# Mandatory Portfolio Disclosure, Stock Liquidity, and Mutual Fund Performance*

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## ABSTRACT

This paper studies the impact of mandatory portfolio disclosure of mutual funds on the liquidity of disclosed stocks and on fund performance. We consider a theoretical model of informed trading with different mandatory disclosure frequencies. Using a regulation change in May 2004 that increased the frequency of mandatory disclosure, we find evidence consistent with the model's predictions. First, stocks with higher fund ownership experience a larger increase in liquidity as compared to other stocks subsequent to the mandatory increase in disclosure frequency, especially for stocks disclosed by more informed funds or subject to greater information asymmetry. Second, better performing funds experience a greater drop in their abnormal performance following the regulation change, particularly when they hold stocks with greater information asymmetry or when they take longer to complete their trades. Taken together, our evidence suggests that mandatory portfolio disclosure improves market quality by increasing stock liquidity but imposes costs on informed investors.

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# Mandatory Portfolio Disclosure, Stock Liquidity, and Mutual Fund Performance

Mandatory disclosure of portfolio holdings by institutional money managers is a vital component of securities market regulation. Mandated by the Securities Exchange Act of 1934 and the Investment Company Act of 1940, portfolio disclosure provides the public with information about the holdings and investment activities of institutional investors. Academic research has utilized the disclosed holdings to study many related topics. These topics include voluntary portfolio disclosure (Ge and Zheng (2006)), front running and copycat trading activities (e.g., Frank et al. (2004), Coval and Stafford (2007), Verbeek and Wang (2010), Brown and Schwarz (2012)), window dressing behavior of disclosing institutions (e.g., Lakonishok et al. (1991), Musto (1997, 1999), Agarwal, Gay, and Ling (2012)), the hiding of certain positions (Agarwal et al. (2013) and Aragon, Hertzel, and Shi (2012)), the costs of disclosure to hedge funds (Shi (2012)), and intra-quarter trading (Wang (2010) and Puckett and Yan (2011)).

Among the mandatory disclosure requirements on institutional investors, those on mutual funds provide perhaps the most detailed information about their portfolios.[1] However, the impact of mutual funds' portfolio disclosure on their disclosed stocks and the funds themselves has not yet been examined in the extant empirical literature. To fill this gap, this study examines how mandatory portfolio disclosure affects the (i) liquidity of the stocks disclosed by mutual funds, and (ii) mutual fund performance. One of the challenges in conducting such a study is that it is difficult to identify the causal effects of portfolio

[1] See Section I for more detailed discussion.

disclosure on stock liquidity and fund performance. We overcome this challenge by using a Securities Exchange Commission (SEC)-mandated regulation change in May 2004 regarding the disclosure requirements for mutual funds. This change forced mutual funds to increase their portfolio disclosure from a *semiannual* to a *quarterly* frequency. We use this regulation change for a quasi-natural experiment to identify the effects of mutual funds' portfolio disclosure on stock liquidity and fund performance.

We motivate our empirical analyses using the theoretical literature on mandatory disclosure and informed trading. Huddart, Hughes, and Levine (2001) (henceforth HHL) build on the Kyle (1985) model and study mandatory disclosure of trades by informed traders. We extend the HHL model by considering different mandatory disclosure frequencies. We analyze the impact of disclosure frequency on stock liquidity and informed trader's profits and produce several testable predictions.

First, our model predicts that more frequent mandatory disclosure by informed traders improves market liquidity as measured by market depth, namely the inverse of the Kyle (1985) lambda. The intuition is that, with mandatory disclosure, the market maker can infer information from the disclosed positions of informed traders as well as from the aggregate order flows, which reduces the impact of informed trades on prices. Second, the liquidity improvement is greater for stocks subject to higher information asymmetry. Third, our model predicts that the informed trader's profits decrease in the frequency of mandatory disclosure because the market's learning of disclosed trades limits the trader's ability to reap the full benefits of his information. Finally, the magnitude of the informed trader's profit drop is positively related to both stocks' information asymmetry and the number of periods the trader

takes to complete his trades.

To test these predictions of our model, we start by examining the impact of portfolio disclosure on the liquidity of the stocks disclosed by mutual funds subsequent to an increase in disclosure frequency. A large body of literature has shown that mutual funds' disclosed portfolios contain valuable information.[2] Given this evidence, we expect that stocks with higher fund ownership should experience greater increases in liquidity with more disclosure. To test this hypothesis, we employ a difference-in-differences approach to examine the change in stock liquidity during the two-year period around May 2004. The identification of our analyses relies on a cross-sectional comparison of liquidity changes in stocks with high mutual fund ownership (the treatment group) and those in stocks with low fund ownership (the control group). According to the SEC's Electronic Data Gathering, Analysis, and Retrieval (EDGAR) database, a vast majority of actively managed U.S. equity funds (over 97%) had to switch from reporting two times to four times each year due to the regulation change. Our empirical analyses focus on this sample of affected funds.

We find that stocks with higher mutual fund ownership experience significantly larger increases in their liquidity subsequent to the mandatory increase in disclosure frequency. Moreover, the improvement in stock liquidity is economically large. For instance, a one standard deviation increase in mutual fund ownership is associated with a 0.19 and 0.08 standard deviation decrease in the Amihud (2002) illiquidity measure and relative bid-ask spread, respectively. This evidence supports our model's prediction that more frequent mandatory portfolio disclosure of informed traders improves stock liquidity.

[2] See Section II for discussion of this literature.

We corroborate this finding by conducting several sets of placebo tests. First, we carry out cross-sectional placebo tests by including other institutional investors (non-mutual funds or hedge funds) as control groups. The underlying argument is that the regulation change in 2004 only applies to mutual funds, but not to other institutional investors. Specifically, we conduct difference-in-difference-in-differences tests and find that mutual fund ownership has a larger impact on stock liquidity than that of non-mutual-fund ownership or hedge fund ownership after the regulation change. Second, we conduct a time-series placebo test using an alternative sample period. We choose November 2006 as our placebo event date to avoid any overlap with other market events affecting stock liquidity (e.g., the Long Term Capital Management debacle in 1998, the burst of the dotcom bubble in 2000, the decimalization of stock prices in 2001, and the financial crisis from 2007 to 2009). We do not find similar effects of mutual fund ownership on stock liquidity during this alternative period. The results from both the cross-sectional and time-series placebo tests help mitigate concerns that our results are driven by a time trend in stock liquidity.

Next, we test whether the improvement in stock liquidity is larger for the stocks held by more informed funds and stocks associated with greater information asymmetry. To test this hypothesis, we conduct difference-in-difference-in-differences analyses on the (i) subsamples of funds classified using proxies of the likelihood of funds being informed and (ii) subsamples of stocks categorized using proxies of the extent of information asymmetry.

In the fund subsample analyses, we use two proxies for the likelihood of a fund being informed: (i) fund's risk-adjusted performance (Carhart (1997) four-factor alpha), and (ii) the Daniel, Grinblatt, Titman, and Wermers (1997) (DGTW) benchmark-adjusted fund returns.

Using both these proxies, we find the stocks held by more informed funds (i.e., higher past abnormal performance) experience greater increases in liquidity after the increase in the disclosure frequency. Next, in the stock subsample analyses, we consider three measures to proxy for the information asymmetry of a stock: liquidity, analyst coverage, and firm size. Consistent with our model, we find that less liquid stocks, stocks with lower analyst coverage, and stocks with smaller market capitalization experience a larger increase in liquidity than do other stocks subsequent to the increase in disclosure frequency. In addition, these results further help in controlling for time trend in stock liquidity since the liquidity trend should not affect the subsamples of stocks differently.

While in the aforementioned analyses we focus on the impact of portfolio disclosure on the disclosed stocks, we next examine the impact of an increase in mandatory portfolio disclosure on mutual fund performance. Consistent with our model's prediction, we find that informed funds bear costs from the increase in mandatory portfolio disclosure. Specifically, better performing funds, i.e., those in the top quartile based on past four-factor alphas or DGTW-adjusted returns, experience significant declines in their abnormal performance following the 2004 regulation change. After controlling for potential mean reversion in fund performance, the drop in abnormal performance of top quartile funds ranges from 1.9% to 4.5% on an annualized basis.

This deterioration in the fund performance can be related to our earlier finding of an increase in stock liquidity. Following the regulation change, more informed funds hold more liquid stocks and may therefore earn lower four-factor alphas. To investigate this issue, we calculate changes in five-factor alphas by adjusting for the Pástor and Stambaugh (2003)

liquidity factor. We find that about one-fourth of the abnormal performance decline can be attributed to the changes in liquidity of the disclosed stocks. However, three-fourth of the performance decline of the top performing funds remains.

Lastly, we examine how informed funds' portfolio characteristics and trading behavior affect the extent to which more frequent disclosure hurts their performance. Specifically, we study the relation between the performance drop of informed funds and i) the information asymmetry in the stocks that they hold and ii) the time (i.e., the number of quarters) it takes the funds to complete their trading strategies. Consistent with our model's predictions, we find that the performance decrease is greater when top performing funds hold stocks that are subject to greater information asymmetry or when they take longer to finish their trades.

Our paper contributes to the large literature that studies issues related to portfolio disclosure. To the best of our knowledge, our study is the first to examine the implications of portfolio disclosure on both the quality of capital markets and individual fund performance. For this purpose, we first provide a theoretical model allowing for mandatory disclosure with different frequencies and generate several testable predictions. Then, we use the regulation change in 2004 to test these predictions and establish causal relations (i) between portfolio disclosure and the liquidity of disclosed stocks, and (ii) between disclosure and fund performance.

Our evidence suggests that an increase in portfolio disclosure of informed institutional investors can improve market quality by increasing stock liquidity, which should help reduce the cost of capital of issuing companies as well as the transaction costs of investors. This effect is similar to that of an increase in issuer or corporate disclosure, which has been shown

to lead to more liquid capital markets (Diamond and Verrecchia (1991), Fishman and Hagerty (1998, 2003), and Admati and Pfleiderer (2000)). However, we find that informed funds experience a drop in their abnormal performance and bear substantial costs from more frequent portfolio disclosure. To the extent that mandatory portfolio disclosure reveals information about proprietary investment strategies of money managers, it can affect their incentives to collect and process information and, in turn, affect the informational efficiency of financial markets (Grossman and Stiglitz (1980)). Therefore, for policy decisions related to portfolio disclosure, regulators should weigh the benefits of a more liquid capital market against the costs borne by institutional money managers.

The remainder of the paper is organized as follows. Section I provides the institutional background. Section II discusses the related literature and the testable predictions of our model. Section III describes the data and explains the construction of variables. Section IV presents the empirical analyses of the impact of the change in mandatory disclosure on the liquidity of the disclosed stocks. Section V examines the effect of the regulation change on mutual fund performance. Section VI offers concluding remarks.

## I. Institutional Background

Mandatory disclosure of institutional investors' portfolio holdings is a key part of securities market regulation. The SEC requires mutual funds to disclose their portfolio holdings through periodical filings. Since May 2004, the Investment Company Act of 1940 mandates that individual mutual funds disclose their portfolio holdings quarterly in Forms N-CSR and N-Q with a delay of no longer than 60 days. The other important disclosure

requirement, mandated by Section 13(f) of the 1934 Securities Exchange Act, is the Form 13F that requires mutual fund companies to disclose their aggregate holdings (at the company level) on a quarterly basis, with no more than a 45-day delay.[3]

Although the two ownership disclosure regimes described above apply in parallel, the former requirement typically offers much more detailed information about the investment of mutual funds than that provided by the 13F form for two reasons. First, the 13F data is at the company level only while the N-CSR and N-Q data is at the individual fund level. Since mutual fund companies often operate multiple funds, the aggregated 13F data is less informative. Second, 13F forms are only filed by large investors (those with more than $100 million in 13F securities) and include information only on the large (more than 10,000 shares and market value exceeding $200,000) positions in the 13F securities, which consist of equities, convertible bonds, and exchange-listed options.[4] In contrast, N-Q and N-CSR forms are filed by *all* mutual funds for *all* types of securities regardless of the fund's size or the size of the positions held in individual securities. These requirements make the mutual fund disclosure through N-Q and N-CSR forms more informative than the 13F forms filed by mutual fund families.

The disclosure requirements for individual mutual funds, however, have changed over time. Prior to May 2004, the SEC only required mutual funds to file their portfolio holdings twice a year using the semi-annual N-30D form. In May 2004, the SEC enacted a new rule

[3] Institutions filing 13F forms can seek confidential treatment on certain portfolio holdings which, if approved by the SEC, allows them to delay the disclosure by up to one year. See Agarwal, Jiang, Tang, and Yang (2013) and Aragon, Hertzel, and Shi (2012) for details. Also, the 13F forms have always been required on a quarterly basis and thus do not experience a regulatory change in the frequency of mandatory disclosure.

[4] See http://www.sec.gov/divisions/investment/13ffaq.htm for more information on 13F filings.

that changed the N-30D form to the N-CSR form, and required mutual funds to complete and file the form at the end of the second and fourth fiscal quarters.[5] In addition, the new rule also required mutual funds to file N-Q forms at the end of the 1st and 3rd fiscal quarters, thus increasing the reporting frequency to four times per year.[6] To balance the benefits of more transparency to investors and the potential costs on mutual funds, e.g. of front-running and copycat behavior, the SEC allowed the funds to file the disclosure forms with a 60-day delay.

Before the regulation change in May 2004, individual funds could also report their portfolio information more frequently than what the SEC required. They could use the SEC Form N-30B2 to disclose their holdings voluntarily, in addition to the required filing of the semi-annual Form N-30D. Like Form N-30D, Form N-30B2 allows funds to disclose their portfolio holdings, but it is filed voluntarily at the fiscal quarter ends when the N-30D forms are not filed. Though this is an option that funds had prior to the regulation change, we find that only a small number of funds actually used it.[7] In our empirical analyses in Section III, we show that less than 2.5% of all mutual funds voluntarily disclosed their quarter-end holdings using N-30B2 before 2004. Thus, the May 2004 regulation that increased the disclosure frequency affected the disclosure activities of almost all mutual funds.[8]

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[5] Anecdotal evidence suggests that this regulation change on portfolio disclosure was perhaps triggered by the accounting scandals involving Enron, Worldcom, and Tyco, and the ensuing Sarbanes-Oxley Act in July 2002.

[6] See the SEC Final Rule IC-26372 on May 10, 2004 at http://www.sec.gov/rules/final/33-8393.htm.

[7] Some fund companies can choose to disclose the largest holdings of their funds on a quarterly basis on their websites. For example, holdings of Fidelity OTC portfolio are available at http://fundresearch.fidelity.com/mutual-funds/composition/316389105. Such *voluntary* disclosure by funds will bias us against finding any impact of change in mandatory disclosure on stock liquidity and fund performance.

[8] We rely on the SEC's Electronic Data Gathering, Analysis, and Retrieval (EDGAR) database to determine the voluntary funds. Interestingly, the Thomson Reuters database shows a much larger fraction of such funds which report more than twice prior to May 2004. Recently, Schwarz and Potter (2013) discuss the discrepancies between the fund holdings data from EDGAR and Thomson Reuters. We provide more details on this issue in

## II. Related Literature and Empirical Hypotheses

Our paper is motivated by two strands of literature. First, a large number of papers have shown that mutual funds' disclosed portfolios contain valuable information for investors (e.g., Grinblatt and Titman (1989, 1993), Grinblatt, Titman, and Wermers (1995), Daniel, Grinblatt, Titman, and Wermers (1997), Wermers (1999, 2000), Chen, Jegadeesh, and Wermers (2000), Cohen, Coval, and Pastor (2005), Kacperczyk, Sialm, and Zheng (2005, 2008), Alexander, Cici, and Gibson (2007), Jiang, Yao, and Yu (2007), Kacperczyk and Seru (2007), Cremers and Petajisto (2009), Baker, Litov, Wachter, and Wurgler (2010), Ciccotello, Greene, and Rakowski (2011), Wermers, Yao, and Zhao (2012), and Huang and Kale (2013)). Therefore, any change in the portfolio disclosure requirement should affect the underlying asset markets and individual mutual funds.

Second, a strand of theoretical literature studies the impact of mandatory disclosure on informed trading (e.g., Fishman and Hagerty (1995), John and Narayanan (1997), Huddart, Hughes, and Brunnermeier (1999), Huddart, Hughes, and Levine (2001), and George and Hwang (2011)). Perhaps most relevant to our context is the study by Huddart, Hughes, and Levine (2001, henceforth "HHL"), which extends the Kyle (1985) model of an informed trader by introducing mandatory disclosure of trades at the end of each trading period. HHL proves the existence of a mixed strategy equilibrium in which the informed trader adds a random noise to a linear strategy in each period to prevent the market maker from fully inferring his private information. Such a "dissimulation" strategy minimizes the loss in trading profits due to mandatory disclosure.

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Section III and repeat our analysis using both EDGAR and Thomson Reuters databases.

In this paper, we extend the HHL model to consider different frequencies of mandatory disclosure. We provide closed-form solutions of the equilibrium, analyze the impact of disclosure frequency on stock liquidity and informed trader's profits, and produce several testable predictions. To conserve space, we present our model and analytical results in the Appendix and include the proofs in the Supplementary Appendix.

First, our model shows that more frequent mandatory disclosure by informed traders improves market liquidity as measured by the market depth, or the inverse of the Kyle (1985) lambda. The intuition is that with more frequent mandatory disclosure the market maker can infer more information from the informed trader's disclosed positions and his order flow. This additional information leads to a reduction in the impact of informed trades on prices. We note that this intuition holds even though the informed trader adds random noise to his trades, because the market maker is still able to infer some information from the noisy signal. In our empirical setting, the increase in mandatory disclosure instituted in 2004 by the SEC affects the vast majority of mutual funds. Based on our model's prediction, if mutual funds are in general informed, we expect that stocks with a higher mutual fund ownership should experience greater increases in liquidity than other stocks after the regulation change on mandatory disclosure.

Second, our model predicts that the improvement in liquidity depends positively on the extent of asymmetric information in the stock. When the insider is more informed or when the fundamental value of the stock is subject to greater information asymmetry, the market can learn more information from increases in portfolio disclosure, causing stock liquidity to improve more. Therefore, we hypothesize the liquidity improvement to be greater

for stocks with higher ownership by more informed funds as compared to stocks primarily held by funds less likely to be informed. We also expect that the liquidity increases depend positively on information asymmetry at the stock level.

Third, our model predicts a decrease in the informed trader's profits after an increase in the frequency of mandatory portfolio disclosure. The underlying intuition is that because the market maker learns more information with more frequent disclosure, the informed trader is less able to fully reap the benefits of his information. Thus, we posit that informed funds are likely to experience a drop in their abnormal performance as a result of more frequent portfolio disclosure after May 2004.

Finally, our model predicts that the magnitude of the informed trader's profit drop depends positively on the extent of information asymmetry in the stocks disclosed. Thus, we expect the performance decline to be larger for informed funds when these funds hold stocks that are subject to greater information asymmetry. Further, our model predicts that informed traders are hurt more when their trades take a greater number of periods to complete. Therefore, we expect that informed funds that take longer to finish their trades should experience a greater decline in their performance.

## III. Data and Variable Construction

### *A. Data description*

To determine whether or not a mutual fund voluntarily reports before the regulation change in May 2004, we obtain the N-30D, N-30B2, N-CSR, and N-Q forms filed by that fund from the SEC EDGAR database. We use computer programs to parse the documents and

obtain the mutual fund identifier information and the filing dates of these forms. Table I reports the reporting frequencies of all funds using these SEC forms in each year from 1994 to 2011, the period over which data is electronically available from the EDGAR database.

Panel A of Table I reports the total number of filings of each type of forms year by year. Our results reveal several stylized facts. First, the total number of filings almost *doubled* from 6,714 in 2003 to 12,695 in 2005 as shown in the last column. We break down the numbers for each form type and find that this dramatic increase in the total number of filings is completely due to the introduction of the N-Q form in 2004. The N-Q forms accounts for about half of all filings from 2005 onward. Second, voluntary filings by mutual funds using Form N-30B2 account for only a small portion of the total filings and this number is relatively stable over time. For instance, in 2003, out of 6,714 mutual fund filings, only 240 (3.6%) are N-30B2 forms. This evidence suggests that the 2004 regulation to increase disclosure frequency affects the disclosure behavior of almost all mutual funds.

[Insert Table I Here]

Panel B of Table I presents mutual funds' annual reporting frequencies from 1994 to 2011. The results show that most funds file twice over the period from 1994 to 2003 and four times from 2005 to 2011. In 2004, most funds report two or three times because the regulation took effect only in the second part of that year. These patterns further confirm that the 2004 SEC regulation has widespread effects of more frequent disclosure on mutual funds. To identify the effects of the 2004 SEC regulation change on the stock market, we consider all actively-managed U.S. equity mutual funds from the Thomson Reuters Mutual Funds Holdings (S12) database in 2003 and 2004. We focus on the vast majority of funds that do not

disclose stock holdings to the SEC voluntarily through Form N-30B2 during the 12-month period from May 2003 to April 2004.

We use the portfolio holdings data from the Thomson Reuters S12 database for our empirical analyses. We identify the funds impacted by the regulation change using the filing frequencies we obtain from the EDGAR database as described above. We merge the Thomson S12 and the EDGAR databases as follows. First, we collect funds' filings information, including fund names and tickers, filing form types, filing dates, and central index keys (CIKs), from the EDGAR database. Next, we use the tickers from EDGAR to match with the Center for Research in Security Prices (CRSP) mutual fund data. We then merge the resulting data with the Thomson S12 data using the Wharton Research Data Services' (WRDS) MFLINKS tables.[9]

We are able to find CIKs for 2,582 out of the 2,658 actively-managed U.S. equity mutual funds in the S12 database during our sample period. Our final sample consists of 2,520 funds that disclosed no more than two times before the regulation change.[10] Mutual fund holdings data reported to the EDGAR and Thomson Reuters databases are not identical and discrepancies between the two have recently been documented by Schwarz and Potter (2013). Therefore, for robustness, in addition to conducting our analyses using Thomson S12 data, we repeat the analyses using the fund holdings data from the EDGAR database and

[9] For the S12 funds which cannot be matched this way, we use the SEC's search facilities for mutual funds (http://www.sec.gov/edgar/searchedgar/mutualsearch.htm) and for company names (http://www.sec.gov/edgar/searchedgar/companysearch.html) to manually find the CIK for each fund to match with the S12 data.

[10] There are only 62 mutual funds that disclosed voluntarily using the N-30B2 form and are thus not affected by the regulation in 2004. We exclude them from our analysis that follows.

report our findings in the Supplementary Appendix.[11]

*B. Variable construction*

We construct several stock-level variables that we use in our empirical tests. First, for each stock-month observation, we calculate the variable *Mutual Fund Ownership* as the aggregate ownership of all actively managed U.S. equity funds of the stock in that month, scaled by the total shares outstanding of the stock at the month end. When stock holdings are not reported by a fund at a given month end, we use fund's last reported stock holdings.

While the 2004 regulation change affects the reporting behavior of mutual funds, it does not affect the disclosure frequency of other institutional investors who disclose their holdings through the Form 13F. We use these non-mutual-fund institutions as a control group to identify the effects of the increase in mandatory disclosure frequency of mutual funds. For this purpose, we define *Non-MF Institutional Ownership* as the quarterly aggregate institutional ownership from Thomson Reuters Institutional Holdings (S34), excluding mutual funds and asset management companies.[12] In addition, we isolate hedge funds from the non-mutual-fund institutions to form another control group because they are arguably the most actively managed institutions. We define *Hedge Fund Ownership* as the quarterly aggregate hedge fund ownership in the Thomson S34 database. Classification of institutional investors and hedge funds follows that in Agarwal, Jiang, Tang, and Yang (2013).

We construct our sample of stocks from the CRSP stock database. We consider all

[11] We thank Christopher Schwarz for providing us with the fund holdings from the EDGAR database.

[12] Our results are qualitatively similar if we consider an alternative measure of Non-MF Institutional Ownership by further excluding insurance companies because many insurance companies (such as A.I.G.) establish trusts that operate mutual funds (see Chen, Yao, and Yu (2007)).

common stocks from CRSP over the period May 2003 to April 2005. We choose this period to consist of one year prior to and one year after the SEC disclosure regulation change in May 2004. For each stock-month, we construct two variables to proxy for stock liquidity: *Amihud* illiquidity measure, the monthly average of (the logarithm of) daily Amihud measures; and the relative bid-ask spread measure, *Rspread*, the monthly average of (the logarithm of) daily bid-ask spreads scaled by mid-price.[13] We compute these measures as follows,

$$Amihud_{i,t} = \sqrt{\left|r_{i,t}\right| / \left(P_{i,t} * Vol_{i,t}\right)} \tag{1}$$

$$Rspread_{i,t} = \left(Ask_{i,t} - Bid_{i,t}\right) / \left(\frac{Ask_{i,t} + Bid_{i,t}}{2}\right) \tag{2}$$

where *i* indexes stocks and *t* indexes dates, $r_{i,t}$ is the daily stock return, $P_{i,t}$ is the daily price, and $Vol_{i,t}$ is the daily volume. These proxies have been widely used in the literature (Amihud and Mendelson (1986), Amihud (2002), and Lesmond (2005)). We also employ several commonly used stock characteristic variables as controls: *Momentum*, i.e., the momentum variable (12-month cumulative return) of Jegadeesh and Titman (1993); *Book-to-Market*, i.e., the ratio of book equity to market equity; and *Size*, i.e., the natural logarithm of market equity.

To evaluate the impact of the 2004 regulation change, we first compute the average of monthly variables for the 12 months prior to May 2004 and then for the 12 months after May 2004 (inclusive of May 2004). Next, we compute the changes in the annual averages as the difference between the average after May 2004 and the average before May 2004. We denote the resulting change variables by the prefix Δ.

We report summary statistics of the variables in Panel A of Table II. We observe that

[13] We use natural logarithmic transformations to mitigate the effect of any outliers.

both the *Amihud* and *Rspread* measures decrease after May 2004, i.e., the average stock liquidity improves from 2003 to 2005. In the year prior to May 2004, mutual funds in our sample hold, on average, 13.9% of outstanding shares of stocks. *Non-MF Institutional Ownership* and *Hedge Fund Ownership* are 22.3% and 7.9%, respectively.

[Insert Table II Here]

Finally, we use two measures of fund abnormal performance: i) Carhart (1997) four-factor alpha and ii) Daniel, Grinblatt, Titman, and Wermers (1997) (DGTW) benchmark-adjusted returns. Since we consider the performance one year before and after the regulation change, it is noisy to estimate the in-sample alphas based on only 12 monthly fund returns. Therefore, we compute the out-of-sample monthly alpha using the fund returns in each month minus the sum product of the factor returns in that month and the betas estimated from the 24-month window ending in the prior month, as follows:

$$R_{j,s} = \hat{\alpha}_{j,t-1} + \sum_{k=1}^{4} \hat{\beta}_{j,k,t-1} F_{k,s} + \varepsilon_{j,s}, \quad s = t-24, \ldots, t-1 \tag{3}$$

$$\alpha_{j,t} = R_{j,t} - \sum_{k=1}^{4} \hat{\beta}_{j,k,t-1} F_{k,t} \tag{4}$$

where *s* and *t* indicate months, *j* indicates funds, $R$ is the monthly fund return, and *F* is the monthly returns of the four factors (excess market, size, book-to-market, and momentum). We sum the monthly alphas to obtain the annualized alpha. For the DGTW measure, we first compute the cumulative benchmark-adjusted returns between two successive report dates in the Thomson S12 database and then divide them by the number of months in the period to obtain a monthly measure. We then sum the monthly DGTW measure to obtain the annualized figure. We will discuss the summary statistics of these measures in Section V.

## IV. Impact of Mandatory Portfolio Disclosure on Stock Liquidity

### *A. Regulatory Change in Mandatory Disclosure and Stock Liquidity*

To empirically test the effects of the change in funds' portfolio disclosure frequency on stock liquidity, we estimate the following regressions of the changes in liquidity variables. For each liquidity proxy variable *y*, we estimate the following cross-sectional regression:

$$\Delta y_{i,t} = \alpha + \beta MFOwn_{i,t-1} + \gamma y_{i,t-1} + \Gamma' X_{i,t-1} + \varepsilon_{i,t} \quad (5)$$

where *i* indicates the stock, *t* is the year after May 2004, $\Delta y_{i,t}$ is the change in liquidity from the one year before to the one year after May 2004, $MFOwn_{i,t-1}$ is the lagged (i.e., one year before May 2004) *Mutual Fund Ownership*, $y_{i,t-1}$ is the lagged liquidity variable, and $X_{i,t-1}$ are lagged stock characteristics, including *Momentum*, *Size*, and *Book-to-Market* ratio.

The identification of the regression in equation (5) relies on a cross-sectional comparison of stocks with higher mutual fund ownership (the treatment group) to those with lower mutual fund ownership (the control group). Equation (5) essentially uses a difference-in-differences approach to estimate the effect of the 2004 disclosure regulation change on the treatment group.[14] The first difference is the change in stock liquidity over the 12 months before and after May 2004 for the stocks. The second difference is the difference in the liquidity changes of the treatment and control groups.

Panel B of Table II reports the estimation results of equation (5). Our primary independent variable of interest is *Mutual Fund Ownership*. The results show that for both liquidity measures *Amihud* and *Rspread*, the coefficients of *Mutual Fund Ownership* are

[14] For illustration purposes, we discuss here the case with two groups. We actually use a continuous variable of the mutual fund ownership in the regression but the intuition is the same.

negative and statistically significant in all the four columns at the 5% level or better. Since lower *Amihud* and *Rspread* imply greater liquidity, larger fund ownership is associated with greater improvement in stock liquidity after the 2004 regulation change. These findings are also economically significant. For instance, based on the estimates in columns (2) and (4), a one standard deviation increase in mutual fund ownership is associated with a 0.19 standard deviation decrease in *Amihud* and a 0.08 standard deviation decrease in *Rspread*. This evidence is consistent with our model's prediction that more frequent portfolio disclosure by informed traders will lead to an increase in the liquidity of the underlying stocks they trade.

*B. Cross-Sectional and Time-Series Placebo Tests*

First, we conduct a set of cross-sectional placebo tests. The above results cannot rule out the possibility that mutual fund ownership proxies for institutional ownership and stocks with higher institutional ownership experience greater improvement in liquidity after May 2004. To distinguish this alternative scenario from the effect of disclosure regulation, we add *Non-MF Institutional Ownership* to equation (5) and estimate the following regression:

$$\Delta y_{i,t} = \alpha + \beta MFOwn_{i,t-1} + \beta' NonMFOwn_{i,t-1} + \gamma y_{i,t-1} + \Gamma' X_{i,t-1} + \eta_{i,t} \quad (6)$$

Intuitively, equation (6) uses a difference-in-difference-in-differences approach to estimate the effect of the 2004 disclosure regulation change on stock liquidity. The coefficients on *Mutual Fund Ownership* and *Non-MF Institutional Ownership* represent the difference-in-differences effect of the ownership variables on changes in liquidity as discussed before in reference to equation (5). The difference of these two coefficients provides an estimate of the effect of the increase in disclosure frequency on stock liquidity

after controlling for non-mutual fund institutional ownership.

Among non-mutual-fund institutions not affected by the increase in disclosure frequency, hedge funds are arguably more actively managed and better informed. Therefore, we use them as an alternative control group and estimate the following equation:

$$\Delta y_{i,t} = \alpha + \beta MFOwn_{i,t-1} + \beta'' HFOwn_{i,t-1} + \gamma y_{i,t-1} + \Gamma' X_{i,t-1} + \eta_{i,t} \quad (7)$$

We report the estimation results of equations (6) and (7) in Panel A of Table III. The last two rows present the differences in the coefficients of *Mutual Fund Ownership* and *Non-MF Institutional Ownership* (or *Hedge Fund Ownership*) and the corresponding test statistics. In all but one specification, we find that the mutual fund ownership has a statistically greater impact on liquidity than does non-mutual-fund institutional ownership or hedge fund ownership. These results suggest that it is not institutional ownership *per se*, but rather the increase in mutual fund portfolio disclosure after May 2004 that leads to the improvement in stock liquidity.

[Insert Table III Here]

Second, we conduct a time-series placebo test. Specifically, we estimate equation (5) using the year before and after November 2006 as our placebo period. Note that we cannot choose a period prior to the regulation change because of events such as the Russian sovereign bond default and the Long-Term Capital Management debacle in 1998, the burst of the dotcom bubble in 2000, and the decimalization of stock prices quotes in 2001, all of which significantly affected stock liquidity. Furthermore, we choose the placebo period such that it is as far away from the event date in 2004 as possible and not affected by the 2007–2009 "great recession", which started in December 2007 according to the National

Bureau of Economic Research (NBER).

We first estimate the regressions as in equation (5) for the placebo period. We then compare the coefficients for the placebo period with those for the two-year period surrounding the 2004 regulation change as reported in Panel B of Table II. We report the results of this comparison in Panel B of Table III. For the sake of brevity, we keep only the coefficients of the mutual fund ownership variables. Our results show that fund ownership has a positive effect on liquidity in 2004, but has either a small or insignificant effect in 2006. The difference in the effects for the two time periods is highly significant, as shown by the *F*-tests in the last row. The results of our placebo test further confirm that the liquidity changes are driven by the increase in mandatory disclosure frequency in 2004.

Taken together, the results from the cross-sectional and time-series placebo tests in this section show that liquidity improvement is concentrated in stocks held by mutual funds and not by other institutions and is not driven by a temporal factor unrelated to the 2004 disclosure regulation change.

*C. Mutual Fund and Stock Subsample Analyses*

Our model predicts that increases in stock liquidity due to more frequent disclosure should be concentrated in i) funds that are more informed and ii) stocks that have greater information asymmetry. In this section, we use subsamples of mutual funds and stocks to test these predictions.

First, we test whether the improvement in liquidity is concentrated in stocks disclosed by more informed funds. If portfolio disclosure contains valuable information, then an

increase in disclosure by well-performing funds should have greater impact than by funds with poor past performance. To test this hypothesis, we consider two proxies of funds being informed: i) Carhart (1997) four-factor alpha and ii) Daniel, Grinblatt, Titman, and Wermers (1997) (DGTW) benchmark-adjusted returns. Using these two proxies, we divide the mutual funds into two subsamples: more informed, i.e., the top-quartile funds, and less informed, i.e., the non-top-quartile funds. We include the aggregated ownership of the funds in both groups in the following regression and test the difference of the coefficients of the two ownership variables:

$$\Delta y_{i,t} = \alpha + \beta MFOwn_{i,t-1}^{top} + \beta' MFOwn_{i,t-1}^{non-top} + \gamma y_{i,t-1} + \Gamma' X_{i,t-1} + \varsigma_{i,t} \quad (8)$$

Our findings in Table IV show that the ownership of the top-quartile funds has a statistically larger impact on liquidity than the ownership of the non-top-quartile funds.[15] These results support our model's prediction that the market learns more information from the holdings of more informed funds, which results in a greater improvement in liquidity of the disclosed stocks.

[Insert Table IV Here]

Second, we investigate which type of stocks experience greater increases in liquidity as a result of the regulatory change increasing the disclosure frequency. Our model predicts that the improvement in liquidity should be concentrated in stocks with greater information asymmetry. To test this idea, we divide our sample of stocks into subsamples based on the top

[15] Our findings are not affected by the possibility that funds may try to reduce the impact of the regulation by the window dressing behavior. In untabulated results, we consider the likelihood of fund window dressing (Agarwal, Gay, and Ling (2012)) and find that the improvement in liquidity is concentrated in the funds that are not prone to window dressing behavior.

quartiles of illiquidity (*Amihud* or *Rspread*), analyst coverage, and market capitalization. We then estimate the regression in equation (5) for each subsample and compare the coefficients of fund ownership for the two subsample regressions.

We report the results in Table V. As shown in the table, the differences in the coefficients of fund ownership of the two subsamples have the predicted sign and are significant at the 5% level or better for all four measures of information asymmetry. In particular, smaller stocks, less liquid stocks, and stocks with lower analyst coverage benefit more from the increase in disclosure frequency. This evidence is consistent with our model's prediction that more frequent disclosure leads to higher liquidity when there is greater information asymmetry in the disclosed stocks.

[Insert Table V Here]

Finally, for robustness, we use mutual fund holdings obtained from the EDGAR database, rather than from Thomson S12 database, and repeat all the tests in this section. In the Supplementary Appendix, we report these results in Tables B.II to B.V, which are analogous to Tables II to V. All the results are qualitatively similar.

## V. Impact of Mandatory Portfolio Disclosure on Fund Performance

Our results in the previous section suggest that the market learns more when mutual funds are required to disclose more frequently and, as a result, stock liquidity improves. The increase in liquidity reduces transaction costs and benefits all investors in general. We next examine how more frequent mandatory portfolio disclosure affects fund performance.

*A. Mutual Fund Performance and the Regulation Change*

Our theoretical model predicts that the informed trader's profits decrease when mandatory disclosure becomes more frequent. The intuition is that the market learning of disclosed trades decreases the ability of the informed traders to fully reap the benefits of private information. Consistent with this intuition, fund managers argue that holdings disclosure can lead to front-running or free riding on their trades. Both theory and the reaction from practitioners motivate us to examine the impact of mandatory disclosure on fund performance.

In particular, we consider two measures of funds' abnormal performance: Carhart 4-factor alphas and DGTW-adjusted returns. We use the annualized values of these two variables for funds in our sample during the one-year periods prior to and after May 2004, and then calculate the differences to measure the performance changes. For control variables, we consider fund characteristics including (i) *TNA*, defined as the total net assets under management, (ii) *Turnover*, defined as the average annual turnover from Thomson S12 mutual fund holdings, (iii) *Flow*, defined as the change in TNA scaled by lagged TNA, (iv) *Expense Ratio*, defined as the total operating expenses scaled by TNA, and (v) *Load* status, defined as an indicator variable which equals one if the mutual fund has a class with load, and zero otherwise. Specifically, we estimate the following regression at the fund level:

$$\Delta Perf_{j,t} = \lambda_0 + \lambda_1 TopFund_{j,t-1} + \kappa' X_{j,t-1} + \varphi_{j,t} \quad (9)$$

where $j$ indicates the fund and $t$ is the year after the regulation change. $\Delta Perf_{j,t}$ is the change in abnormal fund performance (Carhart 4-factor alpha or DGTW-adjusted return); $TopFund_{j,t-1}$ is an indicator variable that equals one if the fund is in the top quartile based on

the lagged (in the year before the regulation change) fund performance and zero otherwise; $X_{j,t-1}$ include a number of lagged fund characteristics.

Panel A of Table VI reports the summary statistics of fund performance and other fund characteristics around the 2004 regulation change. The average annualized four-factor alphas of mutual fund increase by 1.7% after May 2004, and the annualized DGTW-adjusted returns drop by 0.7%. This finding indicates no clear direction of performance change around 2004 for the average fund in our sample.

[Insert Table VI Here]

To test our model's prediction, we examine the effect of the May 2004 regulation change on the performance of the top-performing funds. Panel B of Table VI reports the results of regressions of performance changes in equation (9). In columns (1) and (2) of Panel B, we observe that funds with alphas in the top quartile experience a decrease of 9.2% in annualized alphas and a decrease of 3.8% in annualized DGTW-adjusted returns, relative to non-top-quartile funds. Similarly, as shown in columns (3) and (4), funds with top DGTW-adjusted returns experience a decrease of 3.4% in alphas and a decrease of 11.9% in DGTW-adjusted returns. All of the coefficients are statistically significant at the 1% level.

A potential concern about the above result is that the drop in performance of top-performing funds arises from mean reversion or other factors. To alleviate this concern, we conduct an additional test using the same 2006 placebo period used in Section IV.B. Table VII reports the results of this test and compares them with those in Table VI using the difference-in-difference-in-differences approach. We find that top-performing funds also experience performance deteriorations around the 2006 placebo period ranging from 1.3% to

7.5% depending on the performance measure. This evidence suggests the existence of a potential mean reversion effect. However, after accounting for mean reversion by subtracting the 2006 coefficients from those in 2004, the drops in fund performance remain statistically and economically significant. The magnitude of the performance decline, net of mean reversion effect, ranges from 1.9% to 4.5% on an annualized basis. The above results are consistent with our model's prediction that more informed funds bear higher costs of mandatory disclosure as it hinders their ability to fully benefit from their private information.

[Insert Table VII Here]

For robustness, we also estimate all regressions in Table VII by controlling for changes in fund characteristics, rather than using lagged fund characteristics as independent variables. We obtain qualitatively similar results as shown in Table B.VII in the Supplementary Appendix.

*B. Fund Performance and Stock Liquidity*

Mandatory disclosure can lower stock returns through the improvement in liquidity, which in turn can lead to worse fund performance. To separate this *indirect* effect of changes in stock liquidity on fund performance from the *direct* effect of funds' diminished ability to benefit from private information, we estimate the regressions of fund performance using alphas based on a five-factor model which augments the Carhart (1997) four-factor model with the Pástor and Stambaugh (2003) liquidity factor.

Table VIII reports the regression results with five-factor alphas and compares them with those based on four-factor alphas. We find that, after controlling for the impact of the

liquidity factor on fund performance, top-performing funds experience decreases in their five-factor alphas of 3.2% to 7.7% on an annualized basis in 2004. As in the case of four-factor alphas, we also control for potential mean reversion in the case of five-factor alphas. After subtracting the coefficients from the 2006 placebo period, the decreases in five-factor alphas range from 1.6% to 3.3% on an annualized basis, which is about three quarters of the corresponding decreases for four-factor alphas (from 1.9% to 4.5%). Moreover, the differences between the results for four-factor and five-factor alphas are small and statistically insignificant in all but one case, as shown in the last column of Panels A and B in Table VIII.

[Insert Table VIII Here]

*C. Fund Performance and Information Asymmetry of Stocks*

Our model predicts that when trading stocks with greater information asymmetry, the informed trader will experience greater losses because of the revelation of more valuable information to the public. To test this prediction, we next investigate whether the top-performing funds experience a larger drop in performance when they also hold stocks with higher levels of information asymmetry.

We first calculate fund-level information asymmetry measures using stock size, analyst coverage, Amihud illiquidity, and relative spread by value-weighting these measures based on the amount the fund invested in these stocks at the time of disclosure. We then create indicator variables that equal one if a fund is in the top quartile for a fund-level measure of information asymmetry. We estimate regressions of fund performance changes on

the interactions of past fund performance and the information asymmetry variables. Based on our model's prediction, we expect the coefficients of these interactions to be negative and significant.

Table IX presents the results of these regressions. Consistent with our model's predictions, we find that the top-performing funds that also hold stocks with high levels of information asymmetry experience the greatest declines in performance. For example, a top-quartile (based on past alpha) fund whose portfolio contains small stocks suffers an additional 1.6% (3.0%) decrease in alpha (DGTW-adj. return) compared to a top-quartile fund that holds large stocks. Similarly, a top-quartile (based on past DGTW-adjusted return) fund that holds small stocks experiences an additional 5.2% (6.5%) decline in alpha (DGTW-adj. return) relative to other top-quartile funds.

[Insert Table IX Here]

*D. Fund Performance and Trade Length*

The regulation change in May 2004 required mutual funds to increase their disclosure frequency from twice a year to four times a year. Our model predicts that if an informed trader completes his trades over a longer period, he will be more adversely affected by disclosure. This prediction implies that the regulation change would have an even greater adverse effect on funds that take longer to complete their trading strategies.

To test this prediction, we construct a variable *Trade Length* as follows. First, for each stock for a given fund-quarter, we construct a position-level measure by counting the number of consecutive quarters over which the fund either builds or unwinds the position in that stock

during the one-year period prior to that quarter. Second, we value weight the position-level measures across all stock positions held by each fund to obtain a fund-quarter *Trade Length* measure. Third, we average across all quarters in a year to obtain the annual fund-level measure. Finally, we create an indicator variable that equals one if a fund is in the top quartile of the annual fund-level *Trade Length*, and zero otherwise.

We estimate regressions of fund performance changes on the interactions of past fund performance and the *Trade Length* measure. Based on our model's prediction, we expect the coefficients of these interactions to be negative and significant. Panel C of Table IX presents the estimation results. We find that funds in the top quartile of past performance and in the top quartile of *Trade Length* experience even greater declines in DGTW-adjusted returns. For example, funds in the top quartile of past DGTW-adjusted returns that also take longer to complete their trades experience an additional decline of 4.2% compared to other top performing funds. However, when we use changes in four-factor alphas as the dependent variable, the coefficients on the interaction terms are not significant.

*E. Summary*

Taken together, the results in this section suggest that the costs of more frequent mandatory portfolio disclosure are largely borne by top performing funds. We find evidence that these funds experience significant performance deterioration even after accounting for potential mean reversion and changes in liquidity of the stocks held by these funds. Moreover, the performance decline is more acute for funds holding stocks with greater information asymmetry and for funds that take longer to complete their trades. Overall, these results are

consistent with our model's predictions that increase in disclosure frequency facilitates the market's learning of the funds' information but hurts these funds' ability to fully benefit from their information.

## VI. Concluding Remarks

We use a regulatory change in May 2004 that increased the mandatory disclosure frequency of mutual funds from two to four times a year to examine the impact of disclosure on the liquidity of disclosed stocks and on fund performance. This regulation change provides us with a quasi-natural experiment to identify causal relations between the mandatory portfolio disclosure and stock liquidity, and between disclosure and fund performance.

We develop a model based on Huddart, Hughes, and Levine (2001) to allow for mandatory disclosure at different frequencies. We adopt a difference-in-differences approach to test several predictions from our model and document several findings that support these predictions. First, we find that the increase in stock liquidity is positively related to the level of fund ownership. Second, the liquidity improvement is concentrated in stocks held by informed funds and in stocks subject to greater information asymmetry. Third, the abnormal performance deteriorates substantially for funds that perform well prior to the regulation change. This decline in fund performance cannot be explained by mean reversion in fund performance or by changes in stock liquidity. Finally, performance decline is greater for top-performing funds that hold stocks with greater information asymmetry or take longer to complete their trades.

Taken together, our findings suggest that more frequent mandatory portfolio

disclosure by mutual funds helps improve the quality of capital markets by improving the liquidity of the disclosed stocks. However, increasing the disclosure frequency can hurt funds' ability to capitalize on their information and thus can reduce their incentives to collect and process information. Therefore, policymakers should weigh the benefits of disclosure to capital markets against the costs borne by informed funds.

## Appendix: A Model of Frequency of Mandatory Portfolio Disclosure

*I. Model*

We build an extension of the Huddart, Hughes, and Levine (2001) model (henceforth "HHL") and the Kyle (1985) model to study the effects of changes in mandatory disclosure frequency on stock liquidity and informed trader's profits.

Following Kyle (1985), there is a risky security and a risk-free security with zero risk-free rate in the market. In each of the $N$ periods, $n = 1, 2, \ldots, N$, traders submit orders, and a market maker sets the price. There are two types of traders, an informed trader and a noise trader. The informed trader learns of the true value $v$ of the risky security at the beginning of period 1 and strategically submits order $x_n$ in period $n$ to maximize his expected profits. The noise traders' trade in any period $n$ is normally distributed, $u_n \sim N(0, \sigma_u^2)$. The market maker knows the prior distribution, $v \sim N(0, \Sigma_0)$. The random variables $v, u_1, u_2, \ldots, u_N$ are mutually independent. All agents are risk-neutral. Finally, the market maker observes the total order flow $y_n = x_n + u_n$ but not its decomposition in period *n*. The market maker sets the price so that he makes zero expected profits.

There is mandatory disclosure once in every *k* periods. In other words, in every period $n = k, 2k, \ldots, N$, the informed trader is required to disclose his trade $x_n$ to the regulator *after* trading occurs. For simplicity, we assume that $N$ is a multiple of *k*. The regulator disseminates such information to all market participants instantly.

Let $p_n$ denote the stock price that the market maker sets based on the total order flow in period *n*, and $p_n^*$ be the stock price that the market maker updates to at the end of the period if the trade by the informed trader ($x_n$) during the period is disclosed. During the

periods when mandatory disclosure is not required, $p_n$ remains till the end of the period.

Using the standard technique from Kyle (1985), we will show that a unique equilibrium exists in which the informed trader's strategy is of the following form:

$$\begin{aligned} x_n &= \beta_n(v - p^*_{n-1}), \text{ if } n \notin \{k, 2k, \ldots, N\} \\ x_n &= \beta_n(v - p^*_{n-1}) + z_n, \text{ if } n \in \{k, 2k, \ldots, N\} \end{aligned} \tag{A1}$$

where $z_n \sim N(0, \sigma^2_{z_n})$ is normally distributed and independent of $v$ and $\{u_t\}_{1 \le t \le N}$. Intuitively, (A1) indicates that the informed trader adopts a linear strategy during the non-disclosure periods (as in Kyle (1985)) but adds a normal disturbance, $z_n$, during the disclosure periods (as in HHL). The linear coefficient $\beta_n$ measures how aggressively he trades on his private information in each period, and the noise variance $\sigma^2_{z_n}$ represents the level of dissimulation he employs to mask private information in the disclosed trade.

The market maker's optimal response to the informed trader's strategy (A1) is to set the trading price $p_n$ as a linear function of the total order flow,

$$p_n = p^*_{n-1} + \lambda_n(x_n + u_n), \tag{A2}$$

The linear coefficient $\lambda_n$ represents the impact of order flow on price, or the market depth. If the informed trader's action is disclosed at the end of the period, the market maker updates the price based on the following linear rule

$$p^*_n = p^*_{n-1} + \gamma_n x_n, \tag{A3}$$

The linear coefficient $\gamma_n$ captures how responsive the market price is to the disclosure of trade information.

Let $\pi_n$ denote the informed trader's profits on positions in period $n$, and $\tilde{\pi}_n$ denote his total profits over the periods $n, n+1, \ldots, N$. In other words,

$$\pi_n = (v - p_n)x_n, \quad \tilde{\pi}_n = \sum_{k=n}^{N} \pi_n = \sum_{k=n}^{N} (v - p_k)x_k \tag{A4}$$

In equilibrium, the informed trader chooses a trading strategy to maximize his expected profits $E[\tilde{\pi}_n \mid p_1^*, \ldots, p_{n-1}^*, v]$ at the beginning of every period *n*. The conditional variance $\Sigma_n = Var(v \mid p_1^*, \ldots, p_{n-1}^*)$ represents the extent of the remaining private information of the informed trader, after $n-1$ rounds of trades.

The following proposition characterizes the strategies and expected profits of the informed trader, and the pricing rules of the market maker. In the proof of the proposition, we also show that this is the unique equilibrium when strategies are constrained to be of linear forms as in (A2) − (A4). All proofs are in the Supplementary Appendix.

**Proposition 1:** If $k > 1$, then the equilibrium strategies can be characterized as follows.

(i) There are constants $\alpha_n$, $\delta_n$, $\lambda_n$, $\beta_n$, $\Sigma_n$, $\gamma_n$, $\sigma_{z_n}^2$, such that the strategies satisfy (A2) – (A4), and the informed trader's expected profits are given by

$$E[\tilde{\pi}_n \mid p_1^*, \ldots, p_{n-1}^*, v] = \alpha_{n-1}(v - p_{n-1}^*)^2 + \delta_{n-1}, \text{ for } 1 \le n \le N. \tag{A5}$$

We define constants $\mu_n \equiv \alpha_n \lambda_n$, for $1 \le n \le N-1$ and $\mu_N = 0$, to facilitate the presentation of results below. Given $\Sigma_0$ and $\sigma_u^2$, the constants $\alpha_n$, $\lambda_n$, $\beta_n$, $\Sigma_n$, $\gamma_n$, and $\sigma_{z_n}^2$ solve the following recursive equation system:

(a) If *n* = *N*,

$$\alpha_{N-1} = \frac{1}{4\lambda_N}, \beta_N = \frac{1}{2\lambda_N}, \lambda_N = \beta_N \frac{\Sigma_N}{\sigma_u^2}, \Sigma_N = \frac{1}{2}\Sigma_{N-1}. \tag{A6}$$

(b) If $n = N-1$, or *n* < *N* is not equal to *km* or $km-1$ for some integer *m* > 0,

$$\lambda_{n+1}=\frac{\lambda_n}{4\mu_n(1-\mu_{n+1})},\alpha_{n-1}=\frac{1}{4\lambda_n(1-\mu_n)},\beta_n=\frac{1-2\mu_n}{2\lambda_n(1-\mu_n)},$$
$$\lambda_n=\frac{\beta_n\Sigma_n}{\sigma_u^2},\Sigma_n=\frac{1}{2(1-\mu_n)}\Sigma_{n-1}. \tag{A7}$$

(c) If $n<N-1$ is equal to $km-1$ for some integer $m > 0$,

$$\lambda_{n+1}=\frac{\lambda_n}{4\mu_n},\alpha_{n-1}=\frac{1}{4\lambda_n(1-\mu_n)},\beta_n=\frac{1-2\mu_n}{2\lambda_n(1-\mu_n)}$$
$$\lambda_n=\beta_n\frac{\Sigma_n}{\sigma_u^2},\Sigma_n=\frac{1}{2(1-\mu_n)}\Sigma_{n-1}. \tag{A8}$$

(d) If $n < N$ is a multiple of $k$,

$$\lambda_{n+1}=\frac{\lambda_n}{1-\mu_{n+1}},\alpha_{n-1}=\frac{1}{4\lambda_{n+1}(1-\mu_{n+1})},\beta_n=\frac{1-2\mu_{n+1}}{4\lambda_n(1-\mu_{n+1})},$$
$$\lambda_n=\frac{\beta_n\Sigma_{n-1}}{2\sigma_u^2}=\frac{(1-\mu_{n+1})\beta_n\Sigma_n}{\sigma_u^2},\Sigma_n=\frac{1}{2(1-\mu_{n+1})}\Sigma_{n-1},\gamma_n=2\lambda_n,\sigma_{z_n}^2=\frac{1}{2(1-\mu_{n+1})}\sigma_u^2. \tag{A9}$$

(e) In the first period, the market depth parameter is given by

$$\lambda_1=\frac{\sqrt{1-2\mu_1}}{2(1-\mu_1)}\frac{\sqrt{\Sigma_0}}{\sigma_u}. \tag{A10}$$

(ii) The sequence of constants $\{\mu_n\}_{1\le n\le N}$ that appear in the recursive formulas (A6) – (A10) do not depend on $\Sigma_0$ and $\sigma_u$, and are uniquely determined by the following equations:

(a) If $n = N$, then $\mu_N=0$.

(b) If $n=N-1$, or $n < N$ is not equal to $km$ or $km-1$ for some integer $m > 0$, then $0<\mu_n<1/2$ and

$$8(\mu_n^3-\mu_n^2)-\frac{1}{1-2\mu_{n+1}}(2\mu_n-1)=0. \tag{A11}$$

(c) If $n<N-1$ is equal to $km-1$ for some $m > 0$, then $0<\mu_n<1/2$ and

$$8(\mu_n^3-\mu_n^2)-\frac{2(1-\mu_{n+2})}{1-2\mu_{n+2}}(2\mu_n-1)=0. \tag{A12}$$

(d) If $n < N$ is a multiple of $k$, then $\mu_n = 1/4$.

(iii) In the case of full disclosure in each period (or the case of $k$ = 1), the equilibrium strategies are characterized below. Denote the constants by $\hat{\alpha}_n$, $\hat{\delta}_n$, $\hat{\lambda}_n$, $\hat{\beta}_n$, $\hat{\Sigma}_n$, $\hat{\gamma}_n$, $\sigma^2_{\hat{z}_n}$.

(a) If $n = N$, then

$$\hat{\alpha}_{N-1}=\frac{1}{4\hat{\lambda}_N},\hat{\lambda}_N=\frac{1}{2\sigma_u}\sqrt{\frac{\Sigma_0}{N}},\hat{\beta}_N=\frac{1}{2\hat{\lambda}_N},\hat{\Sigma}_N=\frac{1}{2}\hat{\Sigma}_{N-1}. \tag{A13}$$

(b) If n < N, then

$$\begin{aligned}&\hat{\alpha}_{n-1}=\frac{1}{4\hat{\lambda}_n},\hat{\lambda}_n=\frac{1}{2\sigma_u}\sqrt{\frac{\Sigma_0}{N}},\hat{\beta}_n=\frac{1}{2(N-n+1)\hat{\lambda}_n},\\&\hat{\Sigma}_n=\frac{N-n}{N-n+1}\hat{\Sigma}_{n-1}=\frac{N-n}{N}\Sigma_0,\hat{\gamma}_n=2\hat{\lambda}_n,\sigma^2_{\hat{z}_n}=\frac{N-n}{N-n+1}\sigma_u^2.\end{aligned} \tag{A14}$$

Part (i) gives the recursive formulae for the strategy parameters. Part (ii) directly computes the series of key constants $\mu_n$ (used in the recursive formulae) through backward induction. Part (iii) for the case $k$ = 1 simply replicates the solution given in Proposition 4 in HHL. In the special case $k = N$, the equilibrium given in the above proposition reduces to the Kyle (1985) model.

**Proposition 2.** (i) Assume $k$ = 2, that is, the informed trader is required to disclose once every two periods. Denote the total illiquidity for the case in which the informed trader is required to disclose every two periods by $\Lambda_N=\sum_{i=1}^{N}\lambda_i$ and denote the total illiquidity for the case the

informed trader is required to disclose every period by $\hat{\Lambda}_N = \sum_{n=1}^{N} \hat{\lambda}_n$. Then

$$\hat{\Lambda}_N < \Lambda_N. \tag{A15}$$

That is, more frequent disclosure leads to lower average illiquidity or higher average liquidity. Furthermore, the difference $\Lambda_N - \hat{\Lambda}_N$ increases with the extent of asymmetric information $\sqrt{\Sigma_0}$.

(ii) Denote the expected profits of the informed trader in the case in which the informed trader is required to disclose every two periods by $\Pi_N$ and every period by $\hat{\Pi}_N$. Then

$$\Pi_N > \hat{\Pi}_N. \tag{A16}$$

In other words, the informed trader's profits are decreasing in the frequency of disclosure. The difference $\Pi_N - \hat{\Pi}_N$ increases with the extent of asymmetric information $\sqrt{\Sigma_0}$.

(iii) If $N' > N \geq 2$, then

$$\hat{\Pi}_{N'} - \Pi_{N'} < \hat{\Pi}_N - \Pi_N. \tag{A16}$$

In other words, the informed trader's profit decline from more frequent disclosure is greater when the total number of periods is larger.

This proposition shows that market liquidity increases as a result of more frequent disclosure. Furthermore, the liquidity improvement depends positively on the extent of asymmetric information about the underlying security. The informed trader, however, makes less profits due to the more frequent mandatory disclosure. His profit decline is greater when information asymmetry is higher or when trading takes longer. Note that the cases $k = 2$ and $k = 1$ in the proposition correspond closely to the regulation where the mandatory disclosure

frequency is increased from semi-annual to quarterly.

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**Table I**
**SEC Reporting Frequencies of Mutual Funds' Portfolio Holdings**

This table reports the reporting frequencies of mutual funds' portfolio holdings to the SEC from 1994 to 2011. Panel A reports the frequencies of different SEC forms used by the mutual funds to report their holdings. N-30D is the form that contains semi-annual portfolio holdings of mutual funds reported to the SEC before the May 2004 regulation. N-30B2 is the SEC form that contains voluntarily reported portfolio holdings. N-CSRS and N-CSR are the SEC forms that contain the portfolio holdings at the end of the 2nd and 4th fiscal quarters after May 2004. N-Q is the SEC form that contains portfolio holdings at the end of the 1st and 3rd fiscal quarters after May 2004. Panel B reports the number of mutual funds according to the number of filings they report to the SEC each year. A mutual fund is identified by a unique central index key (CIK) number in this table.

*Panel A. Frequencies of Mutual Fund Holdings Reports by Year*

| Year | N-30D | N-30B2 | N-CSR | N-CSRS | N-Q | Total |
|---|---|---|---|---|---|---|
| 1994 | 1,159 | 270 | 0 | 0 | 0 | 1,429 |
| 1995 | 3,565 | 549 | 0 | 0 | 0 | 4,114 |
| 1996 | 5,714 | 632 | 0 | 0 | 0 | 6,346 |
| 1997 | 6,040 | 458 | 0 | 0 | 0 | 6,498 |
| 1998 | 6,217 | 446 | 0 | 0 | 0 | 6,663 |
| 1999 | 6,282 | 405 | 0 | 0 | 0 | 6,687 |
| 2000 | 6,259 | 282 | 0 | 0 | 0 | 6,541 |
| 2001 | 6,305 | 305 | 0 | 0 | 0 | 6,610 |
| 2002 | 6,216 | 290 | 0 | 0 | 0 | 6,506 |
| 2003 | 2,850 | 240 | 2,682 | 939 | 3 | 6,714 |
| 2004 | 450 | 272 | 3,850 | 2,488 | 2,195 | 9,255 |
| 2005 | 330 | 257 | 3,434 | 2,632 | 6,042 | 12,695 |
| 2006 | 423 | 358 | 3,290 | 2,667 | 5,871 | 12,609 |
| 2007 | 455 | 431 | 3,261 | 2,746 | 5,889 | 12,782 |
| 2008 | 456 | 432 | 3,224 | 2,723 | 5,843 | 12,678 |
| 2009 | 379 | 458 | 3,082 | 2,675 | 5,613 | 12,207 |
| 2010 | 347 | 448 | 2,862 | 2,709 | 5,463 | 11,829 |
| 2011 | 349 | 418 | 2,891 | 2,657 | 5,374 | 11,689 |

*Panel B. Number of Mutual Funds (Unique CIKs) by Reporting Frequencies*

| | Number of Funds Reporting | | | |
|---|---|---|---|---|
| Year | Once | Twice | Three Times | Four or More |
| 1994 | 89 | 506 | 37 | 54 |
| 1995 | 1,174 | 1,136 | 130 | 63 |
| 1996 | 551 | 2,196 | 175 | 208 |
| 1997 | 469 | 2,356 | 162 | 194 |
| 1998 | 505 | 2,378 | 158 | 214 |
| 1999 | 487 | 2,422 | 137 | 214 |
| 2000 | 435 | 2,518 | 109 | 166 |
| 2001 | 504 | 2,450 | 124 | 183 |
| 2002 | 435 | 2,438 | 115 | 183 |
| 2003 | 571 | 2,428 | 174 | 161 |
| 2004 | 235 | 1,081 | 1,772 | 293 |
| 2005 | 167 | 352 | 188 | 2,629 |
| 2006 | 187 | 323 | 128 | 2,652 |
| 2007 | 185 | 394 | 100 | 2,627 |
| 2008 | 178 | 324 | 128 | 2,592 |
| 2009 | 121 | 354 | 146 | 2,452 |
| 2010 | 153 | 345 | 113 | 2,368 |
| 2011 | 141 | 308 | 112 | 2,330 |

**Table II**
**Impact of Mandatory Portfolio Disclosure on Stock Liquidity**

Panel A of this table reports the summary statistics of the variables we use in our analysis. Panel A reports the liquidity variables, institutional ownership, and other stock characteristics variables for the one-year period prior to the regulation (May 2003 to April 2004). Annual averages are reported for these variables. *Amihud* is the illiquidity measure of Amihud (2002) and is calculated as the square root of the absolute value of the daily return divided by daily trading volume. *Rspread* is the relative bid-ask spread measure, calculated as the difference between the closing bid and ask prices, divided by the midpoint of the bid and ask prices. We take the log of both liquidity measures. The changes in liquidity variables are defined as values in the one-year period after (including) May 2004 minus values in the one-year period before May 2004. *Mutual Fund Ownership* is the Thomson Reuters S12 stock ownership of U.S. equity funds that disclosed their holdings to the SEC not more than twice in the one-year period prior to May 2004. *Non-MF Institutional Ownership* is the total ownership of Thompson Reuters S34 institutions minus the ownership of mutual funds and asset management companies. *Momentum* is the momentum factor of Jegadeesh and Titman (1993). *Book-to-Market* is the ratio of book assets to book assets minus book equity plus market equity. *Size* is the natural logarithm of market equity. All variables are winsorized at the 1% and 99% levels. Panel B reports the regression results of the changes in stock liquidity variables around May 2004 on the mutual fund ownership and other control variables. The independent variables are the lagged variables prior to May 2004. Standard errors are adjusted for heteroskedasticity and clustered at the stock level and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

*Panel A. Summary Statistics*

| Variable | Mean | Median | Std. Dev | Min | Max | N |
|---|---|---|---|---|---|---|
| *Liquidity Variables* | | | | | | |
| Amihud | –8.959 | –8.979 | 1.479 | –12.013 | –5.814 | 4,635 |
| Rspread | –5.495 | –5.544 | 1.280 | –7.804 | –2.858 | 4,635 |
| ΔAmihud | –0.130 | –0.108 | 0.397 | –1.385 | 0.847 | 4,635 |
| ΔRspread | –0.227 | –0.224 | 0.379 | –1.331 | 0.755 | 4,635 |
| *Institutional Ownership and Stock Characteristics* | | | | | | |
| Mutual Fund Ownership | 13.88% | 11.73% | 11.48% | 0.00% | 43.79% | 4,635 |
| Non-MF Institutional Ownership | 22.34% | 21.13% | 16.60% | 0.02% | 61.63% | 4,635 |
| Hedge Fund Ownership | 7.90% | 5.90% | 7.78% | 0.00% | 35.66% | 4,635 |
| Momentum | 0.617 | 0.358 | 0.828 | –0.374 | 4.652 | 4,635 |
| Book-to-Market | 0.645 | 0.556 | 0.523 | –0.709 | 2.921 | 4,635 |
| Size | 5.634 | 5.548 | 1.937 | 1.918 | 10.842 | 4,635 |

*Panel B. Impact of the Regulation Change in Portfolio Disclosure on Stock Liquidity*

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent Variable | ΔAmihud | ΔAmihud | ΔRspread | ΔRspread |
| Mutual Fund Ownership | –0.444*** | -0.6917*** | –0.193*** | -0.2667*** |
| | –6.78 | -10.184 | –3.02 | -4.092 |
| Amihud | –0.039*** | -0.2425*** | | |
| | –7.64 | -14.255 | | |
| Spread | | | –0.026*** | -0.1248*** |
| | | | –4.45 | -9.397 |
| Momentum | | -0.0885*** | | -0.0829*** |
| | | -8.877 | | -9.224 |
| Book-to-Market | | -0.1217*** | | -0.1117*** |
| | | -8.400 | | -8.168 |
| Size | | -0.1624*** | | -0.0777*** |
| | | -14.333 | | -10.481 |
| Constant | –0.423*** | -1.1717*** | –0.344*** | -0.3199*** |
| | –9.85 | -13.081 | –11.63 | -8.003 |
| Observations | 4,635 | 4,635 | 4,635 | 4,635 |
| Adj. R-squared | 0.011 | 0.091 | 0.003 | 0.060 |

**Table III**
**Impact of Mandatory Portfolio Disclosure on Stock Liquidity:**
**Cross-sectional and Time-Series Placebo Tests**

Panel A of this table reports the regression results of the changes in stock liquidity variables over May 2004 on the mutual fund ownership and non-mutual fund institutional ownership (or Hedge Fund Ownership). The dependent variables are the changes in the liquidity variables over May 2004. The independent variables are the lagged variables prior to May 2004 as defined in Table II. The last two rows report the differences between the coefficients of Mutual Fund Ownership and Non-MF Institutional Ownership (or Hedge Fund Ownership) and the F-test *p*-values of the differences. Panel B of this table compares the regression results of the changes in stock liquidity variables over the SEC disclosure regulation in 2004 with the same regressions conducted for a placebo sample formed in 2006. In the placebo regressions we use the changes in the liquidity variables from one year prior to November 2006 to one year afterward as the dependent variable. The independent variables in the placebo tests are the lagged variables prior to November 2006. Standard errors are adjusted for heteroskedasticity and clustered at the stock level and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

*Panel A. Cross-sectional Placebo Tests*

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent Variable | ΔAmihud | ΔRspread | ΔAmihud | ΔRspread |
| Mutual Fund Ownership | –0.5959*** | –0.2577*** | –0.6340*** | –0.250*** |
| | –7.845 | –3.47 | –8.97 | –3.74 |
| Non-MF Institutional Ownership | –0.1465** | –0.015 | | |
| | –2.439 | –0.265 | | |
| Hedge Fund Ownership | | | –0.242*** | –0.071 |
| | | | –2.81 | –0.837 |
| Amihud | –0.2497*** | | –0.2423*** | |
| | –14.018 | | –14.41 | |
| Spread | | –0.1259*** | | –0.127*** |
| | | –9.14 | | –6.35 |
| Constant | –1.214*** | –0.324*** | –1.208*** | –0.322*** |
| | –12.79 | –7.68 | –13.26 | –8.033 |
| Controls for Stock Characteristics | Yes | Yes | Yes | Yes |
| Observations | 4,619 | 4,619 | 4,619 | 4,619 |
| Adj. R-squared | 0.092 | 0.060 | .092 | .060 |
| Diff. of Coeffs. (MF – Non-MF) | –0.445*** | –0.242** | –0.392*** | –0.179 |
| Test of Difference (*p*-value) | 0.0001 | 0.0333 | 0.0019 | 0.1550 |

*Panel B. Time-series Placebo Tests*

| Dependent Variable | (1) ΔAmihud | (2) ΔAmihud | (3) ΔRspread | (4) ΔRspread |
|---|---|---|---|---|
| *Regression in 2004* | | | | |
| Mutual Fund Ownership | –0.444*** | –0.692*** | –0.193*** | –0.2667*** |
| | –6.78 | –10.18 | –3.016 | –4.091 |
| Control for Lagged Liquidity | Yes | Yes | Yes | Yes |
| Controls for Stock Characteristics | No | Yes | No | Yes |
| *Placebo Test in 2006* | | | | |
| Mutual Fund Ownership | –0.181*** | –0.394*** | –0.042 | –0.1034* |
| | –3.113 | –5.85 | –0.789 | –1.818 |
| Control for Lagged Liquidity | Yes | Yes | Yes | Yes |
| Controls for Stock Characteristics | No | Yes | No | Yes |
| Difference (2006–2004) | –0.263*** | –0.297*** | –0.151* | –0.164* |
| *p*-value | 0.0025 | 0.0002 | 0.0724 | 0.0589 |

**Table IV**

**Impact of Mandatory Portfolio Disclosure on Stock Liquidity: Subsamples of Mutual Funds**

This table reports the regression results of the changes in stock liquidity variables over May 2004 on mutual funds divided based on various characteristics. The dependent variables are the changes in the liquidity variables over May 2004. The independent variables are the lagged variables prior to May 2004. All variables are annual averages. Most variables are defined in Table II. The last two rows report the differences between the coefficients of the above and below median ownership and the F-test p-values of the differences. Panel A reports the results when funds are separated based on whether or not they are in the top quartile of abnormal performance (*4-factor Alpha)* for the prior year. *4-factor Alpha* is computed as the out-of-sample monthly alpha using the fund returns in each month minus the sum product of the Carhart (1997) 4-factor returns in that month and the betas estimated from the 24-month window ending in the prior month. The annual *4-factor Alpha* measure is then the sum of the 12 monthly alphas prior to May 2004. Panel B reports the results when funds are separated based on whether or not they are in the top quartile of *DGTW Adj.-Return*, computed as the cumulative benchmark-adjusted returns between two successive report dates in the Thomson S12 database and then divided by the number of months in the period to obtain a monthly measure. We then sum the monthly DGTW measure to obtain the annualized figure. Standard errors are adjusted for heteroskedasticity and clustered at the stock level, and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

| *Panel A: Four-factor Alpha* | | |
|---|---|---|
| | (1) | (2) |
| | ΔAmihud | ΔRspread |
| *Top Quartile 4-factor Alpha Ownership* | –1.209*** | –1.086*** |
| | –6.50 | –5.83 |
| *Non-Top Quartile 4-factor Alpha Ownership* | –0.558*** | –0.043 |
| | –6.91 | –0.55 |
| Diff. of Coeffs. (Top – Non-Top) | –0.651*** | –1.043*** |
| Test of Differences (*p*-values) | <0.0001 | <.0001 |

| *Panel B: DGTW Adj.-Return* | | |
|---|---|---|
| | (1) | (2) |
| | ΔAmihud | ΔRspread |
| *Top Quartile DGTW Adj.-Return Ownership* | –1.414*** | –1.096*** |
| | –10.19 | –8.19 |
| *Non-Top Quartile DGTW Adj.-Return Ownership* | –0.179* | 0.303 |
| | –1.78 | 3.24 |
| Diff. of Coeffs. (Top – Non-Top) | –1.235*** | –1.399*** |
| Test of Differences (*p*-values) | <.0001 | <.0001 |

**Table V**

**Impact of Mandatory Portfolio Disclosure on Stock Liquidity: Subsamples of Stocks**

This table compares the regression results of the changes in stock liquidity variables in 2004 for subsamples of stocks grouped by their past liquidity, analyst coverage, and size. The stocks are placed into two subsamples based on whether or not they fall into the top quartile of the given variable. Most variables are defined in Table II. *Analyst Coverage* is the number of analysts covering the stock, as provided by IBES. Panel A divides the stocks based on *Amihud*. Panel B divides the stocks based on *Rspread.* Panel C divides the stocks based on *Size.* Panel D divides the stocks based on *Analyst Coverage.* All regressions contain controls for prior liquidity and stock characteristics. Standard errors are adjusted for heteroskedasticity and clustered at the stock level, and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

| *Panel A: Amihud* | | |
|---|---|---|
| | (1) ΔAmihud | (2) ΔRspread |
| *Top Quartile Liquidity Stocks* | | |
| Mutual Fund Ownership | –0.189*** | –0.0313 |
| | –2.08 | –0.36 |
| *Non-Top Quartile Liquidity Stocks* | | |
| Mutual Fund Ownership | –0.948*** | –0.572*** |
| | –9.49 | –5.98 |
| Diff. of Coeffs. (Top – Non-Top) | 0.758*** | 0.541*** |
| Test of Differences (*p*-values) | <0.0001 | <0.0001 |

| *Panel B: Rspread* | | |
|---|---|---|
| | (1) ΔAmihud | (2) ΔRspread |
| *Top Quartile Liquidity Stocks* | | |
| Mutual Fund Ownership | –0.161* | –0.075 |
| | –1.85 | –1.04 |
| *Non-Top Quartile Liquidity Stocks* | | |
| Mutual Fund Ownership | –0.873*** | –0.473*** |
| | –8.73 | –4.70 |
| Diff. of Coeffs. (Top – Non-Top ) | 0. 712*** | 0.398*** |
| Test of Differences (*p*-values) | <0.0001 | 0.0013 |

| *Panel C: Market Capitalization* | | |
|---|---|---|
| | (1) ΔAmihud | (2) ΔSpread |
| *Top Quartile Size Stocks* | | |
| Mutual Fund Ownership | –0.304*** | –0.073 |
| | –3.60 | –0.87 |
| *Non-Top Quartile Size Stocks* | | |
| Mutual Fund Ownership | –0.762*** | –0.383*** |
| | –7.76 | -4.10 |
| Diff. of Coeffs. (Top – Non-Top) | 0.458*** | 0.310** |
| Test of Differences (*p*-values) | 0.0004 | 0.0141 |

| *Panel D: Analyst Coverage* | | |
|---|---|---|
| | (1) ΔAmihud | (2) ΔSpread |
| *Top Quartile Coverage Stocks* | | |
| Mutual Fund Ownership | –0.267*** | –0.019 |
| | –2.69 | –0.204 |
| *Non-Top Quartile Coverage Stocks* | | |
| Mutual Fund Ownership | –0.952*** | –0.639*** |
| | –9.99 | –6.98 |
| Diff. of Coeffs. (Top – Non-Top) | 0.685*** | 0.620*** |
| Test of Differences (*p*-values) | <0.0001 | <0.0001 |

**Table VI**
**Impact of Mandatory Portfolio Disclosure on Mutual Fund Performance**

Panel A reports the summary statistics of fund performance and characteristics prior to the 2004 disclosure regulation (values in the one-year period before May 2004) and the changes in fund performance after the regulation (values in the one-year period after (including) May 2004 minus values in the one-year period before May 2004). Carhart 4-factor alphas and DGTW-adjusted returns are annualized. *TNA* is the total net assets under management in millions of dollars. *Turnover* is the average annual turnover from holdings data. *Flow* is changes of TNA from last period scaled by lagged TNA. *Expense Ratio* is the total operating expenses scaled by TNA. *Load* is a dummy variable that equals one if the mutual fund has a share class with load. Panel B reports multivariate regressions of changes in fund performance around 2004 on lagged fund performance and characteristics. *Top 4-factor Alpha* is a dummy that equals one if the fund's four-factor alpha is in the top quartile in the one year before May 2004. *Top DGTW-adj. return* is a dummy that equals one if the fund's DGTW-adjusted return is in the top quartile in the one year before May 2004. All regressions contain controls for prior liquidity and stock characteristics. Standard errors are adjusted for heteroskedasticity and clustered at the fund level, and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

*Panel A. Summary Statistics*

| Variable | Mean | Median | Std. Dev | Min | Max | N |
|---|---|---|---|---|---|---|
| *Abnormal Fund Returns* | | | | | | |
| 4-factor alpha | –0.024 | –0.026 | 0.082 | –0.743 | 0.690 | 2,096 |
| Δ 4-factor alpha | 0.017 | 0.016 | 0.091 | –0.658 | 0.810 | 2,096 |
| DGTW-adjusted return | 0.018 | 0.009 | 0.094 | –0.408 | 0.592 | 2,297 |
| ΔDGTW-adjusted return | –0.007 | –0.002 | 0.113 | –0.676 | 0.566 | 2,240 |
| *Other Fund Characteristics* | | | | | | |
| TNA (million $) | 833 | 145 | 2,308 | 2 | 18,309 | 2,393 |
| Turnover | 0.50 | 0.43 | 0.35 | 0.00 | 1.65 | 1,837 |
| Flow | 0.018 | 0.005 | 0.059 | –0.195 | 0.368 | 2,389 |
| Expense Ratio | 0.014 | 0.014 | 0.005 | 0.001 | 0.03 | 2,372 |
| Load | 0.703 | 1 | 0.451 | 0 | 1 | 2,394 |

*Panel B. Impact of Mandatory Portfolio Disclosure on Fund Performance*

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent Variable | ΔAlpha | ΔDGTW-adj. Ret | ΔAlpha | ΔDGTW-adj. Ret |
| Top 4-factor Alpha | –0.092*** | –0.038*** | | |
| | –23.40 | –6.42 | | |
| Top DGTW-adj. Return | | | –0.034*** | –0.119*** |
| | | | –7.97 | –24.84 |
| Log(TNA) | –0.001 | –0.001 | 0.000 | –0.001 |
| | –0.72 | –0.96 | 0.33 | –0.47 |
| Turnover | 0.045** | –0.036 | 0.062*** | –0.015 |
| | 2.35 | –1.25 | 2.83 | –0.60 |
| Flow | –0.029 | –0.122* | –0.148*** | 0.008 |
| | –0.70 | –1.93 | –3.10 | 0.16 |
| Expense Ratio | –0.614 | –1.539*** | –0.653 | –0.661 |
| | –1.59 | –2.65 | –1.48 | –1.40 |
| Load | 0.003 | 0.005 | 0.007 | 0.012** |
| | 0.82 | 0.81 | 1.57 | 2.43 |
| Constant | 0.039*** | 0.032** | 0.019* | 0.027*** |
| | 4.58 | 2.47 | 1.93 | 2.60 |
| Observations | 1,667 | 1,615 | 1,648 | 1,732 |
| Adjusted R-squared | 0.258 | 0.034 | 0.049 | 0.268 |

**Table VII: Impact of Portfolio Disclosure on Mutual Fund Performance: Placebo Tests**

This table compares the regression results of the changes in fund performance over the SEC disclosure regulation in 2004 with the same regressions conducted for a placebo sample formed in 2006. In the placebo regressions we use the changes in the performance variables from one year prior to November 2006 to one year afterward as the dependent variable. The independent variables in the placebo tests are the lagged variables prior to November 2006. All performance variables are annualized. In all regressions, we control for *Log(TNA)*, *Turnover*, *Flow*, *Expense Ratio*, and *Load*. Standard errors are adjusted for heteroskedasticity and clustered at the fund level, and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level.

*Panel A. Fund with Top Four-factor Alpha*

| | (1) | (2) |
|---|---|---|
| Dependent Variable | ΔAlpha | ΔDGTW-adj. Ret |
| *Regression in 2004* | | |
| Fund with Top 4-factor Alpha | –0.092*** | –0.038*** |
| | –23.40 | –6.42 |
| Controls for Fund Characteristics | Yes | Yes |
| *Placebo Regression in 2006* | | |
| Fund with Top 4-factor Alpha | –0.047*** | –0.013*** |
| | –11.95 | –2.52 |
| Controls for Fund Characteristics | Yes | Yes |
| Difference (2004–2006) | –0.045*** | –0.025*** |
| *F*-test | –8.22 | –3.23 |

*Panel B. Fund with Top DGTW-adj. Return*

| | (1) | (2) |
|---|---|---|
| Dependent Variable | ΔAlpha | ΔDGTW-adj. Ret |
| *Regression in 2004* | | |
| Fund with Top DGTW-adj. Return | –0.034*** | –0.119*** |
| | –7.97 | –24.84 |
| Controls for Fund Characteristics | Yes | Yes |
| *Placebo Regression in 2006* | | |
| Fund with Top DGTW-adj. Return | –0.015*** | –0.075*** |
| | –3.84 | –16.80 |
| Controls for Fund Characteristics | Yes | Yes |
| Difference (2004–2006) | –0.019*** | –0.040*** |
| *F*-test | –3.28 | –6.70 |

**Table VIII: Impact of Portfolio Disclosure on Mutual Fund Performance: Liquidity Effects**

This table compares the regression results of the changes in fund performance for five-factor alphas (Carhart four factors + Pástor-Stambaugh liquidity factor) over the SEC regulation in 2004 and the placebo period in 2006. In the placebo regressions, we use the changes in the performance variables from one year prior to November 2006 to one year afterward as the dependent variable. The independent variables in the placebo tests are the lagged variables prior to November 2006. All performance variables are annualized. Standard errors are adjusted for heteroskedasticity and clustered at the fund level, and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

*Panel A. Fund with Top Four-factor Alpha*

| | (1) ΔCarhart 4-factor Alpha | (2) ΔCarhart + PS 5-factor Alpha | Difference |
|---|---|---|---|
| *Regression in 2004* | | | |
| Fund with Top 4-factor Alpha | –0.092*** | –0.077*** | 0.015*** |
| | –23.40 | –17.70 | 2.62 |
| Controls for Fund Characteristics | Yes | Yes | |
| *Placebo Regression in 2006* | | | |
| Fund with Top 4-factor Alpha | –0.047*** | –0.044*** | 0.002 |
| | –11.95 | –11.96 | 0.44 |
| Controls for Fund Characteristics | Yes | Yes | |
| Difference (2004–2006) | –0.045*** | –0.033*** | 0.013 |
| *F*-test | –8.22 | –5.70 | 1.63 |

*Panel B. Fund with Top DGTW-adj. Return*

| | (1) ΔCarhart 4-factor Alpha | (2) ΔCarhart + PS 5-factor Alpha | Difference |
|---|---|---|---|
| *Regression in 2004* | | | |
| Fund with Top DGTW-adj. Return | –0.034*** | –0.032*** | 0.002 |
| | –7.97 | –7.12 | 0.37 |
| Controls for Fund Characteristics | Yes | Yes | |
| *Placebo Regression in 2006* | | | |
| Fund with Top DGTW-adj. Return | –0.015*** | –0.016*** | –0.001 |
| | –3.84 | –4.22 | –0.11 |
| Controls for Fund Characteristics | Yes | Yes | |
| Difference (2004–2006) | –0.019*** | –0.016*** | 0.003 |
| *F*-test | –3.28 | –2.78 | 0.35 |

**Table IX**

**Impact of Mandatory Portfolio Disclosure on Mutual Fund Performance: Interaction Effects**

This table reports multivariate regressions of changes in fund performance around 2004 on lagged fund performance, holdings characteristics, and the interaction of the two. For any fund-level variable *Y*, *Top Y* is the dummy variable that equals one if *Y* is in the top quartile in the one year before May 2004. *Alpha* is the Carhart four-factor alpha. *DGTW-adj. Ret.* is the DGTW-adjusted return. *X* in the table refers to one of the following variables that proxy for information asymmetry: *Size* is the value-weighted average market capitalization of the stocks held by a given fund; *Analyst Coverage* is the value-weighted average analyst coverage of the stocks held by a given fund; *Amihud* is the value-weighted average Amihud illiquidity measure of the stocks held by a given fund; *Rspread* is the value-weighted average relative spread of the stocks held by a given fund. *Trade Length* is the average number of consecutive quarters a fund either builds or unwinds trading positions. Panel A contains the results when the top performance quartile is determined by the Carhart (1997) 4-factor alpha. Panel B contains the results when the top performance quartile is determined by the DGTW-adjusted return measure. Panel C contains the results for the tests based on *Trade* Length. All regressions include controls for fund characteristics as in Table VI. Standard errors are adjusted for heteroskedasticity and clustered at the fund level, and *t*-statistics are reported below the coefficients. Coefficients marked with ***, **, and * are significant at the 1%, 5%, and 10% level respectively.

*Panel A. Funds with Top Four-factor Alpha*

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | ΔAlpha | | | | ΔDGTW-adj. Ret. | | | |
| VARIABLES | X=Size | X= Anal. Cov. | X=Amihud | X=Rspread | X=Size | X= Anal. Cov. | X=Amihud | X=Rspread |
| Top Alpha × Top X | –0.016* | –0.021** | –0.007 | –0.013 | –0.030** | –0.033** | –0.019 | –0.026* |
| | –1.82 | –2.40 | –0.83 | –1.52 | –2.19 | –2.41 | –1.41 | –1.90 |
| Top Alpha | –0.086*** | –0.084*** | –0.088*** | –0.085*** | –0.031*** | –0.030*** | –0.033*** | –0.031*** |
| | –18.89 | –18.44 | –18.70 | –18.30 | –4.50 | –4.35 | –4.71 | –4.39 |
| Top X | 0.002 | 0.002 | 0.001 | –0.000 | 0.001 | 0.007 | 0.005 | 0.003 |
| | 0.48 | 0.37 | 0.22 | –0.08 | 0.08 | 1.11 | 0.75 | 0.38 |
| Control variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,606 | 1,607 | 1,606 | 1,606 | 1,560 | 1,560 | 1,560 | 1,560 |
| Adjusted R-squared | 0.252 | 0.253 | 0.251 | 0.252 | 0.035 | 0.037 | 0.034 | 0.033 |

*Panel B. Funds with Top DGTW-adj. Returns*

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | ΔAlpha | | | | ΔDGTW-adj. Ret. | | | |
| VARIABLES | X=Size | X=Anal. Cov. | X=Amihud | X=Rspread | X=Size | X=Anal. Cov | X=Amihud | X=Rspread |
| Top DGTW-adj. Ret. × Top X | –0.052*** | –0.030*** | –0.034*** | –0.031*** | –0.065*** | –0.038*** | –0.069*** | –0.070*** |
| | –5.44 | –3.18 | –3.55 | –3.17 | –5.91 | –3.57 | –6.34 | –6.42 |
| Top DGTW-adj. Ret. | –0.021*** | –0.027*** | –0.026*** | –0.027*** | –0.103*** | –0.109*** | –0.102*** | –0.102*** |
| | –4.35 | –5.22 | –5.23 | –5.39 | –18.09 | –18.62 | –17.94 | –17.94 |
| Top X | 0.014** | 0.007 | 0.002 | –0.003 | 0.021*** | 0.021*** | 0.029*** | 0.026*** |
| | 2.52 | 1.44 | 0.39 | –0.49 | 3.39 | 3.57 | 4.71 | 4.17 |
| Control variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,591 | 1,591 | 1,591 | 1,591 | 1,668 | 1,668 | 1,668 | 1,668 |
| Adjusted R-squared | 0.068 | 0.056 | 0.060 | 0.060 | 0.283 | 0.275 | 0.286 | 0.286 |

*Panel C. Fund Performance and Trade Length*

| Variables | (1) ΔAlpha | (2) ΔDGTW | Variables | (3) ΔAlpha | (4) ΔDGTW |
|---|---|---|---|---|---|
| Top Alpha × Top Trade Length | 0.01 | –0.036*** | Top DGTW × Top Trade Length | 0.011 | –0.042*** |
| | 1.11 | –2.77 | | 1.16 | –4.02 |
| Top Alpha | –0.092*** | –0.028*** | Top DGTW | –0.039*** | –0.107*** |
| | –19.59 | –3.93 | | –7.47 | –17.98 |
| Top Trade Length | –0.001 | 0.002 | Top Trade Length | 0.000 | 0.020*** |
| | –0.31 | 0.29 | | 0.06 | 3.48 |
| Control variables | Yes | Yes | Control variables | Yes | Yes |
| Observations | 1,601 | 1,559 | Observations | 1,590 | 1,667 |
| Adjusted R-squared | 0.248 | 0.039 | Adjusted R-squared | 0.051 | 0.276 |