Does Public Disclosure Crowd Out Private Information Production?*

Jia Chen†
Guanghua School of Management
Peking University

Ruichang Lu‡
Guanghua School of Management
Peking University

January 15, 2019

Abstract

We investigate how public disclosure affects private information production and pricing efficiency. We consider the implementation of TRACE as an increase in public disclosure in the corporate bond market and use bond analyst reports to measure the private information production. When the disclosure increases, there is a reduction in private information production, indicated by fewer bond analyst reports, fewer pages in each report, and smaller file sizes for each report. Moreover, increased disclosure leads to less delay of bond price, bond prices more closely approximating random walks, and shorter bond return drift after bond analyst reports or credit rating changes.

Keywords: Public disclosure, Crowding out, Private information production, Bond analysts, Pricing efficiency

JEL codes: G12, G14, G24, G28

*The authors thank Jack Bao, Brittany Cole, Bing Han, Jean Helwege, Tu Cam Ho, Michael Impson, Asjeet Lamba, Laura Xiaolei Liu, Qiao Liu, Yang Song, Lucy White, Wei Xiong, Liyan Yang, Rui Zhong, Alex Zhou, and Haoxiang Zhu, and participants of seminars at Peking University, UC Riverside, Renmin University, Fudan University, Shanghai University of Finance and Economics, Nankai University, the 2016 Five-star workshop at Tsinghua PBC School of Finance, the 2016 Conference on Asia-Pacific Financial Markets, the 2016 Australian Banking and Finance Conference, the 2016 Auckland Finance Meeting, the 2017 Conference of the Southwestern Finance Association, the 2017 Midwest Finance Association Meeting, the 2017 Conference of Financial Management Association, and 2017 SFS Cavalcade Asia for helpful comments. A previous version of this article circulated with the title, "Pricing Efficiency and Market Transparency: Evidence from Corporate Bond Market." We are responsible for any remaining errors or omissions.

†Jia Chen, Guanghua School of Management, Peking University, 5 Yiheyuan Road, Beijing, China 100871. Tel: +86 10 62767941; Fax: +86 10 62753590; E-mail: jia.chen@gsm.pku.edu.cn

‡Corresponding author: Ruichang Lu, Guanghua School of Management, Peking University, 5 Yiheyuan Road, Beijing, China 100871. Tel: +86 10 62756253; Fax: +86 10 62753590; E-mail: ruichanglu@gsm.pku.edu.cn

1 Introduction

Public disclosure is fundamental to the functioning of financial markets. The U.S. government thus regulates the U.S. financial markets. The centerpiece of these efforts is the mandated disclosure of financial information, e.g., Regulation Fair Disclosure, Sarbanes-Oxley Act of 2002, and the Dodd-Frank Act of 2010 (Greenstone, Oyer, and Vissing-Jorgensen, 2006; Leuz and Wysocki, 2016). Regulators view increased public disclosure as a way wto "level the playing field" and provide equal access to information for market participants, which they believe will improve market quality.

However, there is a significant public debate on the effectiveness of public disclosure, in the context of stress tests of banks (Goldstein and Leitner, 2018) or transaction information in the corporate bond market (Goldstein and Yang, 2016). Theoretically, the effect and overall desirability of disclosure on market quality is quite ambiguous. On the one hand, public disclosure can increase market liquidity, decrease the cost of capital, and increase market efficiency (Diamond and Verrecchia, 1991; Verrecchia, 2001; Easley and O'hara, 2004; Hughes, Liu, and Liu, 2007; Gao, 2008). On the other hand, there are some potential unintended consequences of disclosure – crowding out of private information production (Verrecchia, 1982a; Gao and Liang, 2013; Banerjee, Davis, and Gondhi, 2018) and reducing risk sharing (Diamond and Verrecchia, 1991; Lambert, Leuz, and Verrecchia, 2007).

In this paper, we exploit a natural experiment that allows us to understand the effect of public disclosure. In July 2002, the National Association of Securities Dealer (NASD)[1] implemented the Trade Reporting and Compliance Engine (TRACE) in the corporate bond market. As a result, all transactions of U.S. corporate bonds must be reported to TRACE shortly after transaction completion. The price and volume information of completed transactions are then disseminated to the public.

The implementation of TRACE is an ideal setting for examining the effect of public disclosure on private information production for four reasons. First, the implementation of TRACE significantly increases the public disclosure in the corporate bond market. Before the implementation of TRACE in July 2002, public disclosure of transaction details of individual bonds was limited in the corporate

[1] The National Association of Security Dealers (NASD) changed its name to Financial Industry Regulatory Authority (FINRA) in 2007.

bond market, where transactions happened over-the-counter with private negotiations.[2] With the implementation of TRACE, investors observe individual bonds' trading prices and volumes in a timely manner and use the information to update their beliefs since that the observed prices and volumes contain valuable private information of other investors. Second, because TRACE is enforced by the regulator, market participants cannot avoid disclosure or choose to disclose other information. Thus, this setting is less subject to the self-selection issues often faced by research that uses other regulatory changes (Leuz and Wysocki, 2016). Third, the implementation of TRACE was not applied to all bonds at the same time. Although TRACE began collecting all price and volume information on all corporate bonds in July 2002, it began the dissemination of trading information in phases[3], gradually including more bonds. Therefore, we have policy events with treatment and control groups and can conduct a difference-in-differences analysis. Fourth, NASD assigned bonds to each phase according to bond issue size and credit quality, characteristics that are transparent and difficult to adjust in the short run. Therefore, the concern of manipulation of entering the treatment is minimal. We can identify no evidence that the firms themselves lobbied for the implementation by changing the issue size or credit rating. We thus use these implementation phases to study the impact of public disclosure on private information acquisition.

We first study how disclosure impacts information production. It is critical to understand whether and how disclosure relates to private information production (Goldstein and Yang, 2017). Disclosure could crowd in or crowd out private information production and lead to different outcomes for market quality. On the one hand, public disclosure can stimulate investment in private information acquisition if traders with short-term investment horizons are allowed to trade on their private information before a public disclosure (McNichols and Trueman, 1994). On the other hand, the public signal may serve as a substitute for private information and reduce traders' incentives and hence crowd out private information production (Verrecchia, 1982b; Diamond, 1985; Gao and Liang, 2013). Goldstein and Yang (2017) show that the crowding out can harm market quality. Given the public debate and the theoretical ambiguity, it is important to empirically investigate public disclosure's effect on private information production and its overall desirability.

We use the number of reports by bond analysts to measure private information production,

[2] See Biais and Green (2007), Bessembinder and Maxwell (2008), and Piwowar (2011) for a detailed account of the evolution of the regulations in the bond market.

[3] See Table 1 for more details.

motivated by Griffin, Kelly, and Nardari (2010). Most corporate bonds are traded in an opaque over-the-counter dealer market and often become absorbed in "buy-and-hold" portfolios shortly after issuance. The resulting low transparency of bond trading provides debt analysts with an opportunity to play a significant role in supporting the informational efficiency of the corporate bond market. According to the Bond Market Association (BMA, 2004), analysts play an important role in informing the market about particular issues or securities. Hence, the reports are critical for the price discovery process of corporate bonds.[4] The more bond analyst reports about a specific bond there are, the more intense is the information production by bond analysts about this bond. Therefore, the number of bond analyst reports is positively related to private information production. In addition, we consider the number of pages and the file sizes of the reports to quantify information content. Therefore, these two variables can positively measure information production.

We begin by verifying that phases implementation represent a shock to the public disclosure. Six months before the implementation, the trends of the information production and pricing efficiency measures are parallel for the treated bonds and control bonds. However, we observe that the information production of the treated bonds significantly declines, relative to that of the control bonds. Specifically, the reduction in the number of bond reports ranges from 28% to 46% in different TRACE phases and is statistically significant. This result indicates that increased public disclosure reduces the intensity of information production. We also find that the number of pages in bond reports and file sizes of the reports on treated bonds decrease, relative to those of the control bonds. The reduction is as large as 36% for the number of pages and between 34% and 43% for the file size. These results suggest that increased public disclosure leads to less information in each report. These findings are consistent with the conjecture that public disclosure can lead to reduced incentives for analysts to produce bond-specific information.

After studying information production, we investigate the effect of increased public disclosure on pricing efficiency. The changes in pricing efficiency indicate that the net effect of increased public disclosure and decreased private information production. We measure pricing efficiency in different ways. First, we follow Hou and Moskowitz (2005) to construct the delay with which bond prices respond to past information. Second, we follow Lo and MacKinlay (1988) to use variance

[4] Detailed discussion of the validity of using the reports by bond analysts is provided in the variable construction section (Section 3.2.1).

ratio to measure the extent to which bond price movements deviate from random walks. We first calculate the ratio of the variance of two-week log returns divided by two times the variance of one-week log returns. Then, we obtain the variance ratio by subtracting one from this ratio and taking the absolute value. Third, we use the drift of bond return after bond analyst reports or credit rating changes. We follow Gleason and Lee (2003) to define the drift measure as the absolute value of the eight-week sum of the abnormal bond return after a bond analyst report or credit rating change. All these proxies are based on an intuitive principle: a security whose price is slow to incorporate information in credit events or market return is less efficient than a security whose price incorporates the information instantaneously.

We find that the post-trade dissemination of price and volume leads to shorter delay, less deviation from random walks, and smaller drifts. According to the difference-in-differences regression analysis, delay decreases 28% for Phase 3A bonds and 23% for Phase 3B bonds. Results are robust to different ways of measuring drift and delay. Variance ratio decreases by about 15% for Phase 3A bonds and 17% for Phase 3B bonds. Drift after bond analyst reports decreases by 42% and 53% after the implementation of Phases 3A and 3B, compared to pre-phase levels. Drift after credit rating changes reduces by about 47% after Phase implementation in Phase 3A and 3B. These findings suggest that greater public disclosure can improve the pricing efficiency, although private information production is reduced.

We further investigate whether the reduction of private information production varies, depending on the illiquidity, trading, or maturity of the bonds. First, we conduct a difference-in-differences analysis for different bond groups sorted by illiquidity, trading, or bond maturity. We use *Amihud* to measure illiquidity and use the ratio of volume divided by the issue amount to measure the trading. We use the median value of these variables before Phase implementation to define high and low illiquidity and trading groups and categorize bonds into long and short maturity, using five years as the cutoff. We find that the difference-in-differences estimates do not significantly differ between bonds with high and low illiquidity. There is some evidence that the difference-in-differences effects are stronger for bonds with high trading or bonds with longer maturity. Therefore, the impact of disclosure is relatively uniform across bonds with different ex-ante illiquidity and trading characteristics.

Finally, we study whether public disclosure in the bond market has a spillover effect on the pricing efficiency in the stock market. We repeat the difference-in-differences regression analysis using the stocks corresponding to the treated bonds and the stocks corresponding to the control bonds. The regression's dependent variable is delay or variance ratio based on the stock prices. We find no significant improvements in the pricing efficiency of stocks matched with the treated bonds, relative to that of the stocks matched with the control bonds.

Our paper contributes to four strands of literature. First, it adds new empirical evidence to the literature that studies the interaction between public disclosure and private information production. Goldstein and Yang (2017) emphasize that many studies endogenize the fraction of informed traders and the precision of informed traders' private information (Verrecchia, 1982b; Diamond, 1985; Kim and Verrecchia, 1994; Gao and Liang, 2013; Colombo, Femminis, and Pavan, 2014). They suggest that more public disclosure can reduce the traders' incentives to become informed or to acquire more precise information. The crowding out happens because public disclosure and private information production substitute for each other. These papers' findings are theoretical, and our paper provides empirical evidence.

Second, our paper relates to an extensive literature on the economic effects of disclosure regulation. Early studies examine the imposition of disclosure regulation on U.S. firms via the Securities Act of 1993, the Exchange Act of 1934, the 1964 Securities Act Amendments, the 1999 Eligibility Rule on the OTC Bulletin Board, the Sarbanes-Oxley Act of 2002, and the recent Dodd-Rank Act. As concluded in the survey paper by Leuz and Wysocki (2016), evidence on causal effects of disclosure and reporting regulation is still relatively rare. The challenges that researchers face when using these regulation changes are confounding events and self-selection issues. Related to our paper, a few studies investigate how equity analysts change their behavior around Regulation Fair Disclosure (Gomes, Gorton, and Madureira, 2007; Gintschel and Markov, 2004; Bailey, Li, Mao, and Zhong, 2003; Heflin, Subramanyam, and Zhang, 2003). They find that the accuracy and informativeness of analysts' reports decline. However, it is difficult to attribute these changes to Reg FD because of other concurrent events (Francis, Nanda, and Wang, 2006). Also, these changes could be due to that firms strategically disclose less public information to the market after Regulation FD, since we could not measure the private communication between firms and analysts. To improve the investigation, our paper uses the implementation of TRACE to identify the causal effect of an increase in public disclosure on private information production.

Third, our paper contributes to the extensive literature on how information disclosure can affect market quality. Theoretically, several works argue that more disclosure can improve market quality (Madhavan, 1995, 1996; Pagano and Röell, 1996).[5] A few recent theoretical papers discuss how disclosure might harm efficiency (Asriyan, Fuchs, and Green, 2015; Bhattacharya, 2016; Banerjee et al., 2018; Goldstein and Yang, 2016; Han, Tang, and Yang, 2016). Empirically, a few papers consider how disclosure impacts trading costs and illiquidity (Bessembinder, Maxwell, and Venkataraman, 2006; Edwards, Harris, and Piwowar, 2007; Goldstein, Hotchkiss, and Sirri, 2007), price dispersion and trading (Asquith, Covert, and Pathak, 2013).

In a contemporaneous paper, Badoer and Demiroglu (2018) argue that after the implementation of TRACE, credit rating agencies incorporate more information into the rating because dissemination elevates rating agencies' reputational concerns by making it easier for investors to detect rating inflation (Piccolo and Shapiro, 2017). In contrast, our paper shows that as important players in the bond market, bond analysts would reduce information provision.[6] We also directly investigate how the increased public disclosure affects pricing efficiency.

Fourth, our paper contributes to the literature on the informational role of bond analysts. Despite the massive size of the bond market, the literature on bond analysts is scarce, compared to that on equity analysts. De Franco et al. (2009) and De Franco, Vasvari, Vyas, and Wittenberg-Moerman (2014) find that bond analysts lead rating agency announcements and the market reaction is greater to bond analysts' reports than to equity analysts' reports. Gurun, Johnston, and Markov (2015) find that bond analysts contribute to the efficiency of securities markets, suggesting their reports are an essential and unique source of information in the bond market. Our paper provides evidence that the informational role of bond analysts would be affected by the information environment in the bond market.

Our study is relevant to ongoing regulatory changes as well. During and after the 2008 financial

[5] Bloomfield and O'Hara (1999) use experiments to show that trade disclosure significantly improves the informational efficiency of the markets but can cause spreads to widen.

[6] Bond analysts differ from credit rating angencies for two reasons. First, the goal of sell-side bond analysts is to identify mispriced debt securities and communicate this information to their clients. Accordingly, sell-side bond analysts rather than credit rating agencies supply bond recommendations and forecasts of bond returns, e.g. De Franco, Vasvari, and Regina (2009) find that bond analyst reports lead rating agency announcements. Second, sell-side bond analysts constantly interact with traders, salespeople, and investors. This constant interaction allows analysts to benchmark their views against the views of other market participants and timely assess the existence and extent of mispricing. In sum, given the differences between credit rating agencies and sell-side bond analysts, sell-side debt analysts play a distinct role in bond markets (Johnston, Markov, and Ramnath, 2009).

crisis, the issues relating to the trading and the valuation of over-the-counter instruments during the crisis prompted many people to promote greater transparency in such markets. For these instruments, regulators have considered implementing trade reporting systems similar to TRACE and the Transaction Reporting System (TRS). Such a system became effective for OTC swap trades in January 2013, and TRACE has expanded its coverage to include agency debentures, mortgage-backed securities, 144-A private placement, and asset-backed securities in recent years. Our paper sheds some light on the potential unintended consequences and overall desirability of increased information disclosure by centralized reporting systems.

The rest of this paper is organized as follows. Section 3 describes the research design and variable construction. Section 4 describes the data and the sample selection process. Section 5 presents our empirical analyses. Section 6 concludes.

2 Institutional background and hypotheses development

2.1 Institutional background: Implementation Phases of TRACE

In this section, we review the implementation of TRACE.[7] Before the introduction of TRACE, transaction prices were reported to only the parties involved in a trade, and only a few dealers actively buy and sell a particular bond issue. Potential buyers and sellers use telephone calls to obtain price quotations, which are only good "as long as the breath is warm." As a result, it was difficult for the bond buyers and sellers to obtain multiple quotations before committing to trade. In addition to telephone quotations, "indicative" quotations through electronic messaging systems were provided to some institutional investors by vendors such as Bloomberg. However, these price quotations are an indication of the desire to trade rather a firm obligation on price and quantity and are available for a subset of bonds.

On January 31, 2001, the Securities and Exchange Commission approved rules requiring the National Association of Security Dealers to compile data on all over-the-counter transactions in publicly issued corporate bonds. For each trade, the dealer is required to identify the bond and to report the date and time of execution, trade size, trade price, yield, and whether the dealer bought

[7] Biais and Green (2007); Bessembinder and Maxwell (2008) provide detailed discussion on the development of corporate bond market and related research.

or sold in the transaction.

Price and volume information of completed U.S. corporate bond transactions became publicly disclosed when NASD launched TRACE in 2002.[8] All transactions in U.S. corporate bonds by regulated market participants have since been required to be reported to TRACE on a timely basis. NASD then made this information transparent by publicly releasing it. NASD called this disclosing process "disseminating." TRACE now covers every US dollar-denominated debt security that is depository-eligible and registered with SEC or issued according to Section 4(2) of Securities Act of 1933 and purchased or sold under Rule 144a.

When NASD implemented TRACE on 1 July 2002, it required all transactions on TRACE-eligible securities to be reported within 75 minutes of trading. As described in Table 1, NASD began disseminating price and volume data for trades in selected investment-grade bonds with an original issue amount of $1 billion or higher. We call these bonds Phase 1 bonds. The dissemination occurred immediately after reporting for these bonds. Additionally, the 50 high-yield securities previously disseminated under Federal Information Processing Standards (FIPS) were transferred to TRACE, whose trades were disseminated. We denote these bonds NASD50. About 520 securities had their information disseminated by the end of 2002.

After NASD and SEC had approved the expansion of TRACE beyond Phase 1, Phase 2 of TRACE was implemented on 3 March 2003, and it expanded dissemination to include smaller investment grade issues.[9] The securities added into dissemination include those with at least $100 million par value or higher and ratings of A- or higher. Also, dissemination began on 14 April 2003 for a group of 120 investment-grade securities rated BBB. We denote these BBB bonds NASD120. After Phase 2 had been implemented, the number of disseminated bonds increased to about 4,650. Meanwhile, the NASD50 subset did not remain constant. On 13 July 2003, the NASD50 list was updated, and the list was then updated quarterly for the next five quarters. In order to have a clean and straightforward control group, we exclude NASD50 and NASD120 bonds from our analysis.

[8] Price and volume information of corporate bonds was publicly available in the 1930s and 1940s when corporate bonds were primarily traded on exchanges.

[9] In an effort parallel to the dissemination of trade information of more bonds, NASD reduced the time delay for reporting a transaction from 75 minutes on 1 July 2002, to 45 minutes on 1 October 2003, to 30 minutes on 1 October 2004, and to 15 minutes on 1 July 2005. On 9 January 2006, the time delay for dissemination was eliminated. We do not examine the changes in time to dissemination. Instead, we focus on how becoming disseminated in TRACE affects the information production and the pricing efficiency of the bonds. To do that, we choose one week as the primary unit of time because most bonds trade infrequently. As a result, it is not likely for the above changes in time to dissemination to affect our analysis.

Finally, on 22 April 2004, after TRACE had been in effect for some bonds for almost two years, NASD approved the expansion of TRACE to nearly all bonds. The last phase came in two parts, which NASD designates as Phase 3A and Phase 3B. Phase 3A includes bonds that are rated BBB or higher and are not yet in TRACE, and Phase 3B includes bonds are rated BB+ or lower. In Phase 3A, effective on 1 October 2004, 9,558 new bonds started having their information disseminated. In Phase 3B, effective on 7 February 2005, an additional 3,016 bonds started dissemination, though sometimes with delay. According to NASD, at that point, there was "real-time dissemination of transaction and price data for 99 percent of corporate bond trades."

Separate empirical estimates in Bessembinder et al. (2006) and in Edwards et al. (2007) imply that TRACE reduced the costs to investors of trade execution or equivalently, corporate bond dealers market-making revenue by approximately $1 billion per year. There were some anecdotal evidence that the implementation of TRACE led to lower dealer profits and reductions in the number of personnel devoted to bond trading post-TRACE. Pittman and Salas (2005) quoted a representative of an executive search firm: "One-fourth of all corporate bond traders, analysts, brokers and sellers have lost their jobs in the past two years".

2.2 Related literature and hypotheses development

Public disclosure of information in financial markets is at the forefront of regulatory efforts to improve financial market quality and stability. One major theoretical support for TRACE is that it "levels the playing field" by providing equal access to information across investors. Prior to the introduction of TRACE, transaction prices were not reported except to the parties involved in a trade. Therefore, bond investors traded on their private information. With the implementation of TRACE, investors observe individual bonds' trading prices and volumes in a timely manner and can use the valuable information containted in the observed prices and volumes to update their beliefs. Theoretically, if private information is exogenous, the public disclosure of trading information will speed up the information aggregation and improve the information efficiency in the bond market (Grossman and Stiglitz, 1980).

A natural question is how changes in disclosure affects the production of private information. Touching on the effect of disclosure, various papers endogenized the amount of private information in the market. On the one hand, more public information can weaken the incentives of traders to become informed and acquire more precise information. Intuitively, when both public information and private information are about the same random variable–fundamental value of the security, they are substitute. Thus, more public information motivates traders to cut back on their costly private acquisition activities, leading to less production of precise private information or less centives for becoming uninformed. In other words, public information crowds out the production of private information. The reduction of the production of private information can weaken and potentially reverse the direct effect of disclosure on market quality (Verrecchia, 1982a; Diamond, 1985; Kim and Verrecchia, 1994; Gao and Liang, 2013; Colombo et al., 2014).

On the other hand, public disclosure can stimulate investment in private information acquisition depends on the timing of information acquisition. If traders are allowed to acquire and trade on private information prior to the public signal's disclosure, a forthcoming public disclosure can stimulate private information collection in the pre-announcement period (McNichols and Trueman, 1994). This is in the spirit of the conventional Wall Street wisdom that "a bargain that remains a bargain is no bargain." Intuitively, when the informed investors have built their long or short positions in the security, they would rather publicize the private information so that the price can be driven to the correct level and their inventory risk is minimized. Therefore, more public disclosure can increase the expected trading profits of the informed investors and increase their incentive of collecting private information. Public information disclosure crowds in the production of private information.

Hence, we state our first hypothesis as follows:

H1: Bond analysts would issue less reports, and the reports would have less information content for bonds subject to dissemination requirement than for the other bonds.

H1a: Bond analysts would issue more reports, and the reports would have more information content for bonds subject to dissemination requirement than for the other bonds.

Public disclosure will improve the informational efficiency of the market if the private information is exogenous or if the crowd-in effect dominates the crowd-out effect. However, things ought to be more complicated once we consider the crowding-out effect on private information. It could also have two opposite effects as well. On the one hand, by making firms' otherwise private information public, disclosure discourages traders from private information acquisition. The reduction in private information acquisition attracts liquidity to the secondary market and eventually results in a more information efficiency in the market. At the heart of this theory is the idea that the private information guiding traders' trading decisions is the root cause of adverse selection and illiquidity in the secondary market.

On the other hand, once private information adjusts endogenously, the overall effect of disclosure on market efficiency is by and large non-monotone and that the results depend on whether crowding out happens in the extensive margin (as in Diamond (1985)) or intensive margin (as in Verrecchia (1982a)).

The overall desirability of public disclosure could also be complicated. First, public disclosure may lead to destruction of trading opportunities as in Hirshleifer (1971). The idea is that when traders face idiosyncratic risks, say due to heterogeneous endowment shocks, public disclosure decreases welfare by reducing the risk-sharing opportunities available to traders (Kurlat and Veldkamp, 2015). In contrast, Goldstein and Leitner (2018) study a model to consider a trade-off between the negative Hirshleifer effect and a positive effect of disclosure to prevent market breakdown. They find that in good times, disclosure is undesirable because of the Hirshleifer effect. However, in bad times, some disclosure is necessary to get the market for risk sharing to work.

Second, public disclosure could provide more than just information about fundamentals, as it plays a coordination role of informing agents of what other agents know and so helping each agent to predict the actions of others (Keynes, 1936). The coordination role exists because short-horizon traders correctly believe that future traders will use public information due to its information value. This coordination role can be detrimental to welfare if agents place too much weight on the public signal relative to weights that would be used by a social planner (Allen, Morris, and Shin, 2006). This coordination role can also be socially valuable as welfare increases with the precision of public information (Angeletos and Pavan, 2007). Gao (2008) shows that greater disclosure always drives stock prices closer to the fundamental value and hence improves pricing efficiency.

Another argument against the implementation of TRACE is that dealers will become reluctant to enter into trades as principals–purchasing bonds from customers or selling bonds by themselves. Instead, they will only be willing to work orders on an "agency basis"–they will search for potential counter-parties for their customers (Gemmill, 1996).[10] However, the availability of transaction

[10]Bessembinder and Maxwell (2008) anecdotally document that after the implementation of TRACE, bond dealers no longer hold large inventories of bonds for some of the most actively traded bonds. For less actively traded bonds, they serve only as brokers.

prices has made strategical trading more feasible. In particular, investors using quantitative investment strategies or algorithmic trading can now analyze larger amounts of more timely data. The trading and quantitative analysis may lead to more liquid and informational efficient market.

Overall, the effects of disclosure on pricing efficiency is ambiguous. We state our second hypothesis as follows:

H2: Bonds subject to dissemination requirement would experience an increase in informational efficiency relative to the other bonds.

H2a: Bonds subject to dissemination requirement would experience an decrease in informational efficiency relative to the other bonds.

3 Research design and variable construction

In this section, we discuss the research design, including the measures of information production and pricing efficiency, the construction of bond return, bond market return, and bond portfolio return, and the difference-in-differences regressions.

3.1 Difference-in-differences methodology

We use a difference-in-differences methodology to empirically test and quantify the impact of market transparency on information production or pricing efficiency in bond market. This methodology can be illustrated in a regression model as follows.

$$y_{i,t} = b_0 + b_1 Treated_i + b_2 Post_t + b_3 Treated_i \times Post_t + \epsilon_{i,t}, \tag{1}$$

where $y_{i,t}$ is a measure of information production or pricing efficiency for bond i in week t, $Treated_i$ is one if bond i's dissemination status changes, and $Post_t$ is a dummy variable that equals one in the period after the dissemination starts and zero otherwise. The coefficient b_3 of the interaction term, $Treated_i \times Post_t$, captures the difference-in-differences effect. This parameter measures how the difference in y between treated bonds and control bonds changes before and after bonds' public dissemination status changes. See details of variable description in Appendix A.

We define the treated bonds as the bonds that become disseminated in each phase implementation. We primarily focus on Phase 3A and 3B. In such analysis, the treated bonds become disseminated when TRACE Phases are implemented, and the control bonds are already in dissemination before a Phase begins. Specifically, we use Phase 1 and 2 bonds as the control bonds for Phase 3A and 3B.[11] We do not use Phase 1 in the difference-in-differences analysis because complete bond return data are not available for the period before TRACE started.[12] We also do not focus on Phase 2 bonds as treated bonds because the control bonds for Phase 2, Phase 3A and 3B bonds, are not yet in dissemination.[13]

We face a trade-off when choosing measurement windows before and after Phase implementation. On the one hand, we should use a short time window, which is close to the event, to focus on the immediate effect of dissemination. On the other hand, we should use a longer window to have enough observations of bond analyst reports, credit rating changes, number of bond analyst reports, and estimated delay and variance ratio. In general, we use the period between two Phase implementation as the measurement window. See Panel B of Table 1 for the details of the timing of measurement windows.

3.2 Variable construction

3.2.1 Measures of information production

Debt analysts play pervasive and significant roles in the capital market. Similar to equity analysts, debt analysts issue not only buy/hold/sell recommendations on the debt security but also forecasts on future performance (e.g., earnings and cash flows). According to the Bond Market Association (BMA, 2004), fixed income analysts help inform the market about particular issues or securities. Academic studies find that bond analyst reports are critical in promoting efficiency in bond price discovery. De Franco et al. (2009) find that bond market reaction is greater to bond analyst reports than to equity analyst reports. There is no evidence of a difference in timeliness between bond and equity analysts' reports, and both bond and equity analysts lead rating agency announcements. De Franco et al. (2014) find that debt analysts routinely discuss conflict events,

[11] Although Phase 3A bonds and 3B bonds are more comparable to each other, we do not include Phase 3A bonds in control bonds for Phase 3B bonds because Phase 3A and 3B are only four months apart and because our test window is about one year before and about one year after a Phase start date.

[12] Although the data from National Association of Insurance Companies (NAIC) covers the period before Phase 1, it is not as complete as TRACE because it contains only transaction data for insurance companies.

[13] In a robustness test, we use Phase 2 bonds as treated bonds in Section 5.5.1.

such as mergers and acquisitions, debt issuance, share repurchases, or dividend payments in their reports. More importantly, these discussions are associated with increases in credit spreads and bond trading volume. Gurun et al. (2015) find that debt returns lag equity returns less when debt research coverage exists, a result that is consistent with debt analysts facilitating the impounding of information in debt prices. Overall, bond analyst reports are an essential and unique source of information in the bond market.

The recent credit market crises, in both credit derivative and housing markets, accelerated the criticism of the failure of credit rating agencies (hereafter CRAs) in providing relevant and reliable predictions on the credit risk of firms. Many investors and regulators have casted doubts about the quality of credit rating reports issued by CRAs. Bond investors and bond analysts argue that the credit information provided by the CRAs is not timely and accurate, which limits the usefulness of the credit information.

We use the number of bond analyst reports[14] (*Number of reports*) as a measure of information production.[15] In addition, we consider the number of pages in a bond analyst report (*Number of pages*) and the file size in thousands of bytes of a report (*File size*) to measure its content. When *Number of pages* is higher or when *File size* is larger, the analyst report contains more information. While *Number of reports* measures how many times private information is produced and released into the market, *Number of pages* and *File size* are positively related to the amount of information in each analyst report.

3.2.2 Measures of pricing efficiency

We adopt Hou and Moskowitz's (2005) *Delay* measure as the first proxy for pricing efficiency. This measure is an estimate of how quickly prices respond to public information in the market and portfolio return movements. When this measure has a lower value, the speed of information incorporation is faster. We use weekly bond returns to calculate this measure. Although returns at a higher frequency, such as daily, can provide more dispersion in delay, they may be influenced

[14] Griffin, Kelly, and Nardari (2010) use the number of equity analyst reports as a measure of information production in the stock market.

[15] A bond analyst report typically covers all bonds issued by the firm, so the number of bond analyst reports is measured at firm level in the pre- and post-periods of each TRACE Phase. If a firm has multiple bonds, some of its bonds could be included in TRACE dissemination before its other bonds. If this is the case, we only include the first bond of the firm that becomes disseminated in TRACE and drop the other bonds from the sample.

by confounding micro-structure issues, such as non-synchronous trading.

We consider bond market return, stock market return, and bond portfolio return as the relevant market information to which bonds respond. For the pre- and post-period of each TRACE phase, we separately estimate a regression of each bond's weekly returns on contemporaneous bond market, stock market, and bond portfolio returns and four weeks of lagged returns.

$$\begin{aligned} Ret^{B}_{i,t} = \alpha_i + & \beta_i^{BM} Ret_{BM,t} + \sum_{n=1}^{4} \delta_i^{BM,(-n)} Ret_{BM,t-n} + \\ & \beta_i^{SM} Ret_{SM,t} + \sum_{n=1}^{4} \delta_i^{SM,(-n)} Ret_{SM,t-n} + \\ & \beta_i^{BP} Ret_{BP,t} + \sum_{n=1}^{4} \delta_i^{BP,(-n)} Ret_{BP,t-n} + \epsilon_{i,t}, \end{aligned} \quad (2)$$

where $Ret^{B}_{i,t}$ is the return on bond i, $Ret_{BM,t}$ is the return on value-weighted bond market return in week t, $Ret_{SM,t}$ is the return of value-weighted stock market[16] in week t, and $Ret_{BP,t}$ is the value-weighted bond portfolio return in week t. If the bond responds immediately to market news, then β_i will be significantly different from zero, but $\delta_i^{(-n)}$ will not be. Otherwise, $\delta_i^{(-n)}$ will differ significantly from zero. This regression identifies the delay with which a bond's prices respond to market information if expected returns are relatively constant over weekly horizons.

Delay is one minus the ratio of the R^2 from the above regression restricting $\delta_i^{(-n)} = 0$ for all n, over the R^2 from the above regression without the restriction.

$$Delay = 1 - \frac{R^2_{\delta(-n)=0,\ \forall n \in [1,4]}}{R^2}. \quad (3)$$

The higher this number, the more return variation is captured by lagged returns, and hence the slower are bond prices to incorporate new market information.

Our second measure of pricing efficiency is *Variance ratio*. *Variance ratio* (Lo and MacKinlay (1988)) captures that prices should follow a random walk in an informationally efficient market. We define *Variance ratio* as the absolute value of the proportion of the variance of two-week log returns divided by two times the variance of one-week log returns minus one, a variable that is

[16] Stock market return is the value-weighted CRSP market index return.

illustrated as follows.

$$Variance\ ratio = \left| \frac{Var\,(Ret_t + Ret_{t+1})}{2\,Var\,(Ret_t)} - 1 \right|, \tag{4}$$

where Ret_t is log bond return defined in Equation (6). Under the null hypothesis that bond prices follow a random walk, bond returns are serially uncorrelated, and the two-week variance is equal to two times the one-week variance. As a result, *Variance ratio* is equal to zero. When the autocorrelation of bond returns is positive, *Variance ratio* is above zero. When the autocorrelation of bond returns is negative, *Variance ratio* is also above zero. When *Variance ratio* is closer to zero, the prices behave more like a random walk and are more informationally efficient.

Following Gleason and Lee (2003), we consider return drift after credit events as the third proxy for pricing efficiency. We use an eight-week window after bond analyst reports or credit rating changes to measure return drift (*Drift*). For example, *Drift* after a bond analyst report is the absolute value of the eight-week sum of the abnormal return after the bond analyst report, excluding the week of the report,

$$Drift = \left| \sum_{t=1}^{8} Abnormal\ return_t \right|. \tag{5}$$

When the value of this variable is lower, the speed of information incorporation is faster. We choose the eight-week window for two reasons. First, because corporate bond trading happens relatively infrequently, it takes time for bond prices to incorporate information. Second, a too short window may primarily capture the initial reaction to the events and omit a large part of the drift. To better capture information diffusion instead of over- or under-reaction, we use a long enough window. Because both directions of the reaction can generate significant drift and because we care about the magnitude of the drift, rather than its direction, we take absolute values when constructing the drift variable.

We use bond analyst reports as the events for several reasons. First, corporate bond investors are almost exclusively institutions. The average level of investor sophistication is higher in the corporate bond market than in the equity market. Institutional investors likely understand well how to use the bond analysts' reports. Therefore, the drift after the reports can well capture how the average investors in the corporate bond market incorporate information. Second, unlike quarterly earnings announcements, fixed income reports are issued throughout the quarter. In an alternative specification of the events, we use *Drift* after credit rating changes by Moody's to measure the pricing efficiency. Rating changes are substantial credit events because rating agencies potentially have preferential access to both publicly available information and proprietary information and because they are alternative information intermediaries with high reputation at stake. Therefore, *Drift* after rating changes is an alternative measure of pricing efficiency in addition to *Drift* after bond analyst reports.

3.2.3 Returns of individual bond, bond market, and bond portfolio

Bond returns are the basis of both the return drift and delay measures. We calculate bond returns as follows. For bond i in week t, we take all trades within the week and calculate the clean price for the week as the transaction size-weighted average price of these trades. Returns are then calculated as

$$Ret_{i,t} = \ln\left(\frac{P_{i,t} + AI_{i,t} + C_{i,t}}{P_{i,t-1} + AI_{i,t-1}}\right), \tag{6}$$

where $P_{i,t}$ is the transaction size-weighted clean price[17], $AI_{i,t}$ is accrued interest, and $C_{i,t}$ is coupon paid in week t. Coupon rates and maturities are obtained from FISD.

To construct the drift, delay, and variance ratio measures, we use bond market returns and returns of benchmark bond portfolios. We define the corporate bond market return as the amount outstanding weighted average of bond returns for all bonds from TRACE.[18] We use the bond market return as a source of market-wide information when we estimate the delay measure. We follow Bessembinder, Kahle, Maxwell, and Xu (2009) to create benchmark bond portfolios segmented by both bond rating and time-to-maturity and calculate amount-outstanding weighted bond portfolio returns. We segment bonds by Moody's six major rating categories (Aaa, Aa, A, Baa, Ba, and below Ba) and three time-to-maturity categories. For investment grade bonds, the time-to-maturity cutoffs are 0 to 5 years, +5 to 10 years, and +10 years. For non-investment grade bonds, the cutoffs are 0 to 6 years, +6 to 9 years, and +9 years. These cutoffs are designed to ensure roughly equal

[17] Bessembinder, Kahle, Maxwell, and Xu (2009) calculate prices as the transaction size-weighted averages of prices, an approach that puts more weight on institutional trades that incur lower execution costs and should more accurately reflect the underlying price of the bond. Bao and Pan (2013) and Bao, Pan, and Wang (2011) also use transaction size-weighted averages of prices.

[18] According to NASD (2005), TRACE covers 99% of corporate bonds.

terciles. Because the Aaa sample size is too small to be split into three subsets based on maturity, we follow Bessembinder, Kahle, Maxwell, and Xu (2009) to divide the Aaa sample into two maturity categories, 0 to 7 years and +7 years. We use the returns of the benchmark portfolios in the construction of the delay measure. This procedure provides a total of 17 benchmark portfolios. The benchmark portfolio return is the amount outstanding weighted return of bonds in the portfolio. We match each bond with the portfolio of the same rating category and the same time-to-maturity category. We then follow Bessembinder, Kahle, Maxwell, and Xu (2009) to construct a bond's abnormal return (AR) as the difference between an individual bond's return and the matching portfolio's return. We use the abnormal bond returns to construct the drift measures

4 Data and sample

4.1 Data sources

We use the enhanced version of TRACE to obtain data on bond prices and obtain bond characteristics and ratings from Mergent FISD (Fixed Income Security Database). We use Compustat to construct firm-level financial and accounting data and use CRSP for equity return data.

We collect sell-side bond analyst reports from ThomsonOne Investext, a provider of full-text analyst reports. We construct a list of all companies from the Compustat-CRSP database and then use these companies' names to manually search for their fixed income reports. We manually collect bond analysts' reports and code the names of the analysts and brokerages that issue the reports. From the reports, we identify reports dates, names of the companies that the reports cover, the number of pages of the reports, and the file size of the reports. We obtain a sample of firm-level reports by excluding reports about industries, geographic areas, general economics, and reports that are aggregated either by industry or time, which often repeat previously published information. In our sample, the sell-side bond analyst report data cover the period from 1 July 2001 to 7 February 2006, a period that is from one year before the implementation of TRACE to one year after the dissemination of the Phase 3B bonds.

4.2 Validity of the difference-in-differences setting

To graphically illustrate and validate the difference-in-differences setting, we make time-series plots of the measures of information production and the measures of pricing efficiency before and after the implementation of TRACE phases. Figure 1 shows the plots for Phase 3A, and Figure 2 presents the plots for Phase 3B. In the plots, the square dots represent the average measures of the treated bonds, and the round dots are the average measures of the control bonds. The TRACE phase is implemented at event time of 0, and one unit of event time represents 6 months. In both figures, we find that the trends of the average measures are parallel before the implementation of Phases. In both figures, we observe that the average *Number of reports*, *Number of pages*, and *File size* of information production of treated bonds experience a drop after the Phase, indicating a decrease in information production for those bonds. The average *Delay* and *Variance ratio* of the treated bonds also falls after the Phase, suggesting an improvement in pricing efficiency for those bonds. On the other hand, the average measures of information production or pricing efficiency of control bonds are stable or slightly increase after the Phase implementation.

4.3 Descriptive statistics

Table 2 reports the means of information production and pricing efficiency measures in pre- and post-period of each TRACE Phase. Panel A of Table 2 provides averages of *Number of reports.* The averages of *Number of reports* are similar between treated (1.63) and control (1.32) bonds before the implementation of Phase 3A. After implementation, the average *Number of reports* of control bonds increases to 2.41, and the average of *Number of reports* of treated bonds increases to 2.25. In Phase 3A, both treated and control bonds receive more reports in the post-period than in the pre-period, and the control bonds' average *Number of reports* increases more than that of the treated bonds. The difference-in-differences effect on *Number of reports* is -0.47 reports, a magnitude that is 28.8% of the average *Number of reports* for treated bonds before the phase (1.63). Before the implementation of Phase 3B, the averages of *Number of reports* are 2.13 for treated bonds and 1.68 for control bonds. After implementation, the average of *Number of reports* decreases to 1.52, and the average of *Number of reports* increases to 2.06. Hence, the control bonds experience an increase in Phase 3B, while the treated bonds experience a reduction. The difference-in-differences effect on *Number of reports* is -0.99. The magnitude of this number is large, relative to the average of *Number of reports* for treated bonds in the pre-period of Phase 3B. Overall, the difference-in-differences effect of TRACE on the number of bond analyst reports is negative and economically significant. These results are consistent with the intuition that private information production is less intense when public disclosure is higher.

Panel B of Table 2 presents the averages of *Number of pages* for treated and control bonds in pre-period and post-periods. Around Phase 3A, both treated bonds and control bonds experience an increase in *Number of pages*. The increase for the treated bonds is 2.01, which is less than that for the control bonds, 2.45. The difference-in-differences effect is -0.44 page. This change is -5.9% of the average *Number of pages* of treated bonds in the pre-period. Around Phase 3B, both the treated and control bonds experience a decrease in *Number of pages*, and the treated bonds experience a larger reduction than the control bonds do. Specifically, the average of *Number of pages* of treated bonds decreases by 4.64 from 12.0 to 7.36, and the average of *Number of pages* of control bonds decreases by 0.27 from 6.66 to 6.39. The difference-in-differences effect is -4.37 pages, representing a -36.4% decrease, relative to the average *Number of pages* of treated bonds in the pre-period of Phase 3B. The results in Panel B show that *Number of pages* significantly decreases after public disclosure increases.

Panel C of Table 2 shows the average *File size* of treated and control bonds in pre- and post-periods. In implementation of both Phases 3A and 3B, average *File size* decreases for all treated and control bonds. Around Phase 3A, the treated bonds' average *File size* decreases by 155.8 from 351.4 to 195.6, and the control bonds' average *File size* decreases by 37 from 178.3 to 141.3. The difference-in-differences effect is -118.8 kilobytes, which is a -33.8% decrease from the average *File size* of treated bonds before Phase 3A. The changes in average *File size* show similar patterns around Phase 3B. The average *File size* decreases by 284.7 for treated bonds and decreases by 93.8 for control bonds, and the difference-in-differences effect is -190.9. This is a 42.8% decrease in average *File size*. The results in Panel C show that *File size* decreases after the implementation of Phases 3A and 3B.

Panel D of Table 2 reports the averages of *Delay* in pre- and post-periods. The mean values of treated bonds' *Delay* decrease for both Phases 3A and 3B. Specifically, the average of *Delay* for treated bonds decreases by 0.06 for Phase 3A (from 0.58 to 0.52) and by 0.07 for Phase 3B (from 0.62 to 0.55). The changes in average *Delay* are mixed for control bonds. The average *Delay* of control bonds decreases by 0.09 for Phase 3A (from 0.36 to 0.45) and increases by 0.07 for Phase 3B (from 0.38 to 0.45). These numbers show that, after implementation, *Delay* decreases more on the treated bonds than on the control bonds. The difference-in-differences effect is -0.15 for Phase 3A (-0.06 - 0.09) and -0.14 for Phase 3B (-0.07 - 0.07). We find that the economic magnitudes of these effects are large, comparing these effects to the mean delay measures before Phase implementation. For example, for Phase 3A, -0.15 is -25.9% (-0.15/0.58), relative to the mean *Delay* of treated bonds (0.58). These results indicate that *Delay* significantly reduces after implementation. This finding is consistent with bond prices incorporating market information faster when public disclosure increases.

Panel E of Table 2 reports the summary statistics of *Variance ratio*. The mean values of treated bonds' *Variance ratio* decrease for both Phases 3A and 3B after implementation. Specifically, treated bonds' *Variance ratio* changes by -0.03 for Phase 3A (from 0.35 to 0.32) and by -0.04 for Phase 3B (from 0.34 to 0.29). The average values of control bonds' *Variance ratio* increase. Control bonds' average *Variance ratio* increases by 0.02 for Phase 3A (from 0.28 to 0.31) and increases by 0.04 for Phase 3B (from 0.27 to 0.31). The difference-in-differences effects are -0.05 for Phase 3A (-0.03 - 0.02) and -0.08 for Phase 3B (-0.04 - 0.04). The economic significance of these effects is large. For example, for Phase 3A, -0.05 is -14.3% (-0.05/0.35), relative to the mean *Variance ratio* of treated bonds before Phase implementation. These results show that *Variance ratio* decreases after Phase implementation, suggesting that bond prices more closely follow random walks after public disclosure increases.

Panel F of Table 2 is about average *Drift* after bond analyst reports. Two patterns emerge from this panel. First, bonds experience a decrease in average *Drift* after the Phase dissemination. For example, average *Drift* is 0.028 for Phase 3A treated bonds before the dissemination and is 0.015 after the dissemination. Second, the reduction in *Drift* from pre- to post-periods is relatively larger on treated bonds than on control bonds for Phases 3A and 3B. The difference-in-differences effects capture the net impact of increased information disclosure, and they are negative for Phase 3A (-0.013) and 3B (-0.019). The economic significance is large. The difference-in-differences effect on average *Drift* is 46.4% for Phase 3A and 52.7% for Phase 3B, compared with the pre-period averages of treated bonds in the corresponding Phase.

Panel G provides the summary statistics for *Drift* after credit rating changes, and we find patterns similar to those in Panel F. In particular, the difference-in-differences effects on average *Drift* after credit rating changes are negative for Phase 3A and 3B. The results in Panels F and G indicate a reduction in *Drift* after bond analyst reports or *Drift* after credit rating changes after Phase implementation, which is consistent with bond prices more quickly incorporating information of credit events when public disclosure is higher.

Overall, these patterns are consistent with what we find in Figure 1 and Figure 2.

5 Difference-in-differences analysis

In this section, we examine the results of difference-in-differences regressions, an approach that shows both economic and statistical significance.

5.1 Private information production

We report difference-in-differences regression estimates for the measures of information production in Table 3. The dependent variables are *Number of reports*, *Number of pages*, and *File size*, and standard errors are clustered at the firm level. The independent variables are *Treated*, *Post*, and *Treated* $\times$*Post*. *Treated* is a dummy variable that is one if the bond is in the dissemination of a TRACE Phase and zero if it is in the control group, and *Post* is a dummy variable that is one if it is after the Phase dissemination and zero otherwise. The coefficient of *Treated*$\times$*Post* captures the difference-in-differences effect.

We present the results of *Number of reports* in the first two columns. The coefficients of *Treated* $\times$*Post* are -0.46 and -0.99 for Phases 3A and 3B, respectively. The coefficients are statistically significant. In summary, results in Table 3 suggest that, after Phase implementation, there are fewer bond analyst reports for the treated bonds, relative to the control bonds. These findings are consistent with the interpretation that greater public disclosure leads to less intense information production. The coefficients of the interaction term are statistically significant at the 10% critical level for Phase 3A and significant at 1% critical level for Phase 3B. The economic magnitudes of these estimates are large. The coefficients of *Treated*$\times$*Post* for Phase 3A (0.46) and 3B (0.99) are 28.2% and 46.5% of the average numbers of analyst reports for the treated bonds before the implementation of corresponding Phases.

We study *Number of pages* of analyst reports in columns (3) and (4) of Table 3. For Phase 3A, the coefficient of $Treated \times Post$ is -0.44 but statistically insignificant. For Phase 3B, the coefficient of $Treated \times Post$ is -4.39 with a t-stat of -2.93. This reduction is 36.6% of the mean *Number of pages* of treated bonds before the implementation of Phase 3B. In sum, we find that *Number of pages* significantly decreases after Phase 3B.

In the last two columns of Table 3, we report the results for *File size*. We find that the coefficients of $Treated \times Post$ are -118.7 and -190.9 for Phases 3A and 3B, respectively. These numbers suggest that the *File size* shrinks by 118.7KB and 199.9KB after the implementation of 3A and 3B, respectively. The t-stats associated with these coefficients are above the threshold of 1% statistical significance level. The economic significance is large. The magnitudes of the file size reduction are 33.8% and 42.8%, relative to the average file sizes of treated bonds before the implementation of corresponding Phases. Hence, we find that *File size* falls after Phase implementation.

In summary, results in Table 3 suggests that, after Phase implementation, there are fewer bond analyst reports for the treated bonds, relative to the control bonds. These findings are consistent with the interpretation that greater disclosure leads to less intense information production.

5.2 Pricing efficiency

Table 4 presents difference-in-differences regression results for pricing efficiency measures. Panel A reports results where *Delay* and *Variance ratio* are the dependent variables, and Panel B reports results where *Drift after bond reports* and *Drift after rating changes* are the dependent variables. Among the independent variables, *Treated* is a dummy variable equal to 1 if the bond is in dissemination and zero otherwise. *Post* is a dummy variable equal to 1 if it is after the Phase implementation and zero otherwise. *Treated*×*Post* is an interaction term between *Treated* and *Post*. We cluster the standard errors at the firm level for all regressions. We are interested in the coefficient of *Treated*×*Post*, which captures the impact of the public disclosure on pricing efficiency.

We report results for *Delay* in the first two columns of Panel A. *Delay* is defined in Equation (3). The coefficients of *Treated*×*Post* are -0.16 and -0.14, showing that *Delay* decreases after the implementation of both Phases. These results confirm those of the summary statistics in Table 2. These difference-in-differences estimates are economically significant. The coefficient estimates for Phases 3A and 3B (-0.16 and -0.14) represent decreases of -27.6% and -22.6%, compared with the averages of *Delay* of treated bonds for the corresponding Phase (0.58 and 0.62; see Panel D of Table 2).[19] These results demonstrate that *Delay* decreases after Phase implementation, which is consistent with the intuition that bond prices more quickly incorporate market information when public disclosure increases.

Columns (3) and (4) show the results of difference-in-differences regressions for *Variance ratio*, which is defined in Equation (4). The coefficients of the interaction term are negative and statistically significant for both Phases 3A and 3B: -0.052 with a t-statistic of -4.17 for Phase 3A and -0.059 with a t-statistic of -2.85 for Phase 3B. The economic significance of those estimates is substantial. The coefficients for Phases 3A and 3B represent decreases of 14.9% and 17.4%, compared with the average *Variance ratio* of the treated bonds before the implementation of Phases 3A (0.35) and 3B (0.34). Those results show that the *Variance ratio* decreases after the implementation of TRACE Phases, meaning that bond prices more closely approximate a random walk when disclosure improves.

We represent the results of *Drift after bond reports* and *Drift after rating changes* in Panel B. The estimated coefficients of the interaction term show that the difference-in-differences effects are significantly negative for Phases 3A and 3B. In the first two columns of Panel B, the effects on *Drift after bond reports* are -0.012 and -0.019, which are reductions of 42.9% and 52.8%, relative to the average *Drift after bond reports* of the treated bonds before the implementation of Phase 3A and Phase 3B (0.028 and 0.036; see Panel F of Table 2). We present the results based on *Drift after rating changes* in columns (3) and (4). The difference-in-different effect is -3.5% with a t-stat of 2.98 for Phase 3A and -3.5% with a t-stat of 2.15 for Phase 3B. The economic significance of the effects for Phases 3A and 3B is large. The estimated coefficients represent reduction of 47.3% and 46.7% in *Drift after rating changes*, compared with the average *Drift after rating changes* for treated bonds before Phase 3A (0.074 and 0.075, see Panel G of Table 2). The evidence in this table supports the view that bond prices more quickly incorporate information when disclosure is greater.

[19] To alleviate the concern that the distribution of *Delay* is bounded between 0 and 1 may affect the results, we replace raw *Delay* with the logistic transformation of *Delay* and repeat the analysis in Panel A. We find similar results.

5.3 Cross-sectional variation by ex-ante bond characteristics

We group treated bonds by bond characteristics and study whether the difference-in-differences effects vary across bond groups. The bond characteristics include illiquidity, trading, and time-to-maturity before TRACE implementation. The information incorporated in trading prices can better substitute for private information for bonds with lower illiquidity or bonds with higher trading because it can be less costly to incorporate information into prices for those bonds. Also, the prices of bonds with longer maturity are more sensitive to information about credit risks than the prices of other bonds. As a result, credit-risk information disclosed in prices can better substitute for private information about credit risk for bonds with longer maturity. Therefore, the effect of better disclosure on private information production and pricing efficiency can be stronger for bonds with lower illiquidity, higher trading, or longer maturity.

We assign treated bonds into groups according to the values of the above three characteristics before Phase implementation. We measure bond illiquidity with *Amihud* and measure trading with the ratio of volume divided by issue amount and calculate medians of these two variables across treated bonds before Phase implementation. We then consider treated bonds whose pre-phase values of characteristics variables exceed the medians and those whose pre-phase values of characteristics variables are equal to or below the medians. We determine the pre-phase value of each bond's illiquidity and trading as follows. For *Drift after bond reports* and *Drift after rating changes*, we measure the averages of daily *Amihud* and the ratio of volume divided by issue amount during the week before the bond analyst report or the credit rating change before the Phase implementation. For *Delay* and *Variance ratio*, we measure the average of daily *Amihud* and the ratio of volume divided by issue amount one year before the Phase implementation. For time-to-maturity, we form groups of treated bonds based on whether the bond's maturity before the Phase implementation is longer than five years.

We then estimate a regression as follows.

$$\begin{aligned} y_{i,t} = & b_0 + b_1 Treated_i + b_2 Post_t + b_3 Treated_i \times Post_t \times LowGroup_i + \\ & b_4 Treated_i \times Post_t \times HighGroup_i + \epsilon_{i,t}, \end{aligned} \tag{7}$$

where the dependent variable $y_{i,t}$ is a measure of information production or pricing efficiency for bond i in week t, $Treated_i$ is an indicator for whether the bond changes its dissemination status and $Post_t$ is a dummy variable that equals to one in the period after the dissemination starts and zero otherwise. The coefficient b_3 of interaction term $Treated_i \times Post_t \times LowGroup_i$ captures the difference-in-differences effect of treated bonds with low pre-phase values of characteristics variables, and the coefficient b_4 of the triple interaction term $Treated_i \times Post_t \times HighGroup_i$ captures the difference-in-differences effect of treated bonds with high pre-phase values of characteristics variables.

We report the results of the above difference-in-differences regressions in Table 5. Panel A of this table presents the results based on measures of information production: number of reports, number of pages, and file size, and Panels B and C show the results based on the measures of pricing efficiency. We report only the coefficients of $Treated_i \times Post_t \times LowGroup_i$ and $Treated_i \times Post_t \times HighGroup_i$. We find that the difference-in-differences effects are negative and significant for both groups in most cases, a result that confirms our baseline results in Tables 2, 3, and 4. We, therefore, highlight cross-group differences for individual measures.

In Panel A, we find that the effects on *Number of reports*, *Number of pages*, and *File size* are stronger for the low-illiquidity bonds than for the high-illiquidity bonds. This pattern exists in all columns except for column (5). This result is consistent with the intuition that information in prices can better substitute for private information when the illiquidity of bonds is low. Examining bonds with different trading, we find that the difference-in-differences effects are stronger for more frequently traded bonds in Phase 3B, a finding that is consistent with the intuition that information in trading prices and volumes can better substitute for the information in bond analyst reports when there is more trading. When trading is insufficient, the information that can be learned from trading prices and volumes is limited, and bond analysts still have strong incentives to produce information. The evidence in Phase 3A is mixed. In Phase 3A, the effects based on *Number of reports* and *File size* are similar between bond groups, and the effects based on *Number of pages* are stronger for bonds with less trading than other bonds. Studying bonds with different time-to-maturity, the effects on *Number of reports* is more negative for bonds with long maturity than for bonds with short maturity, supporting the intuition that dissemination can have a larger impact on long-maturity bonds because bond prices can better substitute for private information for these bonds than for bonds with short maturity. In sum, the results in Panel A show that the difference-in-differences effects on private information production are stronger for bonds with low illiquidity, high trading, or long maturity than other bonds.

We compare the effects on pricing efficiency measures between bonds with different characteristics in Panels B and C. Panel B shows results based on *Delay* and *Variance ratio*, and Panel C presents results based on *Drift after bond reports* and *Drift after rating changes*. The results in Panel B show that the difference-in-differences effects on *Delay* and *Variance ratio* are more negative for bonds with low illiquidity, high trading, or long maturity than for other bonds. This pattern is robust for all cases in this panel. The results in Panel C indicate that the difference-in-differences effects on *Drift after bond reports* and *Drift after rating changes* are stronger for low illiquidity or high trading than for other bonds. The regressions comparing bonds with long and short maturities show mixed results. The effects are more negative for bonds with long maturity than for bonds with short maturity in column (4), but the pattern is the opposite in the other three columns. In summary, we find that the effects on pricing efficiency measures are stronger for bonds with low illiquidity, high trading, or long maturity.

5.4 Spillover to stock market

In this section, we test whether the effect of increased public disclosure spills over from the bond market to the stock market. We focus on the effects on pricing efficiency measures in the stock market and do not consider the information production of equity analysts because equity analysts primarily obtain information from firms' public announcements (Bradshaw, Ertimur, and O'Brien (2017)). If public disclosure changes the pricing efficiency in the bond market, the pricing efficiency of the corresponding stocks may be affected too because investors can observe the prices in the bond market and adjust their valuation accordingly.

To capture the potential spillover, we construct the delay and variance ratio measures based on stock prices. Specifically, we regress individual stock return on contemporaneous stock market return and lagged stock market returns up to four weeks. Similar to the definition in Equation (3), the stock delay measure is one minus the ratio of R^2 from the regression without lagged market returns divided by the R^2 from the regression with lagged market returns. The variance ratio based on stock prices is also similarly defined as in Equation (4). We then estimate difference-in-differences regressions to study whether the delay or variance ratio of stocks associated with treated bonds significantly changes, relative to those of stocks associated with control bonds after the TRACE Phases.

We report the results of spillover effect to the stock market in Table 6. We do not find any significant negative coefficient of *Treated* × *Post*, an indication that an increase in public disclosure in the bond market does not reduce the delay or variance ratio in the stock market. A potential explanation for this finding is that the stock prices have historically been much more informative than the bond prices, and hence the impact of the increased disclosure in the bond market will have little impact on the pricing efficiency in the stock market.

5.5 Robustness tests

5.5.1 Using bonds of Phase 2 as treated bonds

In this section, we use the Phase 2 bonds as treatment group to run a robustness test. In the previous sections, we used the bonds of Phases 3A or 3B as treated bonds so that, when the treated bonds (Phase 3A and 3B bonds) became disseminated, the control bonds (Phase 2 bonds) were already in dissemination. There is little concern on the spillover effect from treated bonds to control bonds. In contrast, when Phase 2 was implemented, the control bonds (Phase 3A and 3B bonds) were not yet in dissemination, and the public trading information of phase 2 bonds could be valuable for the trading of Phase 3A and 3B bonds and could cause spillover effect.

Nevertheless, we test the robustness of our primary analysis with the Phase 2 bonds and report the results in Table 7. The results in Columns (1) to (5) of Table 7 show that the implementation of Phase 2 significantly reduces the information production about the treated bonds, relative to control bonds, and improves the pricing efficiency of treated bonds, relative to control bonds. The results in Columns (7) and (8), however, show that the coefficients on *Treated*×*Post* are positive and statistically insignificant when we use *Drift after bond reports* or *Drift after rating changes* as the dependent variable. This insignificant result can be because the bonds of Phase 2 have much lower levels of drift than the bonds of Phases 3A and 3B do. For example, the average *Drift after bond reports* of bonds of Phase 2 is 0.27 before Phase 2, while the average *Drift after bond reports* of bonds of Phase 3A and 3B before Phase 2 is at a much higher level, 0.075. This significant difference in the drift reflects the fact the bonds of Phase 2 are rated investment grade, while the bonds of Phase 3A and 3B are rated below investment grade. After Phase 2, the average *Drift after bond reports* of bonds of Phase 2 decreases by 55.6% to 0.012, and the average *Drift after bond reports* of bonds of Phases 3A and 3B decreases by 42.7% to 0.043. The drift of the former bonds experiences a larger percentage drop, while the drift of the latter bonds experiences a larger decrease in raw value.

5.5.2 Excluding zero-trading weeks

Because of the infrequent trading in the bond market, many bonds do not trade in a given week, which may lead to non-synchronous trading when calculating the bond return and bond market return. We alleviate this concern in two ways. First, we add the number of zero trading days as an additional control variable in the difference-in-differences regressions. The untabulated results of these regressions are robust. Second, we include in the sample only bonds that are traded every week. The results (untabulated) are robust as well.

5.5.3 Regression discontinuity

We check the robustness of our results with a method of regression discontinuity. We can use this method because the TRACE Phases are determined by the credit rating or issue amounts of the bonds. Specifically, for Phase 3A, we compare the measures of pricing efficiency between BBB- bonds and BB+ bonds. The BBB- bonds are the lowest-rated subset of bonds of Phase 3A, and BB+ bonds are the highest-rated subset of bonds of Phase 3B. The results are qualitatively the same (untabulated) as our main findings for the measures of pricing efficiency. We cannot use the method of regression discontinuity for the measures of information production, due to small numbers of observations of bond analyst reports around the rating cutoff.

5.5.4 Placebo tests

We conduct placebo tests to alleviate the concern that other events around the implementation of TRACE Phases drive our results. Specifically, we assume the implementation of TRACE Phases happens six months before the actual timing of the TRACE Phases and re-define variable *Post* in the difference-in-differences regressions, keeping the definition of treated and control bonds the same as before. The results of the placebo regressions are in Table 8, where Panel A shows the results based on measures of information production, and Panel B and C show the results based on measures of pricing efficiency. We find that the coefficients on the interaction term, $Treated \times Post$, are statistically insignificant in all regressions. These results demonstrate that it is not likely that the effects of the implementation of TRACE Phases identified in the previous analysis are due to the timing of the Phases.

6 Conclusion

Researchers and policymakers often disagree about the overall desirability of public disclosure. Although the literature has argued about the potential benefits and drawbacks of increased disclosure in general, few studies empirically test the impact of public disclosure on private information production and pricing efficiency. This paper fills this gap by examining the causal effects of disclosure, using the implementation of TRACE and a difference-in-differences research design. We find that public disclosure crowds out private information production, which is suggested by less information production by bond analysts (fewer reports, fewer pages per report, and smaller file size of the report). Regarding the net impact on pricing efficiency, we find that greater public disclosure in the corporate bond market increases the speed of information incorporation into bond prices. The results are economically and statistically significant. Subgroup analysis indicates that there is little variation between groups of bonds with different levels of liquidity and trading before Phase implementation. We find that the results are robust to placebo tests, including only frequently traded bonds, and using alternative estimation methods. Our results highlight the potential adverse effect of public disclosure on private information production.

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Appendices

A Definitions of Variables

Variable	Description
Bond return	We define bond return according to Equation 6.
Bond market return (Ret_{BM})	The amount-outstanding weighted average of bond returns for all bonds from TRACE.
Stock market return (Ret_{SM})	The value-weighted CRSP market index return.
Bond portfolio return (Ret_{BP})	The portfolio return is amount-outstanding weighted return of the portfolio. We follow Bessembinder, Kahle, Maxwell, and Xu (2009) to create portfolios segmented by both bond rating and time-to-maturity and calculate amount-outstanding weighted bond portfolio return. We segment bonds by Moody's six major rating categories (Aaa, Aa, A, Baa, Ba, below Ba) and three time-to-maturity categories. For investment grade bonds, the time to-maturity cutoffs are 0 to 5 years, +5 to 10 years, and +10 years. For non-investment grade bonds, the cutoffs are 0 to 6 years, +6 to 9 years, and +9 years. These cutoffs are designed to ensure roughly equivalent terciles. Because the Aaa sample size is too small to split into three subsets based on maturity, we follow Bessembinder, Kahle, Maxwell, and Xu (2009) to split the Aaa sample into two maturity categories, 0 to 7 years and +7 years. The procedure above provides a total of seventeen matching portfolios.
Abnormal return (AR)	Individual bond return minus the return of the corresponding bond portfolio.
Number of bond analyst reports (Number of reports)	The number of bond analyst reports for a bond in a period before or after the TRACE Phase implementation.
Number of pages in bond analyst report (Number of pages)	The number of pages in a bond analyst report.
File size of bond analyst report (File size)	The file size in thousands of bytes of a bond analyst report.
Amihud	The price impact of a trade per unit traded. We first calculate the daily price impact using transactions within each day and then use the mean of daily values over a certain period of time. It is similarly defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012)
Trading	Trading activity is volume divided by issue amount. We first calculate the daily trading activity using transactions within each day and then use the mean of trading activity over a certain period of time.

Variable	Description
Drift	We define the return *Drift* as the 8-week sum of the absolute abnormal bond return ($\sum_{n=1}^{8} \lvert AR_n \rvert$) after the events (bond analyst report or credit rating change).
Delay	We follow Hou and Moskowitz (2005) to define *Delay* in Equation 3. We estimate a regression of each bond's weekly returns on contemporaneous and four weeks of lagged returns on bond market, stock market, and bond portfolio. *Delay* is one minus the ratio of R^2 from the previous regression restricting all coefficients on lagged terms to be zero and the R^2 from the previous regression without the restriction.
Variance ratio	The absolute value of the ratio of the variance of two-week log returns divided by two times the variance of one-week log returns minus one.

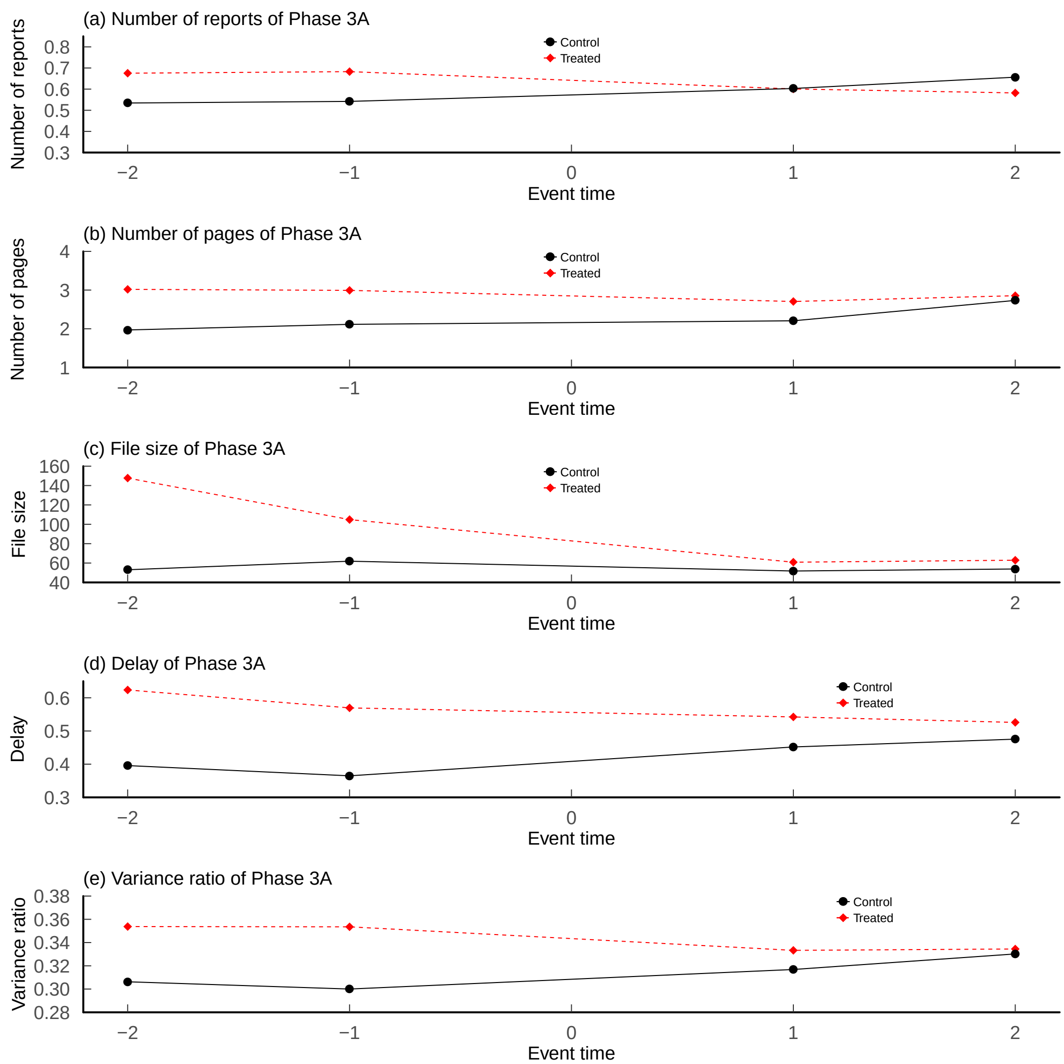

Figure 1: Averages of information production measures and pricing efficiency measures before and after Phase 3A

This figure presents the *Number of reports*, *Number of pages*, *File size*, *Delay*, and *Variance ratio* before and after Phase 3A. The horizontal axis is event time. One unit of event time is six months. The vertical axis is *Number of reports*, *Number of pages*, *File size*, *Delay*, or *Variance ratio*. The square dots with dotted line represent the treated bonds, and the round dots with solid line represent the control bonds.

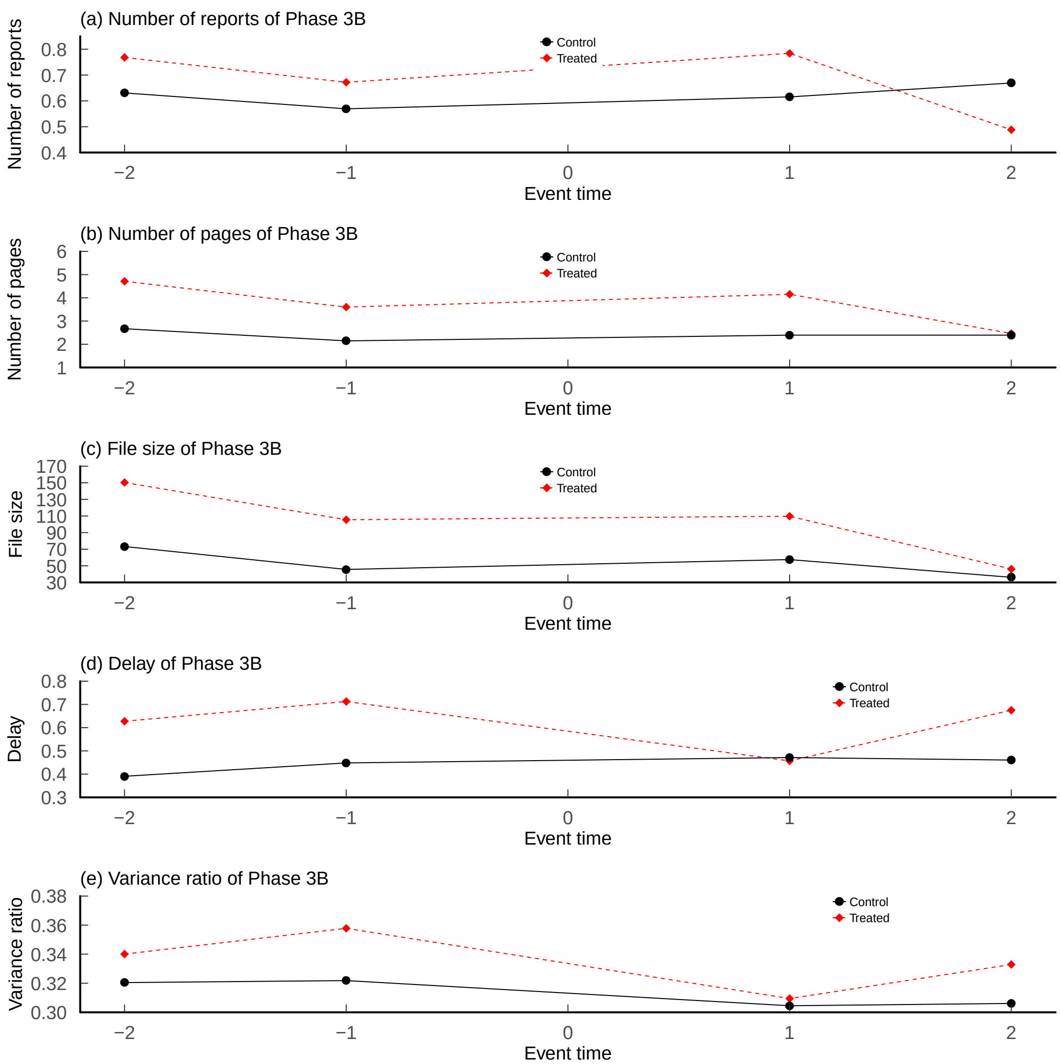

Figure 2: Averages of information production measures and pricing efficiency measures before and after Phase 3B

This figure presents the *Number of reports*, *Number of pages*, *File size*, *Delay*, and *Variance ratio* before and after Phase 3B. The horizontal axis is event time. One unit of event time is six months. The vertical axis is *Number of reports*, *Number of pages*, *File size*, *Delay*, or *Variance ratio*. The square dots with dotted line represent the treated bonds, and the round dots with solid line represent the control bonds.

Table 1: Description of TRACE phases

Panel A: Phases description

Sample	Date	Bonds becoming disseminated
Phase 1	1 July 2002	Investment grade TRACE-eligible bonds having an initial issue of $1 billion or greater.
Phase 2	3 March 2003	Investment grade TRACE-eligible bonds whose original issue size is at least $100 million or bonds rated A or higher. Phase 2 also includes 50 non-investment grade bonds.
Phase 3A	1 October 2004	Bonds rated BBB or higher.
Phase 3B	7 February 2005	Bonds rated BB+ or lower.

Panel B: Definition of pre- and post-periods

Phase	Date	Pre-period	Post-period
Phase 2	3 March 2003	(1 July 2002, 2 March 2003)	(3 March 2003, 3 March 2004)
Phase 3A	1 October 2004	(3 March 2003, 30 September 2004)	(1 October 2004, 31 December 2006)
Phase 3B	7 February 2005	(3 March 2003, 6 February 2005)	(7 February 2005, 31 December 2006)

This table describes the main implementation phases of TRACE and the definition of pre- and post-periods. Panel A reports the implementation dates of the main implementation phases of TRACE and the definition of treated and control groups of bonds for each Phase. Panel B reports the definition of pre- and post-periods for our difference-in-differences estimation.

Table 2: Summary statistics

Panel A: Number of bond analyst reports

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	310	1.63	155	1.32	
Phase 3A	After	310	2.25	155	2.41	
Difference			0.62		1.09	-0.47
Phase 3B	Before	152	2.13	155	1.68	
Phase 3B	After	152	1.52	155	2.06	
Difference			-0.61		0.38	-0.99

Panel B: Number of pages in bond analyst reports

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	310	7.45	155	5.30	
Phase 3A	After	310	9.46	155	7.75	
Difference			2.01		2.45	-0.44
Phase 3B	Before	152	12.0	155	6.66	
Phase 3B	After	152	7.36	155	6.39	
Difference			-4.64		-0.27	-4.37

Panel C: File size of bond analyst reports

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	310	351.4	155	178.3	
Phase 3A	After	310	195.6	155	141.3	
Difference			-155.8		-37	-118.8
Phase 3B	Before	152	445.6	155	206.7	
Phase 3B	After	152	160.9	155	112.9	
Difference			-284.7		-93.8	-190.9

Panel D: Delay

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	1959	0.58	1178	0.36	
Phase 3A	After	1778	0.52	923	0.45	
Difference			-0.06		0.09	-0.15
Phase 3B	Before	311	0.62	1118	0.38	
Phase 3B	After	300	0.55	863	0.45	
Difference			-0.07		0.07	-0.14

Continued on the next page

Panel E: Variance ratio

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	2009	0.35	1189	0.28	
Phase 3A	After	1821	0.32	932	0.31	
Difference			-0.03		0.02	-0.05
Phase 3B	Before	334	0.34	1132	0.27	
Phase 3B	After	315	0.29	875	0.31	
Difference			-0.04		0.04	-0.08

Panel F: Drift after bond analyst reports

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	210	0.028	107	0.010	
Phase 3A	After	315	0.015	166	0.010	
Difference			-0.013		-0.000	-0.013
Phase 3B	Before	173	0.036	135	0.011	
Phase 3B	After	107	0.016	138	0.010	
Difference			-0.020		-0.001	-0.019

Panel G: Drift after credit rating changes

		Treated		Control		
		No. of observations	Mean	No. of observations	Mean	Diff. in Diff.
Phase 3A	Before	227	0.074	123	0.016	
Phase 3A	After	1110	0.046	119	0.022	
Difference			-0.028		0.006	-0.034
Phase 3B	Before	227	0.075	145	0.016	
Phase 3B	After	155	0.048	97	0.024	
Difference			-0.027		-0.005	-0.022

This table reports the summary statistics of information production and pricing efficiency measures. The information production measures include the number of bond analyst reports, the number of pages in bond analyst reports, and the file size of bond analyst reports, and the pricing efficiency measures include Drift after bond analyst reports, Drift after credit rating changes, Delay, and Variance ratio. The detailed variable definition is in Appendix A.

Table 3: Difference-in-differences regressions of information production

Dependent variable:	No. of reports		No. of pages		File size	
	(1)	(2)	(3)	(4)	(5)	(6)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.30	0.45	2.14	5.36	173.0	238.9
	(1.76)	(2.38)	(2.29)	(3.95)	(4.23)	(4.82)
Post	1.08	0.39	2.45	-0.27	-37.1	-93.8
	(5.57)	(2.07)	(2.93)	(-0.31)	(-1.47)	(-3.62)
Treated × Post	-0.46	-0.99	-0.44	-4.39	-118.7	-190.9
	(-1.95)	(-3.74)	(-0.38)	(-2.93)	(-2.87)	(-3.84)
Constant	1.33	1.68	5.30	6.66	178.3	206.7
	(9.67)	(12.7)	(7.16)	(8.10)	(6.83)	(7.51)
No. of observations	930	614	930	614	930	614
Adjusted R^2 (%)	5.0	1.9	1.6	4.2	4.1	12.1

This table reports the difference-in-differences regression estimates for measures of information production. These measures are Number of analyst reports, Number of pages in bond analyst reports, and File size of bond analyst reports, and they are the dependent variables. Among the independent variables, *Post* is a dummy variable equal to one if it is after the Phase implementation and zero otherwise, and *Treated* is a dummy variable equal to one if the bond is subject to the disclosure requirement and zero otherwise. $Treated \times Post$ is the interaction term between *Treated* and *Post*. The details of TRACE phases are in Table 1. The numbers in parentheses are t-statistics. Standard errors are clustered at the firm level.

Table 4: **Difference-in-differences regressions of pricing efficiency measures**

Panel A: Dependent variables are Delay and Variance ratio

Dependent variable:	Delay		Variance ratio	
	(1)	(2)	(3)	(4)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.23	0.25	0.063	0.046
	(8.29)	(13.99)	(3.45)	(2.85)
Post	0.08	0.066	0.022	0.051
	(8.94)	(7.72)	(2.25)	(5.72)
Treated × Post	-0.16	-0.14	-0.052	-0.059
	(-3.65)	(-7.65)	(-4.17)	(-2.85)
Constant	0.37	0.38	0.28	0.27
	(35.59)	(35.42)	(43.12)	(39.11)
No. of observations	5,838	2,592	5,951	2,643
Adjusted R^2 (%)	9.5	9.2	1.1	1.1

Panel B: Dependent variables are Drifts

Dependent variable:	Drift after bond reports		Drift after rating changes	
	(1)	(2)	(3)	(4)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.017	0.026	0.058	0.059
	(5.55)	(5.87)	(5.67)	(6.66)
Post	-0.00025	-0.0012	0.0062	0.0076
	(-0.16)	(-0.80)	(1.31)	(1.43)
Treated × Post	-0.012	-0.019	-0.035	-0.035
	(-4.06)	(-4.14)	(-2.98)	(-2.15)
Constant	0.010	0.011	0.016	0.016
	(7.60)	(8.55)	(8.08)	(8.94)
No. of observations	798	553	1,579	624
Adjusted R^2 (%)	7.0	11.8	5.3	8.8

This table reports the difference-in-differences regression estimates for four measures of pricing efficiency, which are Drift after bond analyst reports, Drift after credit rating changes, Delay, and Variance ratio. The dependent variables are the measures of pricing efficiency. Among the independent variables, *Post* is a dummy variable equal to one if it is after the Phase implementation and zero otherwise. *Treated* is a dummy variable equal to one if the bond is subject to the disclosure requirement and zero otherwise. $Treated \times Post$ is the interaction term between *Treated* and *Post*. The details of TRACE phases are in Table 1. The numbers in parentheses are t-statistics. Standard errors are clustered at the firm level. See Appendix A for details of variable definitions.

Table 5: Difference-in-differences estimates for bonds grouped by illiquidity, trading, and maturity

Panel A: Dependent variables are information production measures

Dependent variable:	No. of report		No. of pages		File size	
	(1)	(2)	(3)	(4)	(5)	(6)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated × Post × Low Amihud	-0.659	-1.391	-1.198	-7.049	-120.7	-291.1
	(-2.37)	(-4.33)	(-0.73)	(-3.73)	(-2.31)	(-4.88)
Treated × Post × High Amihud	-0.371	-0.973	-0.871	-4.667	-128.1	-207.3
	(-1.37)	(-3.05)	(-0.62)	(-2.49)	(-2.80)	(-3.44)
Treated × Post × Low Trading Activity	-0.469	-0.876	-1.184	-3.926	-126.7	-208.1
	(-1.84)	(-3.03)	(-0.82)	(-2.20)	(-2.88)	(-3.79)
Treated × Post × High Trading Activity	-0.442	-1.344	-0.733	-6.845	-103.4	-249.7
	(-1.69)	(-4.25)	(-0.52)	(-4.01)	(-2.18)	(-4.38)
Treated × Post × Short Maturity	-0.319	-0.798	0.816	-3.777	-100.4	-191.3
	(-1.15)	(-2.76)	(0.49)	(-2.29)	(-2.01)	(-3.78)
Treated × Post × Long Maturity	-0.521	-1.158	-0.924	-4.907	-125.9	-190.5
	(-2.30)	(-4.00)	(-0.76)	(-2.79)	(-2.95)	(-3.41)

Panel B: Dependent variables are Delay and Variance ratio

Dependent variable:	Delay		Variance ratio	
	(1)	(2)	(3)	(4)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated × Post × Low Amihud	-0.1840	-0.1317	-0.0752	-0.0877
	(-8.66)	(-5.12)	(-4.90)	(-3.14)
Treated × Post × High Amihud	-0.1228	-0.0774	-0.0105	-0.0310
	(-1.57)	(-2.87)	(-0.50)	(-1.11)
Treated × Post × Low Trading Activity	-0.1090	-0.0953	0.0114	-0.0551
	(-1.28)	(-3.68)	(0.47)	(-2.36)
Treated × Post × High Trading Activity	-0.1936	-0.1108	-0.0918	-0.0700
	(-7.92)	(-4.73)	(-5.96)	(-2.44)
Treated × Post × Short Maturity	-0.0626	-0.0433	-0.0016	0.0332
	(-1.27)	(-1.31)	(-0.11)	(0.77)
Treated × Post × Long Maturity	-0.1964	-0.1163	-0.0622	-0.0840
	(-3.74)	(-5.53)	(-3.29)	(-3.85)

Panel C: Dependent variables are Drifts

Dependent variable:	Drift after bond reports		Drift after rating changes	
	(1)	(2)	(3)	(4)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated × Post × Low Amihud	-0.0140	-0.0198	-0.0492	-0.0573
	(-4.10)	(-4.27)	(-3.97)	(-4.59)
Treated × Post × High Amihud	-0.0109	-0.0196	-0.0337	-0.0126
	(-3.40)	(-4.88)	(-2.72)	(-0.51)
Treated × Post × Low Trading Activity	-0.0118	-0.0178	-0.0392	-0.0415
	(-3.67)	(-4.82)	(-3.45)	(-2.10)
Treated × Post × High Trading Activity	-0.0130	-0.0207	-0.0440	-0.0389
	(-3.96)	(-5.64)	(-3.33)	(-2.77)
Treated × Post × Short Maturity	-0.0138	-0.0191	-0.0497	-0.0159
	(-4.39)	(-5.23)	(-3.67)	(-0.57)
Treated × Post × Long Maturity	-0.00963	-0.0180	-0.0209	-0.0417
	(-3.42)	(-5.48)	(-1.26)	(-3.22)

This table reports the difference-in-differences estimates for different bonds grouped by bond characteristics measured before TRACE phases. The dependent variables are the measures of information production and pricing efficiency. The measures of information production include *Number of bond reports*, *Number of pages*, and *File size*, and the measures of pricing efficiency include *Delay*, *Variance ratio*, *Drift after bond analyst reports*, and *Drift after rating changes*. The bond groups include bonds with high or low illiquidity, bonds with high or low trading, and bonds with long or short maturity. We use median numbers among bonds before the phases as cutoffs to define high and low groups for illiquidity and trading and use five years as the cutoff to define long and short maturity. We use *Amihud* to measure illiquidity and use volume divided by issue amount to measure trading. We measure illiquidity and trading using the average of daily illiquidity and trading during the week before the bond analyst report or the credit rating changes. The numbers in parentheses are t-statistics based on standard errors clustered at the firm level.

Table 6: Spillover to stock market

Dependent variable:	Delay		Variance ratio	
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.086	0.19	-0.00233	0.0286
	(4.81)	(8.56)	(-0.24)	(1.59)
Post	0.014	0.090	0.0747	0.0848
	(0.68)	(3.74)	(7.58)	(4.35)
Treated × Post	0.020	-0.018	0.0193	-0.0308
	(0.77)	(-0.59)	(1.36)	(-1.20)
Constant	0.15	0.17	0.145	0.217
	(9.96)	(10.2)	(21.05)	(15.77)
No. of observations	1,196	860	1,781	889
Adjusted R^2 (%)	4.8	15.3	7.3	3.0

This table reports the difference-in-differences estimates for the spillover to stock market. The sample is the companies whose bonds are subject to disclosure requirement in different phases. The dependent variable is the delay or variance ratio measure based on stock prices. *Post* is a dummy variable equal to 1 if it is after the Phase implementation. *Treated* is a dummy variable equal to 1 if the bond of the company is subject to dissemination requirement. $Treated \times Post$ is the interaction term between *Treated* and *Post*. The details of TRACE phases can be found in Table 1. The numbers in parentheses are t-statistics.

Table 7: Using bonds of Phase 2 as treated bonds

Dependent variable:	No. reports	No. pages	File size	Delay	Variance ratio	Drift after bond reports	Drift after rating changes
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated	-0.040	0.13	-64.1	0.049	0.09	-0.048	-0.091
	(-0.23)	(0.12)	(-2.06)	(3.92)	(7.49)	(-5.00)	(-9.13)
Post	-0.054	0.82	106.8	-0.049	0.028	-0.033	-0.022
	(-0.51)	(1.40)	(3.79)	(-2.57)	(2.06)	(-4.77)	(-1.81)
Treated × Post	-0.43	-4.28	-166.7	-0.11	-0.11	0.018	0.022
	(-1.81)	(-3.42)	(-3.90)	(-5.05)	(-6.97)	(1.77)	(1.63)
Constant	1.39	5.88	234.3	0.61	0.32	0.075	0.11
	(18.6)	(15.3)	(13.0)	(56.88)	(32.47)	(11.3)	(12.5)
No. of observations	822	822	822	4,995	4,642	502	783
Adjusted R^2 (%)	0.8	2.0	3.8	4.4	2.0	8.9	6.7

This table reports the results of difference-in-differences regression analysis that use the bonds of Phase 2 as treated bonds. The control bonds are bonds pf Phase 3A and 3B. The dependent variables include the measures of information production (*Number of reports*, *Number of pages*, and *File size*) and the measures of pricing efficiency (*Delay*, *Variance ratio*, *Drift after bond reports*, and *Drift after rating changes*). Among the independent variables, *Post* is a dummy variable equal to one if it is after the implementation of Phase 2 and zero otherwise, and *Treated* is a dummy variable equal to one if the bond is subject to the disclosure requirement of Phase 2 and zero otherwise. $Treated \times Post$ is the interaction term between *Treated* and *Post*. The details of TRACE phases are in Table 1. The numbers in parentheses are t-statistics. Standard errors are clustered at the firm level.

Table 8: **Placebo tests**

Panel A: Dependent variables are measures of information production

Dependent variable:	No. of reports		No. of pages		File size	
	(1)	(2)	(3)	(4)	(5)	(6)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.109	0.241	0.942	2.698	118.3	139.9
	(0.72)	(1.70)	(1.06)	(3.20)	(2.55)	(3.63)
Post_placebo	-0.0267	0.423	-1.320	1.748	-94.23	-12.04
	(-0.16)	(3.00)	(-1.49)	(2.43)	(-2.56)	(-0.45)
Treated × Post_placebo	0.203	-0.0606	1.601	0.575	44.18	-6.983
	(1.00)	(-0.28)	(1.49)	(0.43)	(0.80)	(-0.15)
Constant	0.787	0.846	3.640	3.325	162.9	136.3
	(6.10)	(8.34)	(4.82)	(6.13)	(5.08)	(5.72)
No. of observations	456	500	456	500	456	500
Adjusted R^2 (%)	1.0	2.7	2.0	4.3	4.3	4.7

Panel B: Dependent variables are Delay and Variance ratio

Dependent variable:	Delay		Variance ratio	
	(1)	(2)	(3)	(4)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.1848	0.1891	-0.0168	0.0203
	(8.80)	(12.33)	(-1.44)	(1.71)
Post_placebo	-0.0324	0.0670	0.0160	0.0119
	(-3.89)	(7.81)	(0.46)	(1.18)
Treated × Post_placebo	0.0022	0.0268	0.0959	0.0229
	(0.19)	(1.47)	(1.38)	(1.25)
Constant	0.3454	0.3229	0.4157	0.3379
	(39.05)	(33.35)	(45.72)	(51.75)
No. of observations	7,267	3,318	6,911	3,738
Adjusted R^2 (%)	11.1	12.5	0.0	0.4

Panel C: Dependent variables are Drifts

Dependent variable:	Drift after bond reports		Drift after rating changes	
	(1)	(2)	(3)	(4)
	Phase 3A	Phase 3B	Phase 3A	Phase 3B
Treated	0.00957	0.00923	0.0364	0.0263
	(2.43)	(2.09)	(3.28)	(1.42)
Post_placebo	0.000577	0.00190	0.00135	0.0152
	(0.12)	(0.36)	(0.12)	(0.59)
Treated × Post_placebo	-0.00174	0.00328	-0.00715	0.00396
	(-0.30)	(0.50)	(-0.47)	(0.13)
Constant	0.0101	0.0108	0.0114	0.0127
	(3.22)	(2.87)	(1.42)	(1.09)
No. of observations	265	248	131	93
Adjusted R^2 (%)	2.3	3.5	10.7	5.4

This table reports the results of placebo difference-in-differences regressions based on the measures of information production and pricing efficiency. We assume the implementation of TRACE Phases happen 6 months before the actual timing of the TRACE Phases and re-define variable *Post* in the difference-in-differences regressions. The definition of treated and control bonds is the same as the previous analysis. *Post_placebo* is a dummy variable equal to one if it is later than 6 months before the Phase implementation and zero otherwise, and *Treated* is a dummy variable equal to one if the bond is subject to the disclosure requirement and zero otherwise. $Treated \times Post\_placebo$ is the interaction term between *Treated* and *Post_placebo*. The details of TRACE phases are in Table 1. The numbers in parentheses are t-statistics. Standard errors are clustered at the firm level.