd
      group by dealer
      order by ntrd_mth desc;
quit;
*********************************
Check two logic to filter
********************************;
** Manually Selected Dealers with Enough Activity ***;
data filter_dealer;
input dealer $;
datalines;
Dealer1
Dealer12
Dealer13
Dealer138
Dealer139
Dealer143
Dealer155
Dealer157
Dealer2
Dealer4
Dealer71
Dealer73
Dealer74
Dealer75
Dealer82
Dealer9
Dealer93
Dealer256
Dealer5
Dealer94
Dealer8
Dealer76
Dealer349
Dealer88
Dealer408
Dealer59
Dealer950
;
run;
*** Distribution of Delay ***;
data delay_distribution;
      set bondtrd4;
      select;
            when (newdelay<-"0:06:00"t) prd=-9;
            when (-"0:06:00"t<=newdelay<-"0:05:00"t) prd=-6;
            when (-"0:05:00"t<=newdelay<-"0:04:00"t) prd=-5;
            when (-"0:04:00"t<=newdelay<-"0:03:00"t) prd=-4;
            when (-"0:03:00"t<=newdelay<-"0:02:00"t) prd=-3;
            when (-"0:02:00"t<=newdelay<-"0:01:00"t) prd=-2;
            when (-"0:01:00"t<=newdelay< "0:00:00"t) prd=-1;
```

```
          when (newdelay="0:00:00"t and (trade_date=report_date and
report_time=trade_time)) prd=0;
          when ( "0:00:00"t<=newdelay< "0:00:15"t) prd=+0.15;
          when ( "0:00:15"t<=newdelay< "0:00:30"t) prd=+0.30;
          when ( "0:00:30"t<=newdelay< "0:01:00"t) prd=+1;
          when ( "0:01:00"t<=newdelay< "0:02:00"t) prd=+2;
          when ( "0:02:00"t<=newdelay< "0:03:00"t) prd=+3;
          when ( "0:03:00"t<=newdelay< "0:04:00"t) prd=+4;
          when ( "0:04:00"t<=newdelay< "0:05:00"t) prd=+5;
          when ( "0:05:00"t<=newdelay< "0:06:00"t) prd=+6;
          otherwise prd=9;
     end;
run;
proc sql;
     create table freq_delay as
     select prd, freq(prd) as nfreq
     from delay_distribution
     group by prd;
quit;
*** Negative Delay ***;
data neg_delay;
     set bondtrd4;
     if newdelay<0;
run;
proc sql;
     create table neg_delay_yr as
     select yr, n(dealer) as neg_obs, sum(value_mb/1000) as
value_mb
     from neg_delay
     group by yr;

     create table neg_delay_yr_dealer as
     select yr, dealer, n(dealer) as neg_dealer, sum(value_mb/1000)
as value_mb
     from neg_delay
     group by yr, dealer
     order by dealer, yr;
     create table neg_delay_BS as
     select trade_type, n(dealer) as neg_dealer,
sum(value_mb/1000) as value_mb
     from neg_delay
     group by trade_type;
     create table neg_delay_BS_dealer as
     select trade_type, dealer, n(dealer) as neg_dealer,
sum(value_mb/1000) as value_mb
     from neg_delay
     group by trade_type,dealer
     order by trade_type,dealer;
quit;
data neg_delay_BS_dealer;
     set neg_delay_BS_dealer;
     if trade_type="S" then do;
          neg_dealer=neg_dealer*-1;
          value_mb = value_mb*-1; end;
run;
** LONG DELAY ***;
```

```
data long_delay;
      set bondtrd4;
      if newdelay>"0:06:00"t;
run;
proc sql;
      create table long_delay_yr as
      select yr, n(dealer) as long_dealer, sum(value_mb/1000) as
value_mb
      from long_delay
      group by yr;

      create table long_delay_yr_dealer as
      select yr, dealer, n(dealer) as long_dealer,
sum(value_mb/1000) as value_mb
      from long_delay
      group by yr, dealer
      order by dealer, yr;

      create table long_delay_yr_day as
      select yr, tradedayofweek, n(dealer) as long_day,
sum(value_mb/1000) as value_mb
      from long_delay
      group by yr, tradedayofweek
      order by yr, tradedayofweek;

      create table long_delay_BS as
      select trade_type, n(dealer) as long_dealer,
sum(value_mb/1000) as value_mb
      from long_delay
      group by trade_type;

      create table long_delay_BS_dealer as
      select trade_type, dealer, n(dealer) as long_dealer,
sum(value_mb/1000) as value_mb
      from long_delay
      group by trade_type,dealer
      order by trade_type, dealer;
quit;
data long_delay_BS_dealer;
      set long_delay_BS_dealer;
      if trade_type="S" then do;
            long_dealer=long_dealer*-1;
            value_mb = value_mb*-1; end;
run;
proc transpose data=long_delay_yr_day out=long_delay_yr_day2;
      var long_day value_mb;
      by yr;
      id tradedayofweek;
run;
proc sort data=long_delay_yr_day2;
      by _NAME_ yr ;
run;
*********************************************
** Filter Obs for overall delay **;
proc sql;
      create table all_delay as
```

```
      select yr, mo, mean(newdelay) as newdelay format time.
      from bondtrd4
      where (faster=. or faster=1)
      group by yr, mo;
quit;
***********************
Daily Delay Analysis
**********************;
** Filter Dealer with Regular Transaction **;
** from bondtrd5  Robustness  try to filter no delay **;
proc sql;
      create table bondtrd5 as
      select b.*
      from bondtrd4 as b, filter_dealer as f
      where b.dealer=f.dealer  and newdelay>0 and
newdelay<"0:06:00"t
      order by b.symbol,b.tradedate, b.settlement_date;
quit;
** pick data to use **;
%let usethis=bondtrd5;
%let depvar =turnover;
ods trace on;
*******************************
** Analyze Daily Delay & Spread
*******************************;
proc sql;
      create table avg_delay_daily as
      select symbol, yr,mo,tradedate, mean(newdelay) as newdelay
      from &usethis
      group by symbol,yr,mo, tradedate;
      create table avg_spread_daily as
      select symbol, yr,mo,tradedate, mean(spread_bp) as spread
      from &usethis
      group by symbol,yr,mo, tradedate;
      create table sum_turnover_daily as
      select symbol, yr,mo,tradedate, sum(value_mb/IssueSize_mln) as
turnover
      from &usethis
      group by symbol,yr,mo,tradedate;
      create table bond_char_daily as
      select distinct symbol, yr,mo,tradedate, Coupon_Pct,
IssueSize_mln, Outstanding_mln,
            issue_term_yr, TTM, spread_bp, change_bp
      from &usethis;
quit;
proc sql;
      create table avg_spread_daily2 as
      select yr, mo, mean(spread) as spread
      from avg_spread_daily
      group by yr,mo;
proc sql;
      create table sum_turnover_daily2 as
      select yr, mo, sum(turnover) as turnover
      from sum_turnover_daily
      group by yr,mo;
quit;
```

```
*********************************************
** Try Aggregate Daily
*********************************************;
data regress_bond_daily;
     merge avg_delay_daily avg_spread_daily sum_turnover_daily
bond_char_daily;
          by symbol yr mo tradedate;
     if tradedate < "01Jan06"d then do;
          D_Period1=1; D_Period2=0; D_Period3=0;
     end;
     else if tradedate < "01Jan09"d then do;
          D_Period1=0; D_Period2=1; D_Period3=0;
     end;
     else do;
          D_Period1=0; D_Period2=0; D_Period3=1;
     end;
     time_trend = yr-2001;
     delay_D_Period1 = newdelay*D_Period1;
     delay_D_Period2 = newdelay*D_Period2;
     delay_D_Period3 = newdelay*D_Period3;
RUN;
*********************************************
** Try TRANSACTION DATA, Not Aggregate Daily
*********************************************;
data regress_bond_bytrade;
     set &usethis;
     ** divide to 3 periods and 3 dummy **;
     if tradedate < "01JAN06"d then do;
          D_Period1=1; D_Period2=0; D_Period3=0;
     end;
     else if tradedate < "01JAN09"d then do;
          D_Period1=0; D_Period2=1; D_Period3=0;
     end;
     else do;
          D_Period1=0; D_Period2=0; D_Period3=1;
     end;
     if trade_type="B" then BS=1;
     else BS=0;
     if tradedayofweek =2 then Mon=1; else Mon=0;
     if tradedayofweek =3 then Tue=1; else Tue=0;
     if tradedayofweek =4 then Wed=1; else Wed=0;
     if tradedayofweek =5 then Thu=1; else Thu=0;
     if tradedayofweek =6 then Fri=1; else Fri=0;
     delay_D_Period1 = newdelay*D_Period1;
     delay_D_Period2 = newdelay*D_Period2;
     delay_D_Period3 = newdelay*D_Period3;
     delay15_D_Period1 = delay15*D_Period1;
     delay15_D_Period2 = delay15*D_Period2;
     delay15_D_Period3 = delay15*D_Period3;
     turnover = value_mb/IssueSize_mln;
     log_value_mb = log(value_mb);
     time_trend = yr-2001;
     time_trend_sq = time_trend**2;
           if d2d_d2c="D2D" then dummy_D2C=0;
     else if d2d_d2c="D2C" then dummy_D2C=1;
           if dealer_group = "BANKL" then D_dealer0=1;
```

```
      else if dealer_group = "BANKF" then D_dealer1=1;
      else if dealer_group = "NDL"   then D_dealer2=1;
      else if dealer_group = "SEC"   then D_dealer3=1;
            if counterparty_group = "BANKL" then D_counter0=1;
      else if counterparty_group = "BANKF" then D_counter1=1;
      else if counterparty_group = "AMC"   then D_counter2=1;
      else if counterparty_group = "SEC"   then D_counter3=1;
      else if counterparty_group = "DCO"   then D_counter4=1;
      else if counterparty_group = "FCO"   then D_counter5=1;
      else if counterparty_group = "IND"   then D_counter6=1;
      else if counterparty_group = "INS"   then D_counter7=1;
      else if counterparty_group = "NDL"   then D_counter8=1;
      else if counterparty_group = "OTH"   then D_counter9=1;
      if D_dealer0=. then D_dealer0=0;
      if D_dealer1=. then D_dealer1=0;
      if D_dealer2=. then D_dealer2=0;
      if D_dealer3=. then D_dealer3=0;
      if D_counter0=. then D_counter0=0;
      if D_counter1=. then D_counter1=0;
      if D_counter2=. then D_counter2=0;
      if D_counter3=. then D_counter3=0;
      if D_counter4=. then D_counter4=0;
      if D_counter5=. then D_counter5=0;
      if D_counter6=. then D_counter6=0;
      if D_counter7=. then D_counter7=0;
      if D_counter8=. then D_counter8=0;
      if D_counter9=. then D_counter9=0;
      drop purpose subpurpose faster yr mo dd ymo hh mm isin issuer
sector bondtype principalpayment bondstructure debttype
           securedtype securedby Coupon_Payment Frequency
Embedded_Option Claim_Type Distribution Duration Registrar
           Underwriter Representative IssuerName
           Sustainability_Goal ListedStatus Issue_Date Maturity_Date
           Registered_Date TTM_yr asof Maturity;
run;
***********************************************************
Delay = Dummy Period + Other Variable
**********************************************************;
** DAILY **;
ods output ParameterEstimates=reg_delaydaily;
proc surveyreg data = regress_bond_daily;
      cluster symbol ;
      model newdelay =  D_Period2 D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr;
quit;
proc export data=reg_delaydaily replace dbms=xlsx
      outfile="&path\Output\reg_delay.xlsx";
      sheet="delaydaily";
run;
** TRANSACTION **;
ods output ParameterEstimates=reg_delaybytrade;
proc surveyreg data = regress_bond_bytrade;
      cluster symbol;
      model newdelay = D_Period2 D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr;
quit;
```

```
proc export data=reg_delaybytrade replace dbms=xlsx
      outfile="&path\Output\reg_delay.xlsx";
      sheet="delay_bytrade";
run;
ods output ParameterEstimates=reg_delaybytrade_ctrl;
proc surveyreg data = regress_bond_bytrade;
      cluster symbol;
      model newdelay =  D_Period2 D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr
                              D_dealer0 D_dealer1 D_dealer2  Tue Wed
Thu Fri dummy_D2C ;
quit;
proc export data=reg_delaybytrade_ctrl replace dbms=xlsx
      outfile="&path\Output\reg_delay.xlsx";
      sheet="delay_bytrade_ctrl";
run;
ods output ParameterEstimates=reg_delay15bytrade;
proc surveyreg data = regress_bond_bytrade;
      cluster symbol ;
      model dum_delay15 = D_Period2 D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr ;
quit;
proc export data=reg_delay15bytrade replace dbms=xlsx
      outfile="&path\Output\reg_delay.xlsx";
      sheet="delay15_bytrade";
run;
ods output ParameterEstimates=reg_delay15bytrade_ctrl;
proc surveyreg data = regress_bond_bytrade;
      cluster symbol ;
      model dum_delay15 = D_Period2 D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr
                              D_dealer0 D_dealer1 D_dealer3   Tue Wed
Thu Fri  dummy_D2C ;
quit;
proc export data=reg_delay15bytrade_ctrl replace dbms=xlsx
      outfile="&path\Output\reg_delay.xlsx";
      sheet="delay15_bytrade_ctrl";
run;
***********************************************************
Regression
**********************************************************;
** DAILY **;
ods output ParameterEstimates=reg_daily_&depvar;
proc surveyreg data = regress_bond_daily;
   cluster symbol ;
   model &depvar =  newdelay  D_Period2  D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr ;
quit;
proc export data=reg_daily_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="daily_&depvar";
run;
** TRANSACTION **;
ods output ParameterEstimates=reg_bytrade_&depvar;
proc surveyreg data = regress_bond_bytrade;
   cluster symbol ;
```

```
   model &depvar = newdelay  D_Period2  D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr ;
quit;
proc export data=reg_bytrade_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="bytrade_&depvar";
run;
** CTRL **;
ods output ParameterEstimates=reg_bytradectrl_&depvar;
proc surveyreg data = regress_bond_bytrade;
   cluster symbol;
   model &depvar =  newdelay  D_Period2  D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr
                         D_dealer0 D_dealer1 D_dealer2  Tue Wed Thu
Fri dummy_D2C;
quit;
proc export data=reg_bytradectrl_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="bytradectrl_&depvar";
run;
** DUMMY **;
ods output ParameterEstimates=delay30_bytrade_&depvar;
proc surveyreg data = regress_bond_bytrade;
   cluster symbol ;
   model &depvar = dum_delay30 D_Period2 D_Period3 TTM issueSize_mln
coupon_pct Issue_Term_yr ;
quit;
proc export data=delay30_bytrade_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="delay30bytrade_&depvar";
run;
** CTRL **;
ods output ParameterEstimates=delay30_bytradectrl_&depvar;
proc surveyreg data = regress_bond_bytrade;
   cluster symbol ;
   model &depvar = dum_delay30 D_Period2  D_Period3 TTM
issueSize_mln coupon_pct Issue_Term_yr
                        dummy_D2C D_dealer0 D_dealer1 D_dealer2  Tue
Wed Thu Fri;
quit;
proc export data=delay30_bytradectrl_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="delay30bytradectrl_&depvar";
run;
** Time Trend **;
** TRANSACTION **;
ods output ParameterEstimates=trade_trend_&depvar;
proc surveyreg data = regress_bond_bytrade;
   cluster symbol ;
   model &depvar =  newdelay time_trend          TTM issueSize_mln
coupon_pct Issue_Term_yr ;
quit;
proc export data=trade_trend_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="trade_trend_&depvar";
run;
```

```
** CTRL **;
ods output ParameterEstimates=trade_trendctrl_&depvar;
proc surveyreg data = regress_bond_bytrade;
   cluster symbol ;
   model &depvar =  newdelay time_trend          TTM issueSize_mln
coupon_pct Issue_Term_yr
                        D_dealer0 D_dealer1 D_dealer2  Tue Wed Thu
Fri dummy_D2C;
quit;
proc export data=trade_trendctrl_&depvar replace dbms=xlsx
      outfile="&path\Output\reg_liq.xlsx";
      sheet="trade_trendctrl_&depvar";
run;
********************************************
Count Buy Sell for PIN
******************************************;
proc sql;
      create table nbuy_dealer as
      select symbol as ticker, tradedate as date,  n(trade_type) as
buys
      from regress_bond_bytrade
      where trade_type="B"
      group by symbol, tradedate;

      create table nsell_dealer as
      select symbol as ticker, tradedate as date, n(trade_type) as
sells
      from regress_bond_bytrade
      where trade_type="S"
      group by symbol, tradedate;
quit;
data nbuysell_dealer;
      merge nbuy_dealer  nsell_dealer; by ticker date;
      if buys=. then buys=0;
      if sells=. then sells=0;
run;
**********************************
Separate Here
*********************************;
proc sql;
      create table nbuysell_period1 as
      select symbol,             trade_type, tradedate as date,
n(trade_type) as ntrd
      from regress_bond_bytrade
      where D_Period1=1
      group by symbol,           trade_type, tradedate;

      create table nbuysell_period2 as
      select symbol,                  trade_type, tradedate as date,
n(trade_type) as ntrd
      from regress_bond_bytrade
      where D_Period2=1
      group by symbol,           trade_type, tradedate;

      create table nbuysell_period3 as
```

```
      select symbol,             trade_type, tradedate as date,
n(trade_type) as ntrd
      from regress_bond_bytrade
      where D_Period3=1
      group by symbol,            trade_type, tradedate;
quit;

data merge_nbuysell_period1;
      merge nbuysell_period1 (where=(trade_type="B")
rename=(ntrd=buys))
             nbuysell_period1 (where=(trade_type="S")
rename=(ntrd=sells));
             by symbol           date;
      if buys=. then buys=0;
      if sells=. then sells=0;
run;

data merge_nbuysell_period2;
      merge nbuysell_period2 (where=(trade_type="B")
rename=(ntrd=buys))
             nbuysell_period2 (where=(trade_type="S")
rename=(ntrd=sells));
             by symbol                date;
      if buys=. then buys=0;
      if sells=. then sells=0;
run;

data merge_nbuysell_period3;
      merge nbuysell_period3 (where=(trade_type="B")
rename=(ntrd=buys))
             nbuysell_period3 (where=(trade_type="S")
rename=(ntrd=sells));
             by symbol                date;
      if buys=. then buys=0;
      if sells=. then sells=0;
run;
%let prd=period1;
data trades;
      set merge_nbuysell_&prd;
      period = year(date)*100+month(date);
run;
proc sql;
      create table trades2 as
      select symbol,         period , sum(buys) as buys, sum(sells)
as sells
      from trades
      group by symbol,           period;
quit;
ods output AdditionalEstimates=pin ConvergenceStatus=cs
 IterHistory=ih FitStatistics=fs;

proc nlmixed data=trades2 fd=central technique=quanew update=bfgs;
 by symbol;
 parms a=.1 .5 .9, d=.1 .5 .9, u=20 200 2000, e=20 200 2000;
 bounds 0 <= a d <= 1, u e >= 0;
```

```
 pin = a*u / (a*u + 2*e);

 temp = (1-a)*pdf('poisson',buys,e)*pdf('poisson',sells,e)
        + a*d*pdf('poisson',buys,e)*pdf('poisson',sells,u+e)
        + a*(1-d)*pdf('poisson',buys,u+e)*pdf('poisson',sells,e);

 if temp = 0 then temp = 1E-300;
 loglik = log(temp);
 model buys~general(loglik);
 estimate 'alpha' a;
 estimate 'delta' d;
 estimate 'mu' u;
 estimate 'epsilon' e;
 estimate 'PIN' pin;
run;
proc print data=pin label;
 label ticker='Stock ticker';
 title 'PIN estimates';
run;
proc print data=cs;
 title 'Convergence Status for MLE procedure';
run;
proc print data=fs;
 title 'Additional statistics';
run;
proc sql;
     create table PIN_Out_&prd as
     select *
     from PIN
     where Label="PIN";
quit;
data combine_PIN;
     merge PIN_Out_period1 (rename=(Estimate=PIN_prd1
Probt=pvalue_prd1))
                PIN_Out_period2 (rename=(Estimate=PIN_prd2
Probt=pvalue_prd2))
                PIN_Out_period3 (rename=(Estimate=PIN_prd3
Probt=pvalue_prd3));
           by dealer;
     drop StandardError tvalue DF  Alpha Lower Upper;
run;
proc export data=combine_PIN replace dbms=xlsx
     outfile="&path\Output\PIN.xlsx";
     sheet="combine_PIN_all";
run;
```

Appendix C. R Code for Bond Price Jump Analysis

```
title: "R Code for Price Jump Analysis"
author: "Christina Sun & Worapree Maneesoonthorn"
output:
  pdf_document: default
  html_document: default
editor_options:
  chunk_output_type: console
---
```{r setup}
#------------  Calculate RV, BV, TQ ----------------------------
library(data.table)
library(tidyverse)
library(dplyr)
library(chron)
library(hms)
library(lubridate)
library(boot)

#change bond name here
bond_code = "LB11NA"

filename1 = paste0(bond_code,".csv")
filename2 = paste0(bond_code,"duration.csv")

LB1 <- read.csv(filename1)
final_result <- read.csv(filename2)
```
```{r}
#-------------------------------------------
LB1$trade_date <- as.Date(LB1$trade_date,format = "%Y-%m-%d")

LB1 <- LB1 %>% group_by(trade_date,symbol) %>%
  arrange(trade_date,trade_time)

# If trade time is the same - take the average price
LB1 <- LB1 %>%
  group_by(trade_date,trade_time,symbol) %>%
  summarise(avg_price = mean(price_clean))
# identify week days and **week number of the year**
LB1$wday <- wday(LB1$trade_date) #, week_start=1
```
```

````
LB1$wnum <- format(LB1$trade_date,format="%W")
#temp = week(LB1$trade_date)

# filter out weeks less than 30 trades per week
LB1_filter <- LB1 %>% group_by(wnum) %>%
  mutate(trade_count = n()) %>%
  filter(trade_count > 30) %>%
  ungroup()
# %>% select(-trade_count)
LB1_filter$yearweek <- paste0(year(LB1_filter$trade_date),LB1_filter$wnum)
# Find the maximum duration for each day of the week - use codes in Summary.R

#max(final_result$Max_minutes)
mean(final_result$Max_minutes)
```
```{r}
# filter out inactive days - max_duration > mean(max duration)
# OR trade number per day < mean(trade number)
#tempdf <- final_result %>% filter(TradesNumber > mean(TradesNumber))
tempdf <- final_result %>%
  filter(Max_minutes < round(mean(final_result$Max_minutes)))
Datelist <- unique(tempdf$trade_date)
LB1_filter <- LB1_filter %>% filter(trade_date %in% as.Date(Datelist))
# ----------- break the data based on the avg max duration (2 hours)
# create POSIXct timestamp
LB1_filter$tc <-
as.POSIXct(paste(LB1_filter$trade_date,LB1_filter$trade_time),format = "%Y-%m-
%d %H:%M:%S")
LB1_filter$tb <- floor_date(LB1_filter$tc,"2 hours")
LB1_filter$cut_time <- format(LB1_filter$tb,format = "%H:%M:%S")
interval = 2

# use the last price as the x-hour price
LB1_filter <- LB1_filter %>%
  group_by(trade_date,cut_time) %>%
  slice(n())
# Calculate the percentage returns, RV, BV, TQ
LB1_filter$r <- 100 * (log(LB1_filter$avg_price) - lag(log(LB1_filter$avg_price)))

LB1_filter = subset(LB1_filter,r!=0)

r43 <- abs(LB1_filter$r)^(4/3)
LB1_filter$BV.prep <- abs(LB1_filter$r) * lag(abs(LB1_filter$r))
LB1_filter$TQ.prep <- r43 * lag(r43) * lag(r43, n = 2)
````

````
mu <- (2 ^ (2/3)) * gamma(7/6) * (gamma(1/2) ^ -1)
weekly.data <- LB1_filter %>%
  group_by(yearweek,symbol) %>%
  summarise(
      r_weekly = sum(r, na.rm = TRUE),
      M = length(r),
      RV = sum(r^2, na.rm = TRUE),
      BV = (pi/2)*(M/(M-1)) * sum(BV.prep, na.rm = TRUE),
      TQ = (mu ^ -3) * (M^2)/(M-2) *sum(TQ.prep, na.rm = TRUE)
  )
# delete the first row - because of the NA created when calculating r, rv, bv, tq, first summation is not correct.
weekly.data = weekly.data[-1,]
weekly.data$JV = pmax(0,weekly.data$RV-weekly.data$BV)
write.csv(weekly.data,file = paste0(bond_code,"measure_full.csv"),row.names = FALSE)

# remove the rows where M = 1 and M =2 - create problems for BV, TQ calculation
new_weekly = subset(weekly.data, M!=1)
new_weekly = subset(new_weekly, M!=2)
```



```{r BNS}
# BNS jump test function
BNS_func <- function(data,M){
  RJ = (data$RV - data$BV)/data$RV

  abs_r = abs(data$r_weekly)
  c <- ((2^(2/3)) * gamma(7/6) * (gamma(1/2)^(-1/2)))^(-3)
  #TP <- sum((abs_r[3:length(abs_r)]^(4/3)) * (abs_r[2:(length(abs_r)-1)]^(4/3)) * (abs_r[1:(length(abs_r)-2)]^(4/3)))
  #TP <- c * ((M^2)/(M-2)) * TP
  TP = data$TQ
  V <- ((pi/2)^2 + pi - 5) * pmax(1, (TP / (data$BV^2))) / M

  BNSstats = RJ/sqrt(V)
  return(BNSstats)
}
```
```{r}
alpha = c(0.001,0.005,0.01,0.05,0.1)
crit = qnorm(1-alpha,0,1)
````

```
BNS_stats = BNS_func(new_weekly,new_weekly$M)
jump = matrix(0, nrow = length(BNS_stats), ncol = length(alpha))
for (i in seq_along(alpha)){
  jump[,i] <- as.integer(BNS_stats > crit[i])
}

fullMeasure = cbind(new_weekly,jump)

colnames(fullMeasure)[9:13] <-
c("BNS(0.1%)","BNS(0.5%)","BNS(1%)","BNS(5%)","BNS(10%)")

write.csv(fullMeasure,file = paste0(bond_code,"measure_clean.csv"),row.names =
FALSE)
```

Regression of JV

```{r}
# Calculate TTM
bond_character <- read.csv("bondChar.csv")
Maturity = as.Date(bond_character$Maturity.Date[bond_character$ThaiBMA.Symbol
== bond_code],format = "%Y-%m-%d")
LB1_filter$TTM = as.numeric(difftime(Maturity,LB1_filter$trade_date,units =
"days")) %>% round()
# Create indicators for regulation
#threat_date <- as.Date("2008-01-07")
threat_date <- as.Date("2006-01-01")
#fine_date <- as.Date("2014-01-21")
fine_date <- as.Date("2009-01-01")

LB1_filter$fine_ind <- ifelse(LB1_filter$trade_date >= fine_date,1,0)
LB1_filter$threat_ind <- ifelse(LB1_filter$trade_date >= threat_date &
LB1_filter$trade_date < fine_date,1,0)
```

```{r}
data_comp <-
  left_join(
  new_weekly |> ungroup(),
  LB1_filter |> ungroup() |> select(TTM, threat_ind, fine_ind, yearweek) |>
group_by(yearweek) |> mutate(TTM = round(max(TTM)/365)) |> ungroup() |> distinct()
  #LB1_filter |> ungroup() |> select(TTM, threat_ind, yearweek) |> group_by(yearweek)
|> mutate(TTM = round(max(TTM)/365)) |> ungroup() |> distinct()
  , by=join_by(yearweek)
) # |> View()
```

````
```{r}
# linear regression
library(jtools)
log_weekly = data_comp
log_weekly = subset(log_weekly,JV!=0)
log_model = lm(log(JV)~threat_ind + fine_ind + TTM,data = log_weekly)
summ(log_model,digits = 4)
```
# BNS bootstrap section
------The following separate the data to different chunks based on regulation dates.

```{r}
# break the jump indicator into chunks based on regulation time

# read clean measures for each bond
bond_code = "LB113A"
filename = paste0(bond_code,"measure_clean.csv")
full_measure = read.csv(filename)

reg.time = c(200601,200901)
pre = full_measure %>% filter(yearweek < reg.time[1])
pre_jump = pre[,9:11]
pre_JV = pre$JV

before = full_measure %>% filter(yearweek>= reg.time[1] & yearweek < reg.time[2])
before_jump = before[,9:11]
before_JV = before$JV

after = full_measure %>% filter(yearweek >= reg.time[2])
after_jump = after[,9:11]
after_JV = after$JV

# calculate the proportion of jumps
colMeans(pre_jump)
colMeans(before_jump)
colMeans(after_jump)

mean(pre_JV)
mean(before_JV)
mean(after_JV)

# save all files
write.csv(pre_jump,file = paste0(bond_code,"pre.csv"),row.names = FALSE)
````
````

```
write.csv(before_jump,file = paste0(bond_code,"before.csv"),row.names = FALSE)
write.csv(after_jump,file = paste0(bond_code,"after.csv"),row.names = FALSE)

write.csv(pre_JV,file = paste0(bond_code,"preJV.csv"),row.names = FALSE)
write.csv(before_JV,file = paste0(bond_code,"beforeJV.csv"),row.names = FALSE)
write.csv(after_JV,file = paste0(bond_code,"afterJV.csv"),row.names = FALSE)

```
```

Bonds_Bootstraps.m

```
clear
close all

bond="LB113A";
period="pre";
filename=strcat(bond, period, ".csv");

data = readtable(filename);

B = 1000; % resampling times
M = 10; % block length

% convert to array
data1 = [data{:,1},data{:,2},data{:,3}];

for i = 1:3
   bsdata = block_bootstrap(data1(:,i),B,M);
   stats = sum(bsdata)./size(bsdata,1);
   Mean(i) = sum(data1(:,i))./size(data1(:,i),1);
   Quant(i,:) = quantile(stats,[0.025 1-0.025]);
end

%%
clear
close all

bond="LB113A";
period="pre";
filename=strcat(bond, period, "JV.csv");
data = readtable(filename);

B = 1000; % resampling times
M = 10; % block length
```
```

```
% convert to array
data1 = data{:,1};

   bsdata = block_bootstrap(data1,B,M);
   stats = sum(bsdata)./size(bsdata,1);
   Mean = sum(data1)./size(data1,1);
   Quant = quantile(stats,[0.025 1-0.025]);
```