Rumors and Runs in Opaque Markets: Evidence from the Panic of 1907

Caroline Fohlin
Thomas Gehrig
Marlene Haas *

December 19, 2015

Abstract

Using a new daily dataset for all stocks traded on the New York Stock Exchange, we study the impact of information asymmetry during the liquidity freeze and market run of October 1907 - one of the most severe financial crises of the 20th century. We estimate that the run on the market increased spreads from 0.5% to 3% during the peak of the crisis and, using a spread decomposition, we also demonstrate that fears of informed trading account for most of that deterioration of liquidity. Information costs rose most in the mining sector - the origin of the panic rumors - and in other sectors with poor track records of corporate reporting. In addition to wider spreads and tight money markets, we find other hallmarks of information-based illiquidity: trading volume dropped and price impact rose. Importantly, despite short-term cash infusions into the market, we find that the market remained relatively illiquid for several months following the panic. We go on to show that rising illiquidity enters positively in the cross section of stock returns. Moreover, we identify information risk as the main driver of illiquidity. Thus, our findings demonstrate how opaque markets can easily transmit an idiosyncratic rumor into a long-lasting, market-wide crisis. Our results also demonstrate the usefulness of illiquidity measures to alert market participants to impending market runs.

JEL classification: G00, G14, N00, N2

*Fohlin (fohlin@jhu.edu) is at Emory University. Gehrig (thomas.gehrig@univie.ac.at) and Haas (marlene.haas@vgsf.ac.at) are at the University of Vienna and at the Vienna Graduate School of Finance. This material is based upon work supported by the U.S. National Science Foundation under Grant No. 0850576 to Fohlin and upon a TransCoop Grant by the Alexander-von-Humboldt Association to Gehrig. We are grateful to Floris Daverveldt for extensive research assistance. The paper greatly benefited from discussions with and comments from Tarun Chordia, Hans Degryse, Nikolaus Hautsch, Nobuhiro Kiyotaki, Albert S. Kyle, Roland Mestel, Carol Osler, Klaus Ritzberger, Mary Rodgers, Ellis Tallmann, and Joseph Zechner. We are grateful to the participants of the University of Vienna Brown Bag Seminar, the 2014 Conference of the Vienna Graduate School of Finance, the 2015 Infiniti Conference, the 2015 CFA Institute Workshop on Financial History (Judge School of Management, Cambridge University), the 32nd Conference of the European Association of Law and Economics in Vienna, as well as the 11th Annual Central Bank Conference on the Microstructure of Financial Markets in Dublin for comments and suggestions. Gehrig thanks the Collegio Carlo Alberto for its hospitality. All errors are our own.

1 Introduction

The Panic of 1907 marked the beginning of the end of unregulated capital markets and weak central monetary authority in the United States. Much like the global financial crisis of 2008, the episode set off an immediate outcry from the public and reactions from federal and state governments. While private initiatives - notably, the concerted effort organized by John Pierpont Morgan - contributed to resolving the crisis, the depth and duration of the crisis, and its after effects, provided central banking advocates the ammunition they needed to push through the Federal Reserve Act, and in the meantime the provision of emergency currency via the Aldrich-Vreeland Act[1] The crisis prompted the famous Money Trust hearings in Congress that led to the Clayton Antitrust Act, as well as a state level investigation in New York that ultimately led to tighter control over access to trading at the NYSE. These regulatory steps laid the foundation for the more far-reaching interventions such as the U.S. Securities and Exchange Commission (SEC) that emerged much later.[2]

Because it took place in an era of weak corporate governance law, highly variable accounting practices, and essentially no regulation of stock markets - all compounded by rudimentary information technology - traders faced a continual threat of informational contagion (e.g., Bernstein et al. (2014)) and difficulties in assessing counterparty risk (see Frydman et al. (2012)[3]). In the environment of October 1907, market participants saw a general decline in market prices combined with the failure of a major brokerage house and plummeting United Copper stock prices, followed by runs on several associated banks and trust companies and spikes in short term borrowing (call money) rates. This series of events stirred panic across the board, because markets were opaque and information was difficult to verify.

The Panic of 1907 provides an opportunity to understand better how information problems impact the financial system, in particular via liquidity in both banks and markets. Yet, most of previous studies examine the panic at the aggregate level and at lower frequency and cannot therefore analyze microstructure effects-where the problem (and presumably, the solution) really lies. In contrast, we offer a much more nuanced view of the unfolding crisis by exploiting a new database of daily transaction, quotation, and volume data for all stocks traded on the NYSE from 1905 to 1910.[4] We start, in the next section, by

[1] Which would come into play in the summer of 1914 (Fohlin and Mozenter, 2015).
[2] This paper builds on an earlier study by Fohlin et al. (2008).
[3] See also Gorton (1988), Calomiris and Gorton (1991), and Moen and Tallman (1992) for earlier work.
[4] See Fohlin (2015) for more detail on the larger data collection project.

describing our novel data set, on which most of our analysis depends.

We uncover a range of new results. First, in section 3, we provide details of the crisis and the economic and institutional context in which it unfolded. Here, we demonstrate that the stock market (the NYSE) showed signs of deteriorating liquidity - rising bid-ask spreads and price impact measures and declining volume - starting in September of 1907, in advance of the most acute period of crisis. The heightened illiquidity lasted until March 1908, several months after the run ended. Next, we explore, in Section 4, the role of funding illiquidity in causing stock market illiquidity (spreads) and demonstrate that funding illiquidity drives stock market illiquidity, but only during illiquidity spikes. We then move on (section 5) to test whether market illiquidity enters into asset pricing and confirm our expectation that bid-ask spread enters as a significant factor.

After establishing the general impact of the two forms of illiquidity, we dig a bit deeper, in sections 6 through 8, and test our hypothesis that opaqueness (information asymmetry) lay at the core of the problem. We undertake a decomposition of spreads (Section 6) and show that the adverse selection component accounts for the largest part of the spread and of the increase in spreads during the peak crisis months; then show that funding illiquidity also drives the three components. We then analyze (Section 7) the cross sectional variation in illiquidity to find that stocks with the worst information opaqueness - mining stocks, unlisted stocks, and stocks with the highest spreads pre-Panic have the greatest illiquidity and adverse selection component during the panic. Finally, in section 8, we refine the initial asset pricing analysis to show that all three spread components are priced into returns. Section 9 concludes.

2 Data Collection

Understanding the 1907 financial crisis at a granular level, and connecting market illiquidity with funding illiquidity, requires high frequency data that has been, until now, unavailable to researchers. In order to provide this microstructure perspective, we use newly-gathered data on transaction prices (first, last, high and low), bid and ask quotations, and volumes (i.e., number of shares traded) for all stocks trading on the NYSE on every trading day from 1905 through 1910.[5] The database covers all stocks, common as

[5]The data constitute a portion of the new NYSE database for 1900-1925 created by and discussed in greater detail in Fohlin (2014), funded by grants from the U.S. National Science Foundation. The raw data come from the NYSE listings printed each day in the New York Times, via the Proquest digital archive. The images are not machine readable, and Optical Character Recognition (OCR) methods proved infeasible, so the data were all entered by hand.

well as preferred stock, as well as rights, warrants and other related equity securities. We concentrate our analyses on common stock. The data itself was reported in the New York Times for every trading day (Monday through Saturday).

We gathered data on book value of common equity and par values of total capital on a semi-annual basis (with observations in January and July of each year) in order to reweight portfolios. This data comes from the New York Times weekly financial supplement. We excluded preferred stock data (following Fama and French (1993)).

In order to be able to control for funding liquidity and riskless rates, we gathered both monthly U.S. call money rates and gold stock reserves (in billions of dollars) from the National Bureau of Economic Research Macro-history Database. Call money is short-term inter-bank lending, typically secured by gold or stocks. In the period we analyze, the call money rate represents the marginal cost of financing for stock purchases. A long-term interest rate comes from Shiller (2000). Ellis Tallman was so kind to also provide us with daily call money rates for the month of October 1907 to February 1908.

Table 1 provides descriptive statistics of relative bid-ask spreads, number of shares traded, capital stock data, call money rates, gold stock, and Shiller's long-term interest rate. Relative bid-ask spreads were on average two percent. About 6,000 shares traded per company on an average trading day. Capital stock data was on average $55 million per company, with a median value of $30 million. Call money rates could range widely but averaged about 3.7 percent, as did the Shiller long-term interest rate. US gold stock averaged $1.5 billion per month.

3 The Panic in Context

The basic facts of the Panic of 1907 are fairly clear. Stocks had been on a bull run for nearly two years, starting in late 1903, but weakness began to emerge in 1906. After considerable declines in the market in March and August 1907 (see Figure 1 (Source: The Center for Research in Security Prices)) the poor sentiment turned to panic in October of 1907. The bear market targeted mining stocks, dominated by copper, most heavily. Those had run up in excess of the broader bull market in 1905 and early 1906 and then dropped more dramatically during the crisis and recovered the least after the crisis ended in 1908 (see Figure 2).[6] Stock market liquidity measures, such as relative spreads and trading volume, highlight the progression of the crisis, transition to outright panic, and

[6]The contemporary/historical usage of "panic" is nowadays referred to as financial crisis.

duration of the recovery in the market: relative spreads started rising around March 1907, while trading volume dropped significantly (Figure 3). These trends accelerated in October 1907. While prices rebounded before the end of the year, spreads remained elevated and trading volume remained depressed and more variable until the following spring.

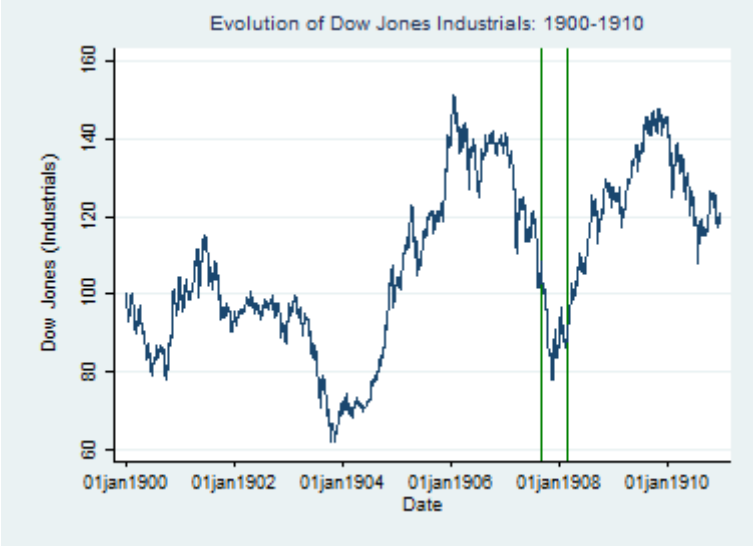

Figure 1: Evolution of Dow Jones Index: 1900-1910

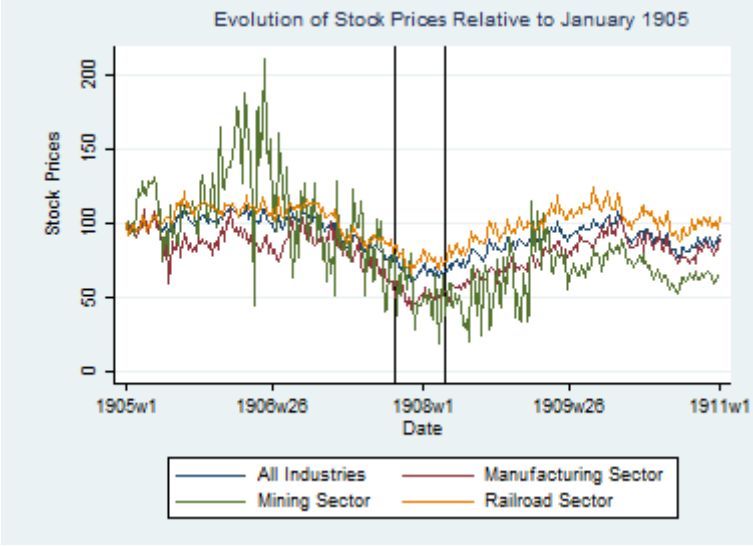

Figure 2: Stock Prices Relative to January 1905

These patterns of market indicators over the 1907 crisis and recovery look a lot like a modern-day market boom-bust cycle. U.S. financial markets had achieved a significant

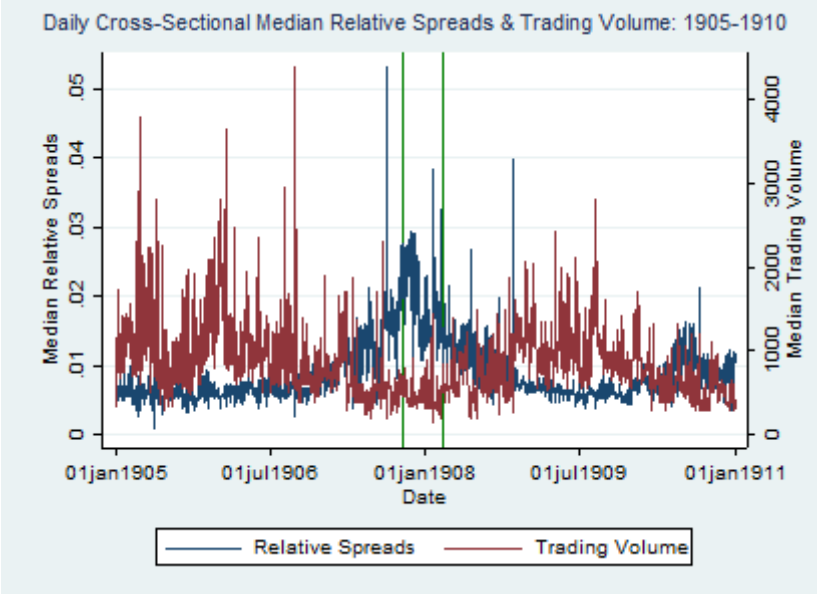

Figure 3: Median of Relative Spreads & Trading Volume: 1905-1910

level of development and integration, both national and international. Stock exchanges and banks operated in all corners of the country (and the world), the New York Stock Exchange had risen to dominance among the U.S. exchanges, and excess funds flowed into New York, by then the clear financial center of the United States, from all over the country and from England, France, Germany, and elsewhere around the world.

The NYSE operated in 1907 much as it does today: a continuous auction mechanism, in which transactions occur throughout the trading day, with no guarantee of a single price. Brokers traded on behalf of their customers and received set commissions as their payment, while specialists, bought and sold shares in order to make markets in securities, and they received the bid-ask spread as their compensation. Specialists managed their trades at circular trading posts, equipped with telephones. Today's floor looks much the same, albeit with obvious modernization and technology.[7]

From its inception, and for most of its history, the NYSE was owned by its members and largely self-regulated. Among the key internal rules were those that dealt with membership. Joining the exchange was a costly venture: a new member had to pay a membership fee and then buy the seat of an existing member. The exchange had fixed the number of seats at 1,100 in 1879, so that the prices of seats varied with the market. Seat prices therefore varied considerably but grew fairly steadily and reached a local peak of $95,000

[7]See "Historical trading floor" or Figure 4

Figure 4: Historical Trading Floor

in the year before the crisis.[8] Notably, seats sold for as little as $51,000 in the panic year and the year following.[9] The Governing Committee of the exchange held ultimate responsibility for exchange operations and had the power to fine or even to expel members for infractions against exchange rules. The value of a member's seat worked as collateral in these cases or in the event of bankruptcy (Mulherin et al. (1991)). The courts upheld these powers as well as the exchanges' right to restrict trading solely to its members and to set other rules (Mulherin et al. (1991)).

The NYSE implemented relatively stringent listing standards and requirements, including registration of all shares (to prevent stock watering), minimum shareholder numbers, and a qualitative assessment of risk. Oil stocks, for example, could not be listed in their early years because they were deemed too risky.

Despite the similarities in organization (albeit with obvious technological innovations), financial markets circa 1907 differed considerably from today in their regulation. Weak (nearly non-existent) regulations over corporate governance and investor protections yielded persistent information opaqueness throughout the initial phases of development of the corporate economy and capital markets. In particular, corporate reporting law remained

[8] In 2014 terms, equivalent to $1.8 - $2.5 million, depending on the deflator used.
[9] Davis and Gallman (2001), page 320.

loose and vague in the United States until the Great Depression and the spate of disclosure regulations that followed.

Internal incentives and particularly the desire to access outside funds from investors encouraged a growing number of companies to publish their balance sheets and income statements, but the practice was far from widespread. The NYSE issued a recommendation in 1895 that listed companies provide both a balance sheet and an income statement in annual reports to investors. Such reporting then became mandatory in 1899. Still, the adherence to and enforcement of the rule remained weak for many years, and the content of these reports varied significantly in their extent and accuracy (Archambault and Archambault (2005) and Sivakumar and Waymire (1993)). In particular, companies in sectors subject to rate regulation saw the greatest incentive to publish their accounts, but their regulation also created incentives to manipulate their earnings statements (Archambault and Archambault (2011)). New laws and exchange rules requiring audited accounts developed only after the Panic of 1907 (Sivakumar and Waymire (1993) and Sivakumar and Waymire (2003)).

Thus, notably, the rapid financial development that funneled large amounts of capital into New York had taken place in spite of poor legal protection for investors and sparse, erratic, and often non-existent or erroneous information on corporate performance. This opaque information environment exacerbated the growing uncertainty over stock valuations over the months before the crisis, most particularly in the mining sector. We can see the role of information as we track the events over the days leading up to the panic. On October 16, 1907, the brokerage house of Otto Heinze was forced to close when he failed in his attempt to corner shares of the United Copper Company and pull a classic short squeeze. The manipulations in United Copper shares caused wild swings in the stock's price, but the price ultimately plummeted and left Otto in financial ruin.

Heinze's failure was only the beginning of the story. United Copper was partly owned by Otto's brother, the notorious copper magnate, F.A. (Augustus) Heinze.[10]. The O. Heinze failure set off rumors that certain financial institutions had financed the failed short squeeze and therefore held unpayable debts from Otto Heinze. But Augustus was the key link in the rumor chain, as he had just a few months prior moved to Manhattan and taken an active interest in banking and finance - including Presidency of the Mercantile Bank and directorships at several other banks and trust companies.[11] Thus, as

[10]For extensive details, see the Smithsonian Magazine article from September 2012 and Chapter 6 of Parker and Whaples (2013).

[11]See the detailed reporting in the *Commercial and Financial Chronicle* in the weeks during and

Figure 5: Price discovery process during the Panic of 1907

rumors spread about counterparties to Otto's brokerage firm, depositors ran on Mercantile National and on the trust companies with known ties to Heinze; first and foremost, the Knickerbocker Trust Company with $69 million in assets (Tallman and Moen (1990)). After the closure of Knickerbocker Trust Company on Tuesday, October 22nd, depositors rapidly began withdrawals from other trust companies.[12] As banks faced withdrawals, money became scarce, and rates on short-term loans spiked; thereby causing difficulties in financing stock market transactions. Falling stock prices set off margin calls and further sell-off in stocks to cover.

In an era in which investors learned price information by traveling to or phoning their brokers-who, in turn, relied on a stream of information printed onto ticker tape arriving via telegraph-the only way to learn news in real time was to appear in person. The now famous photograph in Harper's Weekly during the panic, gives an impression of what that "price discovery" process looked like (see Figure 5 from Harper's Weekly).
The extensive reporting in the *Commercial and Financial Chronicle* of the time as well as contemporary economists and numerous subsequent researchers point out that rumors - and the inability of investors to access and assess information - led to escalation into panic.[13] Market participants could observe the runs on trusts and banks that had close

following the panic.

[12]Again, see the extensive details reported in the *Commercial and Financial Chronicle*.

[13]See Sprague (1908) and Sprague (1910) as well as the modern analyses of Frydman et al. (2012), Gorton (1988), Calomiris and Gorton (1991), and Moen and Tallman (1992).

ties to the Heinze brothers, and they could learn - with some lag - about stock price declines, but they had no way of accurately evaluating in real time the fundamental values of either the financial institutions or the corporations whose stocks served as collateral on millions of dollars' worth of loans.

The crisis narrative of O.M.W. Sprague (Sprague (1910), page 246), an eminent economist of the time, clearly indicates that contemporaries well understood the importance of information and uncertainty, and how those problems led to a crisis of confidence, panic, and runs on banks and the stock market. Here, a brief excerpt from his extensive coverage:

> "After the August decline on the stock exchange a number of unfavorable events served to weaken confidence. The most important of these were the disclosures regarding the affairs of the New York street railway companies, which culminated in the appointment of receivers toward the end of September. There is, however, no evidence that distrust of the solvency of the banks either in New York or elsewhere had been excited. During the crisis distrust rapidly developed, but this was owing to causes similar to those which had produced the same effect in other crises and can be naturally accounted for by the events which marked its beginning.
>
> The initial episode of the crisis was, as has often happened in previous instances, insignificant enough. Copper was, as we have seen, the one branch of industry in which a positive decline had taken place. No time could possibly have been chosen so unfavorable for venturesome attempts at manipulation either of copper itself or of the shares of copper companies. It happened that the particular disaster which precipitated the crisis was a copper gamble, the outcome of which would ordinarily have had no public importance."

Sprague also emphasized the lack of lender of last resort facility for the "shadow banks" of the day, the trust companies, and the antagonistic relationship between these unchartered- and loosely regulated-trust companies and the fairly tightly regulated banks. In particular, the required reserve ratios of national banks exceeded the typical reserves held by trusts, and that gap led to a competitive advantage for the trusts and an arguably self-defeating unwillingness to assist trusts in the face of the 1907 liquidity freeze. In this pre-Fed era, the Clearing House Association of New York, a private clearing house, acted as an emer-

gency lender to its members in crisis times. The trusts were not part of this club (Tallman and Moen (2014)). Moen and Tallman (1992) point out that loans at trust companies contracted by 37% between August 22 and December 19, 1907. Loans at banks contracted by 19% during that same period.

The panic might have deepened if not for the rescue measures implemented in short order: The Treasury Department's $25 million deposit in New York banks followed on October 24th by J. P. Morgan's now-famous bailout plan involving large sums of his own money and that of the city's top bankers. On October 26th, the New York Clearing House Association issued Clearing House loan certificates for its member banks (Tallman and Moen (1990) and Tallman and Moen (2012)). To further calm the markets, treasury certificates were issued on November 19th and 20th. Notably, as Rodgers and Payne (2012) find and as is described in Kindleberger and Aliber (2011), the announcement by the Bank of France that it would discount American commercial paper for gold Eagles held in the Bank's reserves ultimately seemed to have stopped the downward spiral of equity prices. According to Rodgers and Payne (2012), the Bank of France repeated its announcement between November 22 and December 7, 1907. The authors also conclude that the Bank of France actions signaled an ongoing ability to provide liquidity, and thereby a more enduring resolution of the crisis, in contrast to Morgan's temporary injection of funds.

Wilson and Rodgers (2011) point out that, in addition to the various policy responses, the structure of the U.S. capital markets proved to be beneficial for the economy during the Panic of 1907. For example, the payment system for bond-transactions was not necessarily tied to banks. Hence, investors could continue to receive payments even with banks in trouble. Additionally, most bond indentures stipulated that coupon and principal payments had to be made in gold, which further explains why the Bank of France announcements proved so helpful in stabilizing the market.

This downturn displayed characteristics also observed in earlier financial crises (Moen and Tallman (1992)): interest rates increased, stock prices decreased sharply, output in the real economy fell significantly, and financial institutions suffered from deposit withdrawals (see Gorton (1988) and Kindleberger and Aliber (2011)). The resulting contraction of loans yielded significant negative consequences for the real sector (see Moen and Tallman (1992) and Bruner and Carr (2008)).

The Panic of 1907 marks an important turning point in the history of the U.S. financial system. The severity of the Panic of 1907 brought calls for reform of the financial system,

with a particular focus on curbing potentially destabilizing activities in the stock markets and the need for a lender of last resort. Most of this first phase of activity focused on bank liquidity backstops. Consequently, on May 28, 1908, Congress passed the Aldrich-Vreeland Act that provided for emergency currency to infuse liquidity into the system when widespread insolvency threatened. Additionally, the Act introduced the National Monetary Commission and charged it with investigating the Panic of 1907 and recommending measures to regulate capital markets and the banking system (Calomiris and Gorton (1991)). The Commission submitted its final report in 1912 and on December 23, 1913, Congress passed the Federal Reserve Act. Thus, the 1907 crisis stands as the last major crisis without an official institution to coordinate liquidity support in periods of financial distress, and ultimately the stimulus for the foundation of the Federal Reserve System.[14]

Politicians also held up the Panic of 1907 as an example of Wall Street excess and dishonesty and used it to motivate the famous Money Trust hearings in Congress. That investigation produced volumes of testimony by Wall Street insiders and led to the Clayton Antitrust Act. In New York, the Governor appointed a committee to study the crisis and recommend reforms to the financial markets. That investigation ultimately led to tighter control over access to trading at the NYSE. These regulatory steps made little inroads into the problem of information opaqueness that had exacerbated (if not outright caused) the crisis. The regulations did lay the foundation for more far-reaching interventions, such as the U.S. Securities and Exchange Commission (SEC), that emerged a few decades later.

4 Market Liquidity and Funding Liquidity during the Panic of 1907

The narrative of the Panic of 1907 points out the already fragile state of financial markets in the several months prior to the crisis, and general economic conditions had also weakened over the previous year. Odell and Weidenmier (2004) argue that the financial repercussions of the San Francisco earthquake in April of 1906 led to monetary stringency and made financial markets susceptible to a crisis. In the absence of a central bank the role of short-term borrowing rates was performed by the overnight call money market throughout our period of study. These funding liquidity issues should therefore appear in

[14]We consider the situation in the summer of 1914, as an impending crisis, but one that was staved off in part due to the lessons of 1907 and the creation of a liquidity backstop in Aldrich-Vreeland. Fohlin and Mozenter (2015) provide an in-depth study of liquidity during the lead-up to the war and the several months following the reopening of the NYSE in December 1914.

the form of elevated call rates.

As Brunnermeier and Pedersen (2009) establish in a theoretical framework, in periods of crisis positive feedback effects between funding illiquidity and market illiquidity might amplify each other. In such situations a decreasing availability of funds will increase margin requirements and haircuts on collateral inducing fire-sales of the underlying assets and a widening of bid-ask spreads, reflecting higher inventory holding costs of the assets for market makers. To the extent that market liquidity dries up, margin requirements and haircuts will be increased, reducing funding liquidity even further.

This mutually enhancing feedback between funding illiquidity and market illiquidity is particularly important in opaque markets with asymmetric information among traders about assets' true valuations. If information is symmetric, on the other hand, margins and haircuts tend to be stabilizing towards a new equilibrium. Under asymmetric information though Brunnermeier and Pedersen's model would predict an increase in the correlation of measures of funding illiquidity and market illiquidity as well as an increase in commonality between asset returns, volatility and effective spreads as well as investors' flight to quality. Since we cannot observe the historical margins and haircuts set by the exchanges, we can only indirectly test for evidence of this relation between funding illiquidity and market illiquidity.

Taking daily call money rates as our measure of funding illiquidity and spreads as the measure of market illiquidity, Figure 6 suggests that call money rates pushed relative spreads to its maximum at the peak of the crisis in October 1907. In other words, our measure of funding illiquidity seems to drive market illiquidity during these two weeks. Afterwards we see a decoupling of funding liquidity and market liquidity and a convergence of market illiquidity to more normal levels despite the fact that funding liquidity spikes even higher toward the end of 1907.

In order to add statistical inference to the above graphs, we compute correlations between call money rates and one-day-ahead relative spreads. Focusing on one-day-ahead spreads we find that the correlation peaks between October 14 and November 1, 1907, with a correlation coefficient of 0.82. To be more precise, the correlation between call money rates and one-day-ahead relative spreads reaches a maximum of 0.82 for the period from Oct. 14 (Monday) - Nov.1 (Friday), 1907, while it attains only 0.46 before (Sep.23-Oct.11) and 0.32 after the crisis peak (Nov.4, 1907 - Feb. 19,1908).[15] This is strong evidence that

[15]To be more precise, these autocorrelations relate to the minimum of the reported call money rates.

funding liquidity was a major driver of market liquidity particularly during the crisis.

While daily data are so far available only for a short window for daily call money rates, we test this hypothesis on the basis of monthly observations over the full sample, regressing relative spreads on call-money rates, a crisis dummy and an interaction term.

Our regressions confirm the result that funding illiquidity causes market illiquidity during the crisis (see Table 2). In fact, call money rates do not consistently affect spreads but only when interacted with the crisis period.

This result suggests that during the crisis margin requirements were destabilizing, and therefore, in line with Brunnermeier and Pedersen (2009), evidence in favor of asymmetric information among market participants.[16] Another striking result that matches their analysis is that commonality in asset returns shoots up in such periods.

5 lliquidity as a Factor in Asset Pricing

We can further investigate how the markets handled the illiquidity shock by testing, a la Acharya and Pedersen (2005) and Pástor and Stambaugh (2003), whether the market priced in market illiquidity. In the now-standard fashion, we augment a Fama-French three factor model with a fourth liquidity factor, measured by relative bid-ask spreads.

In order to test this model, we first construct size and market-to-book factors using the procedure in Fama and French (1992).[17] We define Book-to-market as:

$$\text{Book-to-Market (B/M)} = \frac{\text{Total capital stock per month}}{(\frac{\text{Total capital stock per month}}{\text{Par value}}) * \text{Stock Price}} \tag{1}$$

We then break our entire sample of stocks into three book-to-market equity groups based on the breakpoints for the bottom 30% (Growth), middle 40% (Neutral), and top 30% (Value) of the ranked values of the book-to-market ratio. We furthermore sort our sample of stocks into size portfolios based on market equity. Market equity in our case is defined

Call money rates were reported in a high-low range. The correlations presented refer to the correlation between the low and relative spreads. Hence they measure the funding rates of the most creditworthy traders. In midst of the turmoil at Oct. 25th this lowest funding rate reached a level of 50%, significantly up from neighboring days. The number reported in the text excludes the observation of Oct. 25th. If one did, however calculate the autocorrelations for Oct.14-Oct.24 and Oct.26-Nov.1 the resulting values are 0.796 and 0.985.

[16] Brunnermeier and Pedersen (2009) show that in the case of symmetric information margins requirements tend to be stabilizing.

[17] Kenneth French's online database starts much later.

as:

$$\text{Market equity} = \left(\frac{\text{Total capital stock per month}}{\text{Par value}}\right) * \text{Stock Price} \tag{2}$$

We split the sample into two equal groups, Small and big (S and B), based on the median value of market capitalization. These sorts follows Fama and French (1992) as well as Fama and French (1993). The Fama/French factors are constructed using the six value-weight portfolios formed on size and book-to-market. SMB (Small minus Big) is the average return on the three small portfolios minus the average return on the three big portfolios:

$$\text{SMB} = \frac{1}{3}(\text{Small Value+Small Neutral+Small Growth}) - \frac{1}{3}(\text{Big Value+Big Neutral+Big Growth}) \tag{3}$$

HML (High Minus Low) is the average return on the two value portfolios minus the average return on the two growth portfolios:

$$\text{HML} = \frac{1}{2}(\text{Small Value} + \text{Big Value}) - \frac{1}{2}(\text{Small Growth} + \text{Big Growth}) \tag{4}$$

Since there is no 3-month T-bill in the period of our study, we define the excess return $R^m - R^0$ relative to a zero-beta portfolio, using the gold flow rate (i.e., growth rate in the gold stock of the U.S. government). This rate correlates with the market return at only -0.01.

Once we have our size and market-to-book factors, we follow a two-stage test procedure (Fama and MacBeth (1973)). In the first stage we estimate firm-specific regression coefficients ("Betas") for the market portfolio and spread. In this regression, $R_{i,t}$ is the firm-specific time-varying return. i denotes the companies and t is a time-index (monthly). $R_t^m - R_t^0$ denotes the excess market return and "Spread" denotes our measure for illiquidity. The regression, which is estimated in the first stage, looks as follows:

$$R_{i,t} - R_t^0 = \beta_{1,i} * (R_t^m - R_t^0) + \beta_{2,i} * Spread_{i,t} + \beta_{3,i} SMB + \beta_{4,i} HML + \epsilon_{i,t} \tag{5}$$

$$E[R_i - R^0] = \lambda_0 + \lambda_1 \widehat{\beta_{1,i}} + \lambda_2 \widehat{\beta_{2,i}} + \lambda_3 \widehat{\beta_{3,i}} + \lambda_4 \widehat{\beta_{4,i}} + \eta_i \tag{6}$$

The results of our asset pricing analysis indicate that liquidity risk is priced positively, such that investors expected and earned a liquidity premium very much in line with

markets a century later. Given the lack of transparency in the stock markets at the time, this result seems remarkable. Moreover, in line with Chabot et al. (2014) we find negative contributions of the SMB and HML factors.[18]

6 Information and Opacity as the Main Drivers of Market Illiquidity

Thus far, we have assembled some of the key pieces of the 1907 puzzle - that funding illiquidity seems to have driven market illiquidity during the peak weeks of the crisis, and that moreover, market investors priced in such illiquidity. What remains for us to determine is whether the core of the illiquidity problem lay - as we hypothesize - in the opaqueness of information in the market.

In order to analyze these questions, we decompose spreads into their three main components information risk, inventory holding risk and operating costs including market power. Information risk, commonly also termed adverse selection risk, captures the risk of market makers trading against better informed traders. Since they typically lose money in such trade they protect themselves against losses by charging wider spreads. Inventor holding costs arise when market makers' exposure deviates from their optimal portfolios, while the order processing cost component compensates for technical costs of order handling plus rents due to market power.

We estimate these three cost components using Gehrig and Haas (2015)'s refinement of the Huang and Stoll (1997) spread decomposition. The refinement insures that the three different cost components add up to 100% of the quoted bid-ask spreads.

In the model of Huang and Stoll (1997), the time frame consists of three separate and sequential events. Stock i's fundamental value, $V_{i,t}$, is unobservable on day t. The bid and ask quotes are set right after the fundamental stock value has been determined. $M_{i,t}$ denotes the quote midpoint and is calculated from the quotes that were posted by a market maker just before a transaction happened. $P_{i,t}$ denotes the respective transaction price. $Q_{i,t}$ denotes a trade direction indicator variable. It takes the value of 1 if the transaction price exceeds the midquote (i.e., if a transaction is buyer-initiated), and it takes the value of -1 if the transaction price is smaller than the midquote (i.e., if a transaction is seller-initiated). It equals zero if the transaction price is equal to the midquote.

[18] We have different numbers of observations in each regression, because we exclude firms with negative company excess returns ($R_i - R^0 < 0$) or too few observations to produce an R^2.

Subsequent transactions and their respective transaction volumes are assumed to be serially correlated. The conditional expectation of the trade indicator variable Q_t at time *t-1* given Q_{t-2} is, therefore, shown to be:

$$E(Q_{i,t-1}|Q_{i,t-2}) = (1 - 2\pi_{i,t})Q_{i,t-2}. \tag{7}$$

where $\pi_{i,t}$ denotes the probability that the current trade is of opposite sign to the previous trade.

Huang and Stoll (1997) estimate equation 7 simultaneously with equation 8 in order to estimate the different cost components of the spread. In equation 8 $S_{i,t}$ denotes the equity bid-ask spread and $\alpha_{i,t}$ denotes the percentage of the spread that is associated with informational cost (i.e., adverse selection cost). From this equation it becomes obvious how adverse selection costs are exactly measured as $\alpha_{i,t}$ is the coefficient of the difference between what the actual trade turned out to be (i.e., $\frac{S_{i,t-1}}{2}Q_{i,t-1}$) and what a market participant expected the trade to be based on the previous trade (i.e., $\frac{S_{i,t-2}}{2}\mathbb{E}[Q_{i,t-1}|Q_{i,t-2}]$). Hence, $\alpha_{i,t}$, or informational costs, only arise if the current trade brings about a surprise relative to the previous trade. $\beta_{i,t}$, the percentage of the spread that is associated with inventory cost. This coefficient is only measured with respect to the current trade and denotes the changes in the market maker's inventory holdings that she later might need to adjust. $\epsilon_{i,t}$ refers to a public information shock and is assumed to be serially uncorrelated.

$$\Delta M_{i,t} = (\alpha_{i,t} + \beta_{i,t})\frac{S_{i,t-1}}{2}Q_{i,t-1} - \alpha_{i,t}\frac{S_{i,t-2}}{2}(1 - 2\pi_{i,t})Q_{i,t-2} + \epsilon_{i,t}. \tag{8}$$

We estimate the parameters of equation 7 and 8, $\alpha_{i,t}$, $\beta_{i,t}$, and $\pi_{i,t}$, using the generalized method of moments (GMM) procedure outlined in Hansen and Singleton (1982) and Hansen (1982). The optimal weighting matrix is constructed using the method proposed in Wooldridge (2002). Under this procedure, the parameter estimates have to be chosen such that they minimize:

$$Q_N(\theta) = \left[N^{-1}\sum_{i=1}^{N} g(w_i, \theta)\right]' \widehat{\Lambda}^{-1} \left[N^{-1}\sum_{i=1}^{N} g(w_i, \theta)\right]. \tag{9}$$

Following the notation of Wooldridge (2002), θ is the vector of unknown coefficients. In this analysis, this vector includes the component for adverse selection risk ($\alpha_{i,t}$), the component for inventory holding risk ($\beta_{i,t}$), and the trade direction reversal probability ($\pi_{i,t}$). The order processing cost component is computed as the residual cost, after subtracting $\alpha_{i,t}$ and $\beta_{i,t}$ from one, since the three cost shares must add up to 100%. $g(w_i, \theta)$

is an (L x 1) vector of moment functions (or orthogonality conditions). These functions are non-linear and given by:

1. $g_1 = (Q_{i,t-1} - (1 - 2\pi_{i,t})Q_{i,t-2})\, Q_{i,t-2}$
2. $g_2 = (Q_{i,t-1} - (1 - 2\pi_{i,t})Q_{i,t-2})\, S_{i,t-1}$
3. $g_3 = (Q_{i,t-1} - (1 - 2\pi_{i,t})Q_{i,t-2})\, S_{i,t-2}$
4. $g_4 = \left(\Delta M_{i,t} - (\alpha_{i,t} + \beta_{i,t})\frac{S_{i,t-1}}{2}Q_{i,t-1} + \alpha_{i,t}\frac{S_{i,t-2}}{2}(1 - 2\pi_{i,t})Q_{i,t-2}\right) S_{i,t-1}$
5. $g_5 = \left(\Delta M_{i,t} - (\alpha_{i,t} + \beta_{i,t})\frac{S_{i,t-1}}{2}Q_{i,t-1} + \alpha_{i,t}\frac{S_t i,t-2}{2}(1 - 2\pi_{i,t})Q_{i,t-2}\right) S_{i,t-2}$
6. $g_6 = \left(\Delta M_{i,t} - (\alpha_{i,t} + \beta_{i,t})\frac{S_{i,t-1}}{2}Q_{i,t-1} + \alpha_{i,t}\frac{S_{i,t-2}}{2}(1 - 2\pi_{i,t})Q_{i,t-2}\right) (Q_{i,t-1} - (1 - 2\pi)Q_{i,t-2})\,.$

$\widehat{\Lambda}$ is the optimal weighting matrix which is determined by also following Wooldridge (2002):

$$\widehat{\Lambda} \equiv \frac{1}{N}\sum_{i=1}^{N} [g(w_i, \theta)]\, [g(w_i, \theta)]'\,. \tag{10}$$

For estimating consistency, we estimate adverse selection costs, inventory holding costs, and order processing costs on a monthly basis for all stocks having at least 15 daily observations in a given month. For each "stock-month" panel, we implement the GMM decomposition code in Matlab and obtain α and β coefficients for each month and stock. We then aggregate the estimation results across companies and time (i.e., over all months for the years of 1905 to 1910). Once that is finished we merge this dataset with a dataset of company-specific, end-of-month stock prices, relative spreads, opening prices, high and low prices as well as total number of shares traded of each month.

In line with our expectations, we find that adverse selection costs contributed most to total spreads. In absolute (dollar) terms (Figures 7) adverse selection costs dominate transaction costs and thus contribute most to constraining liquidity in the market. During the panic, information costs increased steeply from \$0.007 to \$0.02, while inventory holding costs increased from \$0.003 to \$0.009 and order processing costs from \$0.004 to \$0.01. Hence, the cost decomposition supports the view that uncertainty and information asymmetry - namely rumors - drove the 1907 crisis. This finding accords well with our hypothesis, based on theoretical models of rumor-based market runs (He and Manela (2014) and Bernardo and Welch (2004)). In a sense, we also find similar results to what Hellwig and Zhang (2012) predict, that is, that the role of information changes from the onset of a crisis to the end. In the case of the Panic of 1907, we see an increase

of informational costs from the onset of the Panic on. However, the real peak of rumor contagion is reached when the Panic is already evolving (i.e., October 1907), not at the very beginning of it. This suggests that the spreading informational risks (i.e., rumors) affected the whole stock market and worked contagiously during the crisis. Obviously, in the case of information production through fear and rumors, information production may reduce market efficiency (Dang et al. (2010)).

Stock returns show a severe depression during the Panic of 1907 (Figure 2), but clearly returns had been falling for several months prior to the crisis. All companies and sectors experienced severe declines in returns during the panic, but the crisis hit the mining sector the hardest. That sector also took the longest to recover from the crisis. Returns of mining companies stayed on a depressed and volatile level until the beginning of 1909.

In order to statistically analyze illiquidity and its underlying drivers we estimate different panel regressions in which the dependent variables (i.e., k) are 1. relative bid-ask spreads (column 2), defined as the difference between ask and bid prices divided by the average of ask and bid prices; 2. informational costs (column 3), defined as the adverse selection component times the relative bid-ask spread, 3. inventory costs (column 4), defined as the inventory holding component times the relative bid-ask spread, and 4. order processing costs (column 5), defined as the order processing component times the relative bid-ask spread. We regress each dependent variable on a crisis indicator and monthly call money rates. The crisis indicator takes the value of one if the time period equals the third or fourth quarter of 1907 or the first quarter of 1908 and zero otherwise. We base the timing of the crisis on both past literature and our own analysis of volatility. Our own statistical analysis of volatility over time falls in line with the literature, indicating that volatility rose sharply at the end of the third quarter of 1907 and then began a decline that lasted until March 1908 (Figure 8). Volatility in this case is measured as a 30-day rolling window of the standard deviation of stock returns. To assess the impact of call money rates on market liquidity specifically during the Panic of 1907, we furthermore include an interaction term of both the crisis indicator variable and call money rates. The exact econometric model then looks as follows:

$$Y_{k,i,t} = \beta_0 + \beta_1 Crisis_t + \beta_2 CallMoney_t + \beta_3 Crisis_t \cdot CallMoney_t + \beta_2 X_{j,i,t} + FE_i + TE_t + \epsilon_{i,t} \tag{11}$$

Where:

- $Y_{k,i,t}$: Dependent variables k:

    - * Relative Bid-Ask Spreads of company i
    - * Adverse Selection Costs of company i
    - * Inventory Holding Costs of company i
    - * Order Processing Costs of company i
  - $X_{j,i,t}$: Control variables j:
    - * Liquidity indicator variable (highly liquid vs. illiquid stocks)
    - * Size indicator variable (large vs. small stocks based on number of shares traded)
  - FE: Firm fixed effects
  - TE: Time fixed effects

As we found in the basic correlations in section 3, the resulting estimates show that relative spreads and all components relate positively and significantly with call money rates during the Panic of 1907. This indicates that indeed call money rates drove liquidity as well as the underlying cost factors: informational costs, inventory holding costs, and order processing costs. This result is also economically significant: an increase in call money rates by one percent leads to an increase in relative spreads by 0.2% during the panic period. Outside of the crisis period, only order processing costs relate to call money rates. The respective coefficient shows a negative and statistically significant sign.

Thus, call money rates, reflecting money market liquidity, drove a substantial part of stock market liquidity during this period and did so all the more during the panic episode of late 1907 and early 1908. We therefore interpret the Panic of 1907 as a liquidity crisis. Call money rates also relate especially robustly with informational costs and inventory holding costs; highlighting the channel linking call money rates to spreads. [19]

In order to confirm that the findings on call money rates are robust across different liquidity dimensions and also hold at a higher frequency, we perform a similar regression analysis but with *daily* data (Table 2). Specifically, we regress different measures of liquidity on daily call money rates and a crisis indicator variable. [20] In order to exploit the daily call money rates, we use correspondingly high frequency liquidity measures: daily relative bid-ask spreads (column 2), defined as the difference between ask and bid prices divided by the average of ask and bid prices, daily trading volume (column 3), defined as the number of shares traded per day, the daily Amihud Ratio (column 4), defined as the

[19] The crisis indicator variable is omitted in this regression due to collinearity with the interaction term.

[20] The daily data of U.S. call money rates was kindly provided to us by Ellis Tallman, who also uses this proprietary dataset in his recent paper (see Tallman and Moen (2014)).

ratio of the absolute return for a stock ($|r_t|$) to trading volume in monetary terms over a day (see Amihud (2002)), quasi-volatility (column 5), defined as the day's highest price minus its lowest price divided by the last price of that day, and the Invariance measure (column 6) (see Kyle and Obizhaeva (2013)). The regressors include an indicator for the crisis period of October 16, 1907 (the day of the stock corner failure) to January 21, 1908 to daily call loan rates. Call Money Rates $\times$ Crisis denotes an interaction term of both the crisis indicator variable and call money rates. We also include lagged dependent variables in each regression specification to account for autocorrelation in the dependent variables. The daily call loan rate data covers September 30, 1907, to February 19, 1908, which therefore sets the period of our regressions.

To confirm that these findings are robust and attributable specifically to call money rates, we assess the underlying factors moving call money rates and whether those factors simultaneously drive market liquidity. In particular, we regress call money rates on the level of U.S. gold stock reserves, our crisis indicator variable, and an interaction term of the crisis indicator variable and the level of gold stock reserves. The monthly data for gold stock reserves comes from the National Bureau of Economic Research Macrohistory Database and is denoted in billions of Dollars. Call money rates show a strong inverse correlation with the level of gold stock reserves (Table 5). Call rates also rose significantly during the Panic of 1907, however, this effect was partly offset by gold imports during the crisis: the interaction term between the crisis indicator variable and the level of gold stock in the economy is negative and statistically significant, suggesting that as the level of gold stock rose towards 1908 (as described by Rodgers and Payne (2012)), call money rates decreased and helped relieve the tight liquidity conditions of the crisis period. Interestingly, rising gold stocks do not directly ameliorate illiquidity in the stock market; including that variable in the models of Table 4 yields insignificant results. Rather, call money rates capture the impact of gold flows completely. Hence, we confirm Rodgers and Payne (2012)'s finding that the rising level of gold stock helped to end the crisis. But it did so via call money rates and did not directly improve stock market liquidity.

7 Cross Sectional Evidence on Opaqueness and Market Illiquidity

In order to analyze our how severely opaqueness influenced informational risk, we further divide the sample of stocks according to their different opaqueness levels. We therefore expect that adverse selection risk was highest in the most opaque and rumor-ridden sectors (mining companies), among stocks that are ex ante traded with wider spreads, and

for stocks that traded in the NYSE Unlisted department, where companies avoided disclosure rules and the official vetting process of official listing.

First, we compare relative bid-ask spreads and the different cost factors by industry. Indeed, the panic hurt mining stocks' liquidity the most. Besides the fact that the mining sector experienced the greates decline in stock returns during the Panic of 1907, when compared to all other sectors (see Figure 2), spreads of mining companies rose from about 2% before the crisis to about 5% during the Panic of 1907 (Figures 9 to 11). This sharp rise in illiquidity results entirely from adverse selection risk (Figures 12 to 14): adverse selection costs (in dollar-terms) triple from \$0.01 to \$0.03, the steepest increase across all industries. Most importantly, adverse selection costs remain high, even after rescue measures took place. This finding indicates that the rumor-based crisis infected mining stocks severely enough to endure over the longer term. The other two cost types show less significant increases during the Panic of 1907.

The other sectors do experience higher adverse selection costs as well, which supports our hypothesis that informational risk was an important driver of this overall liquidity freeze. But all other industries react *after* the mining sector which suggests that the mining sector - due to the connections of the Heinze brothers, and the overall opacity of the sector and its activities - was really at the heart of this panic.

We also confirm our related hypothesis that stocks in the sectors that published accounting information on a relatively frequent basis (such as the railroad and utilities sectors), do indeed experience lower adverse selection costs compared to other industries, such as manufacturing. Relative transparency, therefore, turns out to be beneficial in terms of lower adverse selection risk and increased stock market liquidity.

We can also conjecture that, regardless of sector identity, illiquid (e.g. low volume, high price impact, or unlisted) stocks were affected disproportionally more by informational risk than liquid stocks. To test this presumption, we divide the cross section of companies into two subsamples: a "liquid" one and an "illiquid" one. We define liquid stocks as those falling into the lowest quartile of relative spreads and illiquid stocks as those falling in the highest quartile of that distribution. As we predict, the most illiquid stocks experience significantly greater increases in informational costs, inventory costs, and order processing costs than liquidity ones (Figure 15). All three spread components are more than three times as large for illiquid stocks than for liquid stocks. Furthermore, informational costs increased during the Panic of 1907 for illiquid stocks, whereas the other two cost types

even declined slightly during the crisis. This suggests that illiquid stocks are particularly subject to adverse selection risk during a liquidity freeze.

We find similar results in comparing listed and unlisted companies: the latter get hit by higher informational costs than do the former (Figures 16). As we expect that unlisted stocks generally suffer more from higher informational costs due to the lack of certification and absence of disclosure rules, the adverse selection problems should intensify during a financial crisis. Information costs were especially elevated when rumors were most active in the last quarter of 1907. It also took longer for adverse selection risk to decrease in unlisted stocks compared to listed stocks. This implies that investments in listed companies that had to publish accounting information, indeed served as a hedge against adverse selection risk and especially so in times of heightened uncertainty. This lends robustness both to our sector analyses, in which we showed that companies from sectors that published on average more than other sectors were subject to less adverse selection risk, and to our illiquidity results.

8 Adverse Selection as a Factor in Asset Pricing

Based on these descriptive analyses the question arises to what extent the various components were actually reflected in the underlying factors. In order to address this issue, we treat each of the factors as a separate potential risk factor within the 3-factor Fama French model analyzed before.
In this last test, we make use of our spread decomposition to test for the relevance of specific spread components in asset pricing. For this analysis, we substitute the illiquidity proxy from before and include the underlying drivers of illiquidity, namely adverse selection costs, inventory management costs, and order processing costs, in order to quantify whether any of these factors explain the cross-section of stock returns over and above the three Fama-French factors. [21]

It turns out that the components of our spread decomposition exhibit a rather low degree of correlation with each other (see Table 6). Hence they can be considered as largely independent contributing factors.

The results are displayed in Table 7. We will concentrate on the second stage output only for readability reasons. The FF-Factors turn out to be negatively related to company ex-

[21] This section follows the methodology outlined in Section 4.

cess returns, which is in line with what we found in the liquidity risk asset pricing analysis of section 5. Importantly, the microstructure cost factor of informational risk is statistically significant and positively related to company excess returns. This implies that our results are robust both to the inclusion of the three FF-factors as well as to the inclusion of the risk-free rate. The risk factors of inventory management risk and order processing risk are in both regression estimations not significantly priced in the cross-section of stock returns. We have to note that we are using the company-specific microstructure cost factors as independent variables in all of the regressions, instead of differences between the highest and lowest quintile portfolio of microstructure cost factors. This is important here because we are interested in the company-specific risk and whether each company's returns are correlated with the company-specific microstructure risk factors. Including risk-factors based on portfolio-weighting here does not make sense. For example, why should company XY suffer from informational risk/rumor-risk of company AB? We hence have to concentrate on company-specific factors in this case and analyze whether they are related to company's returns.

8.1 Robustness Tests

Since we have identified the adverse selection component as the only priced factor, we may check to what extent alternative measures of information risk accord with our finding. In particular we check the evolution of Kyle's Lambda as well as an adverse selection measure estimated from effective spreads (e.g., Hendershott et al. (2011)). We briefly describe the construction of those measures before using them in the above described asset pricing analysis to substitute for the original adverse selection component.

In order to measure Kyle's lambda, we exploit information entailed in the first price, i.e., the opening price. A benefit from using the opening price instead of the mid quote is that opening prices are less noisy because they are taken from the same day (whereas the mid quote is taken from the day in order to construct the lambda measure. Since the mid is taken from the closing ask and bid prices and those are usually rather wide at the end of each trading day, using the mid quotes thus introduces noise into the estimation of informational risk. We hence suggest to instead working with the opening price here:

$$p_t = f_t + \lambda Q_t + \epsilon_t \tag{12}$$

where $lambda^{-1}$ is a measure of market depth. Taking first differences we get:

$$\Delta p_t = \Delta f_t + \lambda \Delta Q_t + \Delta \epsilon_t \tag{13}$$

We estimate lambda for both negative as well as positive order flow. The respective results can be found in Figure 17, in which it becomes clear that Lambda is of very small values.

We next estimate an adverse selection measure which was introduced by Hendershott et al. (2011) and also used in Menkveld and Zoican (2014). It is estimated from the effective spread as well as transactionprices p, mid quoted m, and the trade direction indicator variable q.

$$ES = q_t \frac{m_{t+\Delta} - m_t}{m_t} + q_t \frac{p_t - m_{t+\Delta}}{m_t} \tag{14}$$

The first part of the sum captures the adverse selection component; the second part denotes the residual that cannot be explained by the adverse selection component. Delta denotes a time-increment (lead or lag). In the previously mentioned papers, which were using high frequency data, this time-increment was usually two to five minutes. Since we do not have such low latency data available, we have to work with a lag/lead of one day. The evolution of this proxy for informational risk can be found in Figure 18. As all the other measures of informational risk, it peaks shortly before as well as during the Panic months.

Obviously, all adverse selection risk measures reacted during the Panic of 1907. But are they also priced in the cross-section of stock returns as the adverse selection measure of Huang and Stoll (1997)? Results of the asset pricing analysis using this type of adverse selection measure can be found in Tables 8 and 9.

As becomes clear from the different robustness checks, other measures of adverse selection risk are not priced in all cases. This might be due to the fact that the Lambda measure takes on very small values that are almost not distinguishable from zero.

9 Conclusion

Our analysis offers several new insights into the role of information in financial markets, and in particular, how critical a role information transparency plays in mitigating adverse selection problems that destabilize markets. The period of our study, 1905-1910, surrounds one of the worst financial crises in over 100 years and provides a unique window

on the performance of self-regulated asset markets operating under constrained information in the face of uncertainty shocks from unverifiable rumors.

We trace stock market illiquidity both to funding illiquidity during the peak of the crisis and more broadly demonstrate the liquidity premium demanded in the market. We then decompose equity bid-ask spreads into their underlying cost components and find that adverse selection costs play a dominant role in increasing transaction costs and thus contribute most to freezing liquidity. We find that all of our measures of liquidity show severe deterioration of market quality along with an increase in informational risk. Importantly, short-term cash infusions did not have a lasting effect on trading volume, even though the different risk factors recovered.

Our results demonstrate that an ostensibly short-run liquidity freeze happening in an opaque market setting can severely harm confidence in financial markets over extended periods, constraining liquidity far beyond the most acute phase of the panic. We show further that asymmetric information problems play out - as the theory suggests - in predictable cross-sectional variation in illiquidity. In particular, the liquidity crisis hit the mining sector most severely, because it lay at the heart of the crisis both in terms of illiquidity and heightened informational risk. The mining sector also ranked among the least transparent sectors of the economy and, along with many manufacturing enterprises, provided sparse information to investors. We find that these types of stocks suffered most from adverse selection costs, while the regulated and more transparent utilities and railroads suffered the least. Moreover, both extremely illiquid stocks as well as stocks traded in the NYSE's more opaque "unlisted" department also suffered significantly more during the Panic than well-certified (listed) and liquid stocks.

Finally, our analysis generates important insights for asset pricing. In particular, we show that it is possible to predict asset prices based on estimated components of bid-ask spreads. Informational costs incur risk premia above and beyond the standard market beta and Fama-French factors. Hence, the predictability of transaction costs and liquidity also implies predictability of asset prices. In this sense, asset prices are informationally efficient in, at most, a weak sense. Our findings demonstrate the first order relevance of liquidity components for asset pricing.

References

Acharya, V. V. and Pedersen, L. H. (2005). Asset Pricing with Liquidity Risk. *Journal of Financial Economics*, 77(2):375–410.

Amihud, Y. (2002). Illiquidity and Stock Returns: Cross-section and Time-series Effects. *Journal of Financial Markets*, 5(1):31–56.

Archambault, J. J. and Archambault, M. (2005). The Effect of Regulation on Statement Disclosures in the 1915 Moody's Manuals. *The Accounting Historians Journal*, pages 1–22.

Archambault, J. J. and Archambault, M. E. (2011). Earnings Management among Firms during the Pre-sec Era: A Benford's Law Analysis. *The Accounting Historians Journal*, pages 145–170.

Bernardo, A. E. and Welch, I. (2004). Liquidity and Financial Market Runs. *The Quarterly Journal of Economics*, pages 135–158.

Bernstein, A., Hughson, E., and Weidenmier, M. D. (2014). Counterparty Risk and the Establishment of the New York Stock Exchange Clearinghouse. Technical report, National Bureau of Economic Research.

Bruner, R. F. and Carr, S. D. (2008). *The Panic of 1907: Lessons learned from the market's perfect storm*. John Wiley & Sons.

Brunnermeier, M. K. and Pedersen, L. H. (2009). Market liquidity and funding liquidity. *Review of Financial studies*, 22(6):2201–2238.

Calomiris, C. W. and Gorton, G. (1991). The Origins of Banking Panics: Models, Facts, and Bank Regulation. In *Financial Markets and Financial Crises*, pages 109–174. University of Chicago Press.

Chabot, B., Ghysels, E., and Jagannathan, R. (2014). Momentum trading, return chasing, and predictable crashes. Technical report, National Bureau of Economic Research.

Dang, T. V., Gorton, G., and Holmström, B. (2010). Financial Crises and the Optimality of Debt for Liquidity Provision. *Unpublished working paper. Yale School of Management*.

Davis, L. E. and Gallman, R. E. (2001). *Evolving Financial Markets and International Capital Flows: Britain, the Americas, and Australia, 1865–1914*. Cambridge University Press.

Fama, E. F. and French, K. R. (1992). The cross-section of expected stock returns. *the Journal of Finance*, 47(2):427–465.

Fama, E. F. and French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of financial economics*, 33(1):3–56.

Fama, E. F. and MacBeth, J. D. (1973). Risk, Return, and Equilibrium: Eempirical Tests. *The Journal of Political Economy*, pages 607–636.

Fohlin, C. (2015). A New Database of Transactions and Quotes in the NYSE, 1900-25 with Linkage to CRSP. In *Johns Hopkins Mimeo*.

Fohlin, C., Gehrig, T., and Brünner, T. (2008). Liquidity and Competition in Unregulated Markets: The New York Stock Exchange Before the SEC. *DP 101, Collegio Carlo Alberto*.

Frydman, C., Hilt, E., and Zhou, L. Y. (2012). Economic Effects of Runs on Early 'Shadow Banks': Trust Companies and the Impact of the Panic of 1907. Technical report, National Bureau of Economic Research.

Gehrig, T. and Haas, M. (2015). Lehman Brothers: Did Markets Know? *Available at SSRN 2408489*.

Gorton, G. (1988). Banking Panics and Business Cycles. *Oxford economic papers*, pages 751–781.

Hansen, L. (1982). Large Sample Properties of Generalized Method of Moments Estimators. *Econometrica: Journal of the Econometric Society*, pages 1029–1054.

Hansen, L. and Singleton, K. (1982). Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models. *Econometrica: Journal of the Econometric Society*, pages 1269–1286.

He, Z. and Manela, A. (2014). Information Acquisition in Rumor-Based Bank Runs. *The Journal of Finance*.

Hellwig, K.-P. and Zhang, S. (2012). Market Runs: Liquidity and the Value of Information.

Hendershott, T., Jones, C. M., and Menkveld, A. J. (2011). Does algorithmic trading improve liquidity? *The Journal of Finance*, 66(1):1–33.

Huang, R. and Stoll, H. (1997). The Components of the Bid-ask Spread: A General Approach. *Review of Financial Studies*, 10(4):995–1034.

Kindleberger, C. P. and Aliber, R. Z. (2011). *Manias, Panics and Crashes: A History of Financial Crises*. Palgrave Macmillan.

Kyle, A. S. and Obizhaeva, A. A. (2013). Market Microstructure Invariance: Theory and Empirical Tests. Technical report, working paper, University of Maryland.

Menkveld, A. J. and Zoican, M. A. (2014). Need for speed? exchange latency and liquidity.

Moen, J. and Tallman, E. (1992). The Bank Panic of 1907: The Role of Trust Companies. *Journal of Economic History*, 52(3):611–30.

Mulherin, J., Netter, J., and Overdahl, J. (1991). Prices are Property: the Organization of Financial Exchanges from a Transaction Cost Perspective. *JL & Econ.*, 34:591.

Odell, K. A. and Weidenmier, M. D. (2004). Real shock, monetary aftershock: The 1906 san francisco earthquake and the panic of 1907. *The Journal of Economic History*, 64(04):1002–1027.

Parker, R. E. and Whaples, R. M. (2013). *Routledge Handbook of Major Events in Economic History*. Routledge.

Pástor, L. and Stambaugh, R. F. (2003). Liquidity Risk and Expected Stock Returns. *Journal of Political Economy*, 111(3):642–685.

Petersen, M. A. (2009). Estimating Standard Errors in Finance Panel Data Sets: Comparing Approaches. *Review of Financial Studies*, 22(1):435–480.

Rodgers, M. T. and Payne, J. E. (2012). An Overlooked Central Bank Rescue: How the Bank of France Ended the American Financial Crisis of 1907. *Journal of Economic History*.

Shiller, R. J. (2000). Irrational Exuberance. *Princeton UP*.

Sivakumar, K. and Waymire, G. (2003). Enforceable Accounting Rules and Income Measurement by Early 20$^{\text{th}}$ Century Railroads. *Journal of Accounting Research*, 41(2):397–432.

Sivakumar, K. N. and Waymire, G. (1993). The Information Content of Earnings in a Discretionary Reporting Environment: Evidence from NYSE Industrials, 1905-10. *Journal of Accounting Research*, pages 62–91.

Sprague, O. M. (1908). The american crisis of 1907. *The Economic Journal*, 18(71):353–372.

Sprague, O. M. W. (1910). *History of crises under the national banking system*, volume 538. US Government Printing Office.

Tallman, E. W. and Moen, J. R. (1990). Lessons from the Panic of 1907. *Economic Review*.

Tallman, E. W. and Moen, J. R. (2012). Liquidity Creation without a Central Bank: Clearing House Loan Certificates in the Banking Panic of 1907. *Journal of Financial Stability*, 8(4):277–291.

Tallman, E. W. and Moen, J. R. (2014). The Transmission of the Financial Crisis in 1907: An Empirical Investigation.

Wilson, B. K. and Rodgers, M. T. (2011). Systemic Risk, Missing Gold Flows and the Panic of 1907. *The Quarterly Journal of Austrian Economics*.

Wooldridge, J. (2002). *Econometric Analysis of Cross Section and Panel Data*. The MIT press.

10 Figures and Tables

Variables	Mean	Median	Std	Q25	Q75	Observations
Relative Bid-Ask Spread	0.015	0.001	0.016	0.005	0.019	1438
Trading Volume NYSE	5854	1049	17400	505	3244	1438
Call Money Rates	3.69	3.37	1.57	2.46	5.24	72
Gold Stock (Billion $)	1.50	1.62	0.17	1.33	1.65	72
Capital Stock (Million $)	55	30	65	25	75	1438
Adverse Selection Component	0.49	0.51	0.20	0.44	0.56	1438
Inventory Holding Component	0.26	0.29	0.22	0.01	0.44	1438
Order Processing Component	0.25	0.15	0.27	0.04	0.39	1438

Table 1: Descriptive Statistics: 1905-1910

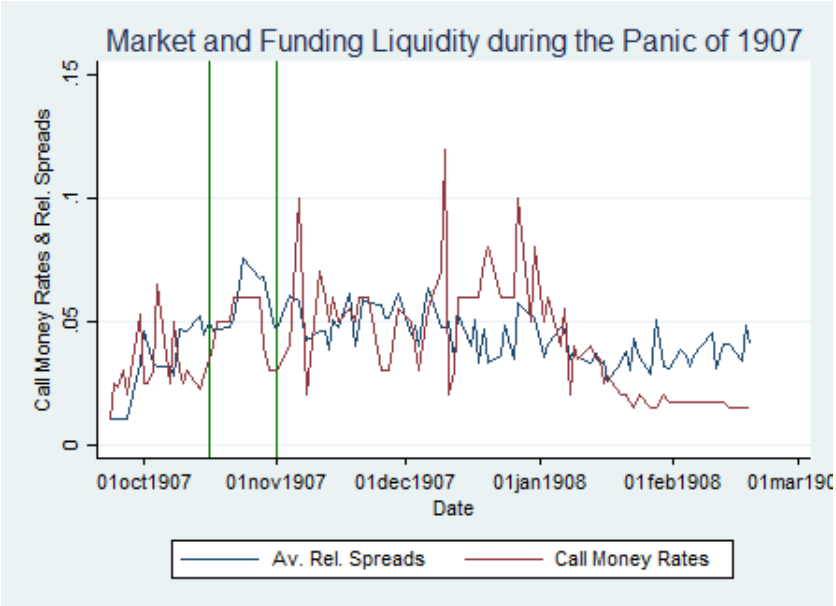

Figure 6: Market and Funding Liquidity During the Panic of 1907

Table 2: Regression Analyses for the Panic of 1907: Daily Rates

This table reports the results from panel regression estimations. The dependent variables are daily relative bid-ask spreads (column 2), defined as the difference between ask and bid prices divided by the average of ask and bid prices, daily trading volume (column 3), defined as the number of shares traded per day, and and quasi-volatility (column 4), defined as the daily high prices minus daily low prices divided by the last price of that day. The regressors include a dummy variable that indicates crisis times and which takes the value of one if the time period equals October 16, 1907 (the day of the stock corner failure) to January 21, 1908, and zero otherwise. A second regressor refers to monthly U.S. call money rates. This data comes from the National Bureau of Economic Research Macrohistory Database and is denoted in percent. Call Money Rates × Crisis denotes an interaction term of both the crisis indicator variable and call money rates. The time period that this daily sample covers is September 30, 1907, to February 19, 1908. The t-statistics are based on standard errors adjusted for heteroskedasticity, and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Relative Spread	Trading Volume	Quasi-Volatility
Crisis	−0.0004	**−688.52*****	0.002
	(−0.79)	(−12.40)	(0.64)
Call Money Rates	**0.001*****	**−55.05***	0.0001
	(23.97)	(−12.54)	(0.53)
Call Money Rates × Crisis	**0.001*****	**169.58*****	**0.001***
	(14.17)	(13.96)	(1.77)
Lagged Spreads	**0.42****	.	.
	(30.56)	.	.
Lagged Trading Volume	.	**0.52*****	.
	.	(20.16)	.
Lagged Quasi-Volatility	.	.	**0.30*****
	.	.	(7.79)
Firm fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No
Controls	No	No	No
Within R^2	0.44	0.27	0.10
Observations	3607	3607	3607

t-statistics in parentheses based on robust standard errors

Table 3: Regression Analyses for Asset Pricing Implications I

This table reports the results from the second stage regression estimation of the two-stage estimation procedure described in Section 4. The dependent variable is the monthly average return over time of each stock. The explanatory variables include a market return beta, and the betas of the Fama-French factos, and a liquidity risk beta. The underlying time period covers the years of 1905 to 1910. The t-statistics are based on standard errors adjusted for heteroskedasticity and autocorrelation, and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Company Excess Returns
Market Excess Return (Gold Flow Rate)	**0.0467*****
	(3.25)
SMB	**0.0340*****
	(-5.96)
HML	**0.0655*****
	(-5.50)
Relative Bid-Ask Spread	**0.0044****
	(2.79)
Fixed effects	No
Time effects	No
Controls	No
Within R^2	0.42
Observations	46

t-statistics in parentheses based on HAC standard errors

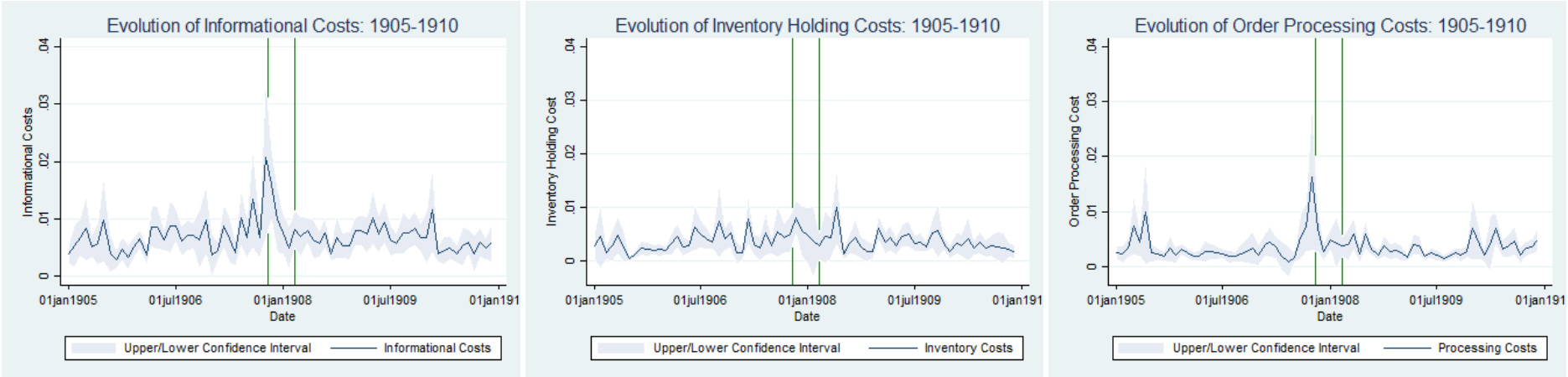

Figure 7: Informational Costs, Inventory Costs, and Order Processing Costs: 1905-1910

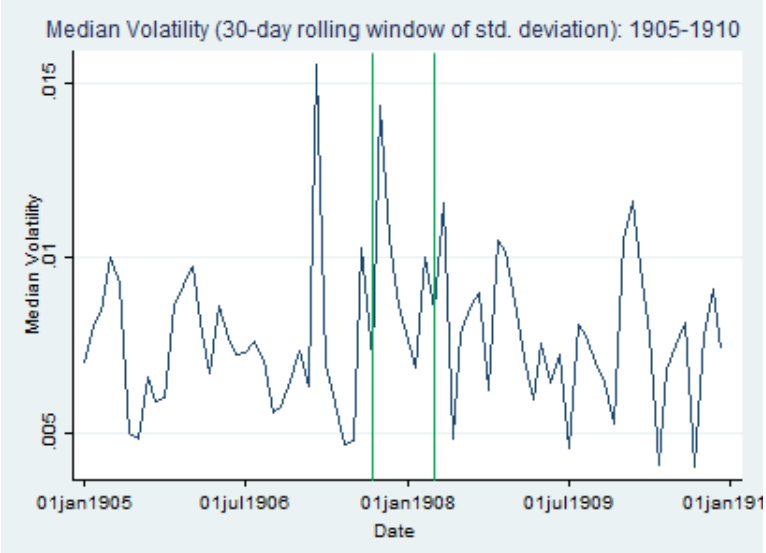

Figure 8: Median Volatility: 1905-1910

Table 4: Regression Analyses for the Panic of 1907

This table reports the results from panel regression estimations. The dependent variables are relative bid-ask spreads (column 2), defined as the difference between ask and bid prices divided by the average of ask and bid prices, informational costs (column 3), defined as the adverse selection component times the relative bid-ask spread, inventory costs (column 4), defined as the inventory holding component times the relative bid-ask spread, and processing costs (column 5), defined as the order processing component times the relative bid-ask spread. The regressors include a dummy variable that indicates crisis times and which takes the value of one if the the time period equals the third or fourth quarter of 1907 or the first quarter of 1908 and zero otherwise. A second regressor refers to monthly U.S. call money rates. This data comes from the National Bureau of Economic Research Macrohistory Database and is denoted in percent. Call Money Rates × Crisis denotes an interaction term of both the crisis indicator variable and call money rates. Controls include the following variables: trading volume; a dummy variable that indicates whether a stock was rather liquid and, hence, takes the value of one if a stock was in the first quantile of the liquidity distribution and zero otherwise; an interaction term between the crisis dummy and the liquidity dummy; a dummy variable that takes the value of one if a company was in the first quantile of the size distribution of companies and zero otherwise; an interaction term between the crisis dummy and the size dummy. The dataset consists of U.S. companies listed at the New York Stock Exchange for the period from 1905 to 1910. The t-statistics are based on standard errors adjusted for heteroskedasticity and within-firm/year clustering (see Petersen (2009)), and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Relative Spread	AS Costs	IH Costs	OP Costs
Crisis	−0.0005	−0.004	0.0006	−0.006
	(−0.19)	(−0.96)	(−0.25)	(−1.78)
Call Money Rates	−0.0001	0.001	0.001	**−0.0002****
	(−0.86)	(1.03)	(0.67)	(−2.78)
Call Money Rates ×Crisis	**0.002*****	**0.002****	**0.001****	**0.002****
	(3.74)	(2.08)	(1.76)	(2.39)
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Within R^2	0.23	0.10	0.03	0.07
Observations	1727	1727	1727	1727

t-statistics in parentheses based on HAC standard errors

Table 5: Regression Analyses for the Determinants of Call Money Rates

This table reports the results from a regression estimation. The dependent variable are monthly call money rates (column 2). This data comes from the National Bureau of Economic Research Macrohistory Database, is denoted in percent, and covers the period of 1905 to 1910. Call Money Rates are regressed on the level of U.S. gold stock, a crisis indicator variable, and an interaction term of both a crisis indicator variable and the level of gold stock. The crisis indicator variable takes the value of one if the the time period equals the third or fourth quarter of 1907 or the first quarter of 1908 and zero otherwise. The monthly data for gold stock comes from the National Bureau of Economic Research Macrohistory Database and is denoted in billions of Dollars. The t-statistics are based on robust standard errors, and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Call Money Rates
Gold Stock	$\mathbf{-5.09}^{***}$
	(-3.93)
Crisis	$\mathbf{13.27}^{***}$
	(3.47)
Gold Stock $\times$Crisis	$\mathbf{-7.63}^{***}$
	(-3.01)
Firm fixed effects	No
Time fixed effects	No
Controls	No
Within R^2	0.21
Observations	71

t-statistics in parentheses
based on robust standard errors

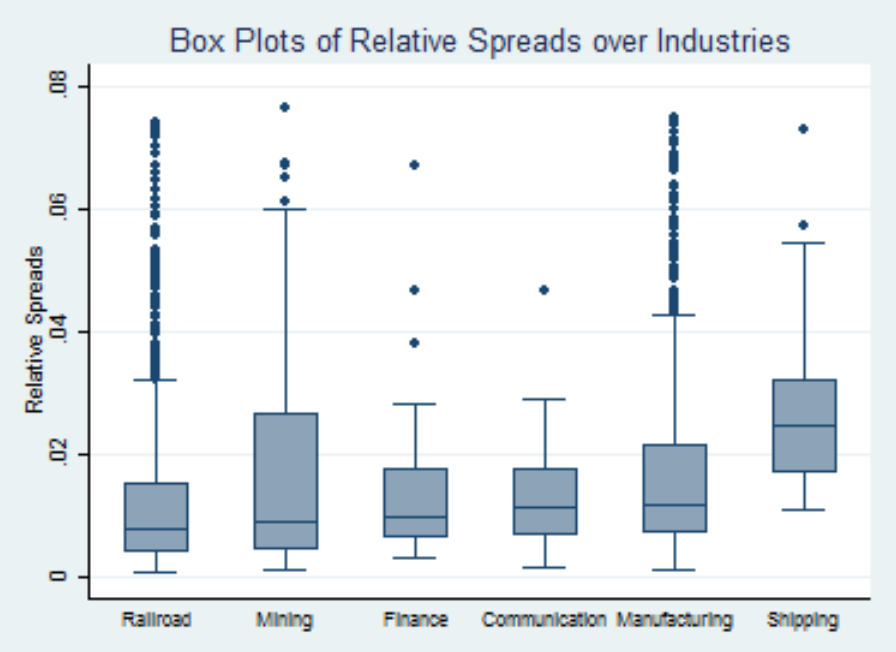

Figure 9: **Box Plots of Relative Bid-Ask Spreads per Industry**

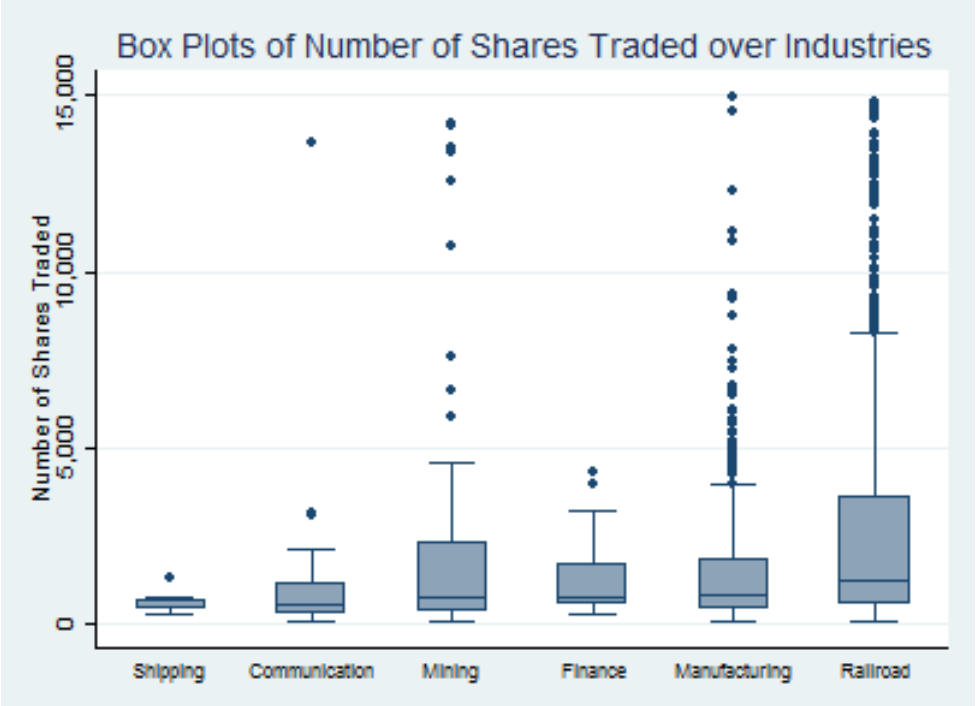

Figure 10: **Box Plots of Trading Volume Per Industry**

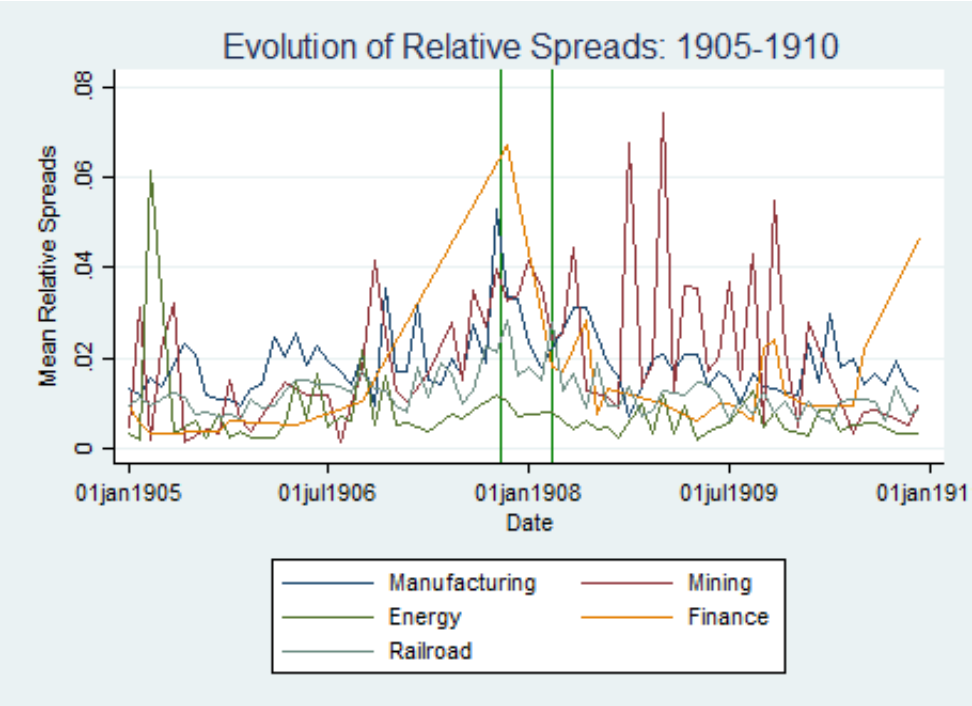

Figure 11: **Average Relative Industry Bid-Ask Spreads: 1905-1910**

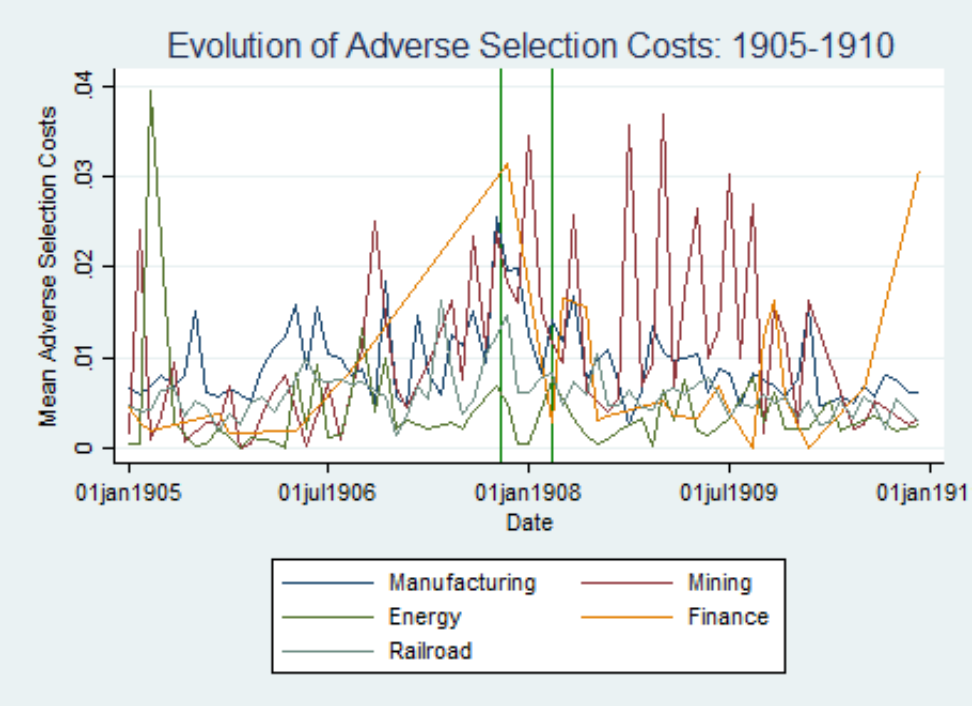

Figure 12: **Informational Costs across Industries: 1905-1910**

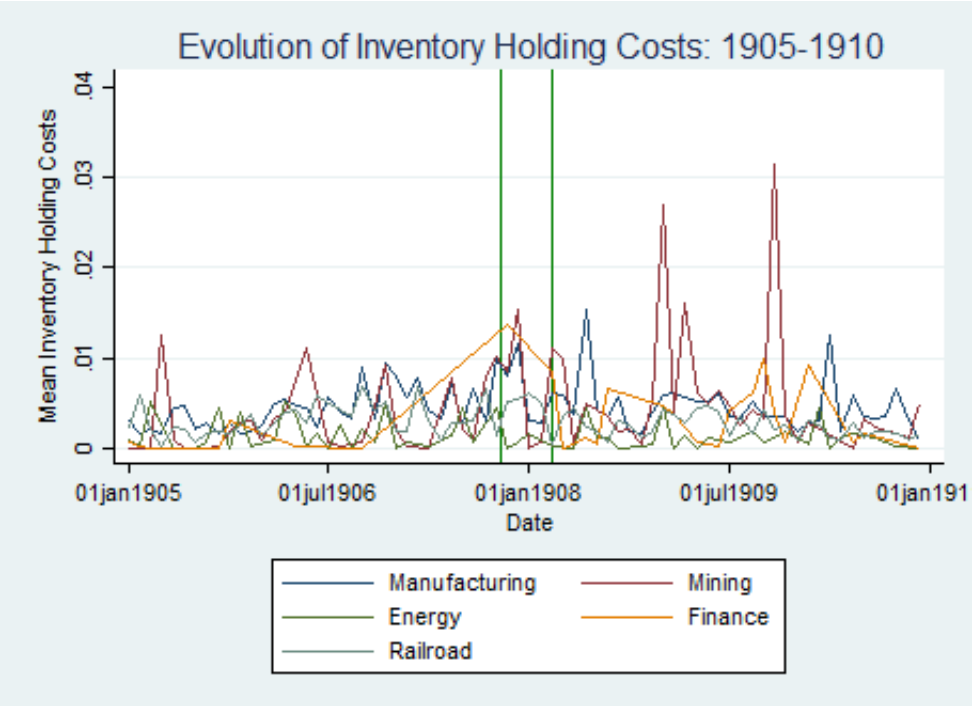

Figure 13: **Inventory Costs across Industries: 1905-1910**

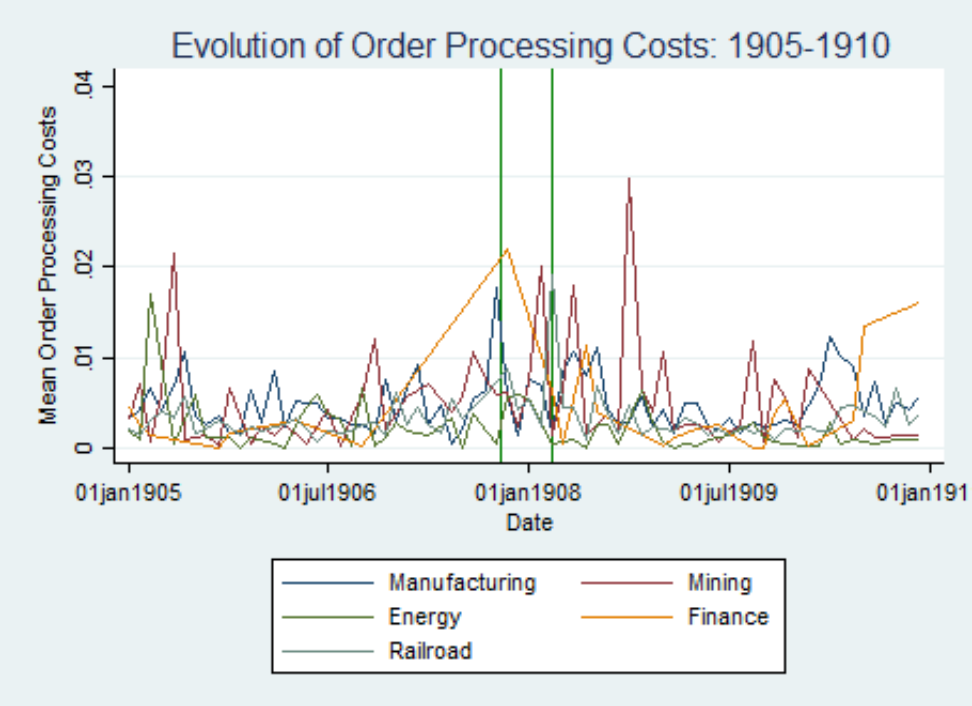

Figure 14: **Order Processing Costs across Industries: 1905-1910**

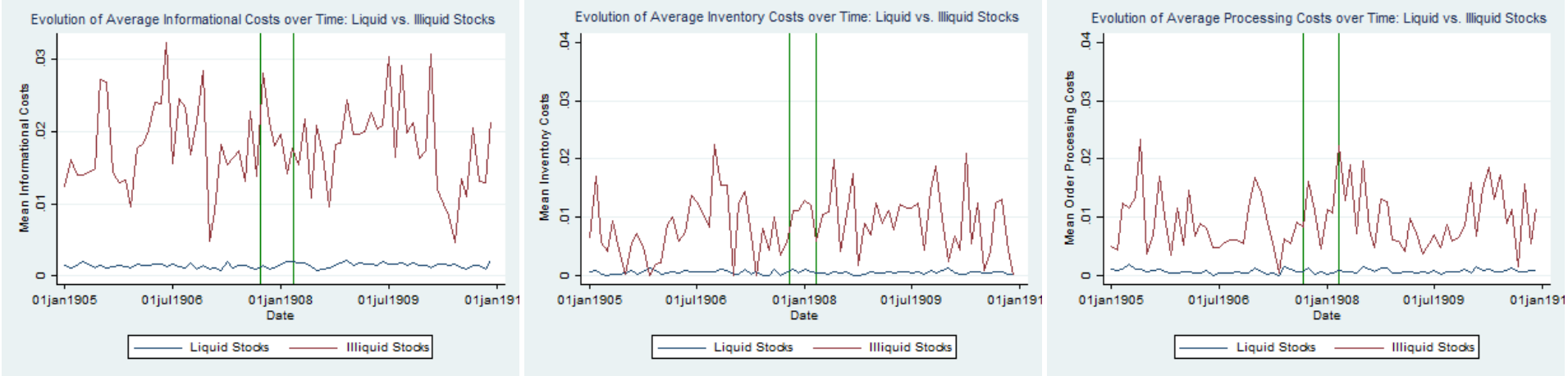

Figure 15: Informational Costs, Inventory Costs, and Order Processing Costs: Liquid vs. Illiquid Stocks

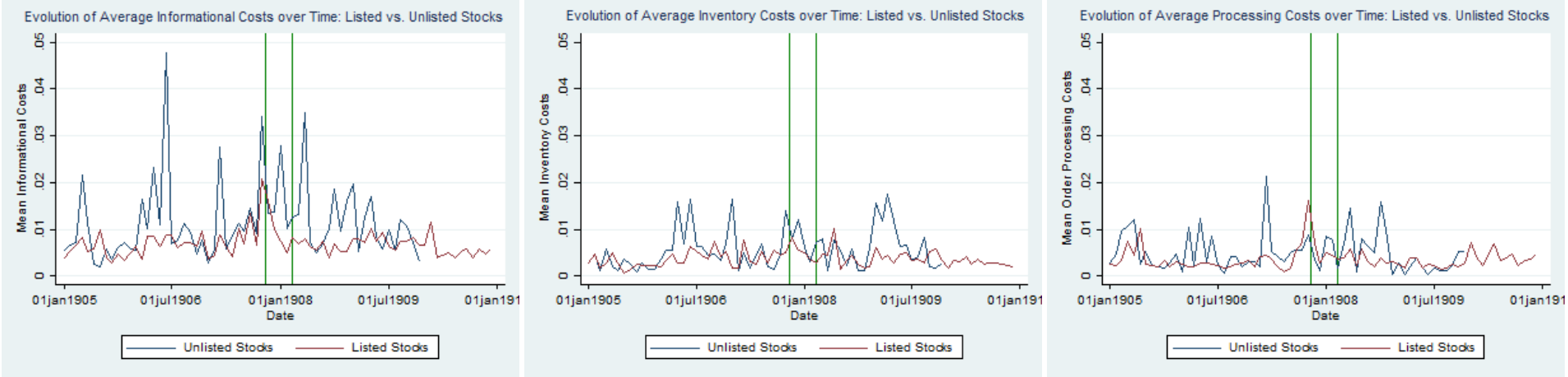

Figure 16: Infomational Costs, Inventory Costs, and Order Processing Costs: Listed vs. Unlisted Stocks

Table 6: Correlation Matrix of Cost Drivers

This matrix reports average correlations of the three different cost types of informational costs (i.e., ASCost), inventory holding costs (i.e., IHCost), and order processing costs (i.e., OPCost).

$$
\begin{array}{c} \\ ASCost \\ IHCost \\ OPCost \end{array}
\begin{array}{c}
\begin{array}{ccc} ASCost & IHCost & OPCost \end{array} \\
\left(\begin{array}{ccc} 1.00 & & \\ 0.22 & 1.00 & \\ 0.34 & 0.02 & 1.00 \end{array} \right)
\end{array}
$$

Table 7: Regression Analyses for Asset Pricing Implications II

This table reports the results from the second stage regression estimation of the two-stage estimation procedure described in Section 4. The dependent variable is the monthly average return over time of each stock. The explanatory variables include a market return beta, an adverse selection risk beta, an inventory holding risk beta, an order processing risk beta, and the the Fama-French factors betas, all of which were estimated in the first stage of the estimation procedure. The underlying time period covers the years of 1905 to 1910. The t-statistics are based on standard errors adjusted for heteroskedasticity and autocorrelation, and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Company Excess Returns
Market Excess Return (Gold Flow Rate)	**0.0436****
	(2.50)
SMB	**−0.0179*****
	(−3.02)
HML	**0.0620*****
	(−5.23)
ASCost	**0.0032****
	(2.14)
IHCost	0.0013
	(1.37)
OPCost	0.0008
	(1.27)
Fixed effects	No
Time effects	No
Controls	No
Within R^2	0.39
Observations	46

t-statistics in parentheses based on HAC standard errors

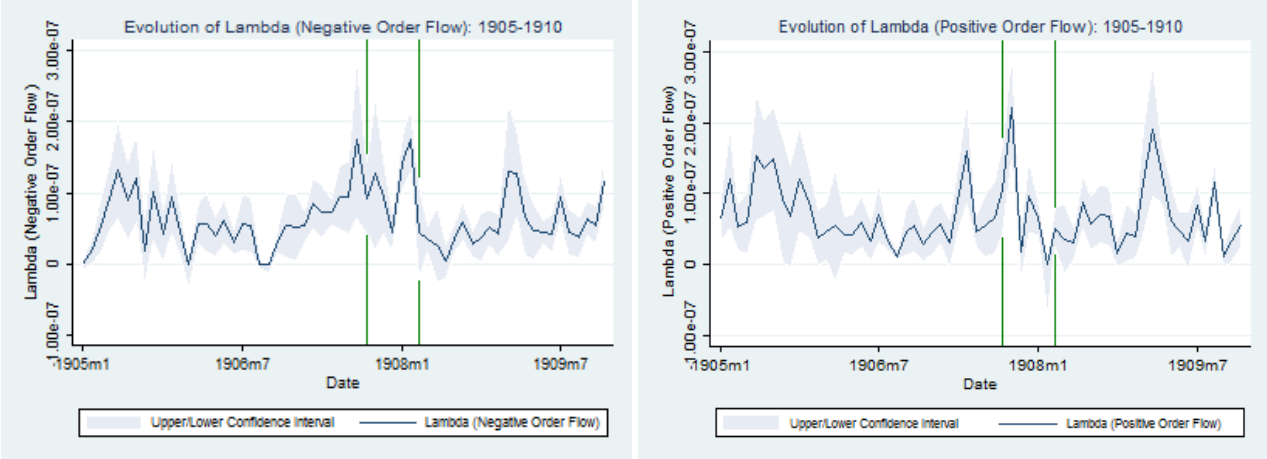

Figure 17: Evolution of Lambda for Negative and Positive Order Flow

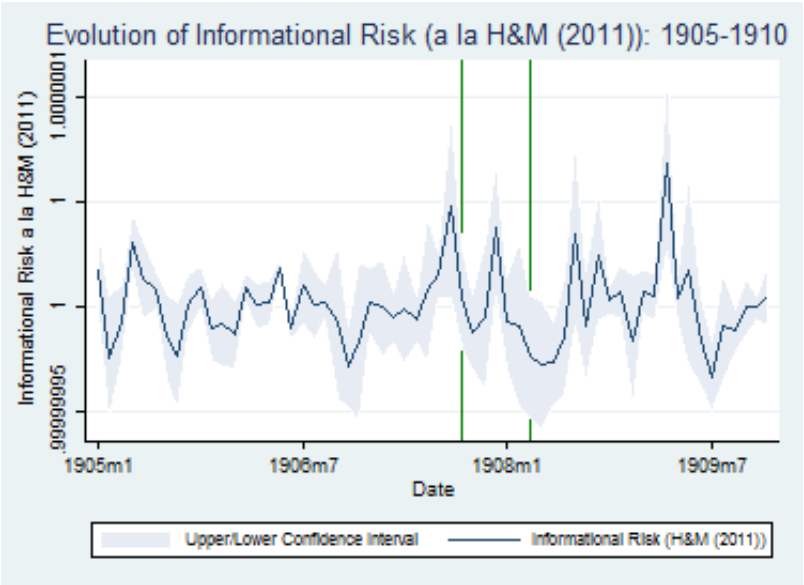

Figure 18: Evolution of Informational Risk according to Hendershott et al. (2011)

Table 8: Robustness Test I: Regression Analyses for Asset Pricing Implications II

This table reports the results from the second stage regression estimation of the two-stage estimation procedure described in Section 4. The dependent variable is the monthly average return over time of each stock. The explanatory variables include a market return beta, an adverse selection risk beta, and the the Fama-French factors betas, all of which were estimated in the first stage of the estimation procedure. The underlying time period covers the years of 1905 to 1910. The t-statistics are based on standard errors adjusted for heteroskedasticity and autocorrelation, and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Company Excess Returns
Market Excess Return (Gold Flow Rate)	0.0112
	(1.08)
SMB $-\mathbf{0}$	$\mathbf{0080}^{***}$.
	(-2.36)
HML	-0.0010
	(-0.38)
Kyle's Lambda	-0.00000012
	(-0.38)
Fixed effects	No
Time effects	No
Controls	No
Within R^2	0.22
Observations	66

t-statistics in parentheses based on HAC standard errors

Table 9: Robustness Test II: Regression Analyses for Asset Pricing Implications II

This table reports the results from the second stage regression estimation of the two-stage estimation procedure described in Section 4. The dependent variable is the monthly average return over time of each stock. The explanatory variables include a market return beta, an adverse selection risk beta, and the the Fama-French factors betas, all of which were estimated in the first stage of the estimation procedure. The underlying time period covers the years of 1905 to 1910. The t-statistics are based on standard errors adjusted for heteroskedasticity and autocorrelation, and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	Company Excess Returns
Market Excess Return (Gold Flow Rate)	−0.000024
	(−0.01)
SMB	**−0.0159***
	(−1.57)
HML	−0.0393
	(−1.11)
ASC (Hendershott et al. (2011))	−0.0137
	(−0.09)
Fixed effects	No
Time effects	No
Controls	No
Within R^2	0.36
Observations	60

t-statistics in parentheses based on HAC standard errors