Slow capital, fast prices:

Shocks to funding liquidity and stock price reversals

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This version: April 28, 2015

Abstract

A V-shaped price pattern is often observed in financial markets – in response to a negative shock, prices fall "too far" before reversing course. The recent financial crisis provides several examples of such temporary mispricing – investors were often only able to sell at fire-sale prices. This paper examines one particular channel why natural buyers may not be able to step in: the link between a liquidity provider's balance sheet and asset prices. To address this question I turn to a specific episode during the Great Depression where a large exogenous shock to a liquidity provider's balance sheet resulted in severe capital constraints. Using evidence from German universal banks, who acted as market makers for selected stocks in the interwar period, I show in a difference-in-differences framework that binding capital constraints made stocks 15–20 percent more likely to be illiquid if they were connected to the distressed liquidity provider. This resulted in V-shaped price patterns during times of illiquidity, where prices declined on average 2.5 percent and reversed over the next one to three days. Investing in these particular stocks would have yielded substantial gains. These findings can be rationalized by a model that incorporates imperfect competition and asymmetric information. Under this model, broker-dealers' market–making reduces price volatility (and uninformed traders' reactions to price movements) in normal times whereas in distressed times, the price impact of noise trading is high and leads to sharp price declines that are unrelated to fundamentals. (JEL: G12, G14, N24)

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1 Introduction

V-shaped price patterns are common in financial markets – in response to a negative shock, prices fall "too far" before reversing course. The recent financial crisis provides several examples of such temporary mispricing (Mitchell and Pulvino 2012). When investors ran for the exit, typical providers of liquidity such as hedge funds did not step in. Why did capital move so slowly to these new investment opportunities? Several theories explain the slow reallocation of capital with frictions in financial markets, such as the wealth of a liquidity provider (Gromb and Vayanos 2002, Brunnermeier and Pedersen 2009).[1] Immediacy can only be guaranteed if a trader does not face binding capital constraints – a situation likely to fail in turbulent times such as the Great Recession.[2] If capital constraints bind, asset prices start to move and diverge from fundamentals.

There is growing empirical support that liquidity providers' funding conditions matter for asset prices. Mitchell, Pedersen, and Pulvino (2007) provide several examples where a reduction in arbitrageurs' capital went together with asset price disruptions. Despite this evidence, it has proven difficult to establish a causal link between a liquidity provider's balance sheet and asset prices. In today's markets, the role of liquidity provider is often amorphous and can change over time – in the recent crisis, hedge funds went from providing liquidity to demanding liquidity. Furthermore, to establish a causal relation between funding liquidity and asset prices, the balance sheet shock has to be large and exogenous. For all these reasons, there is currently no compelling evidence establishing a causal link between capital–constrained liquidity providers and price overshooting in asset markets.

In this paper, I examine a well-identified exogenous shock to a broker-dealer's balance sheet during another period of great turmoil – the Great Depression. I use evidence from German universal banks during the interwar period, which acted as market makers for selected stocks. A difference-in-differences framework shows that binding capital constraints made stocks 15 to 20 percent more likely to be illiquid if they were connected to the distressed liquidity provider. In these periods of illiquidity, V-shaped price patterns emerged and prices fell by an average of 2.5 percent, before reversing over the next one to three days. These return reversals led to a large increase in the short-run volatility of stocks. Returns of other stocks associated with the constrained liquidity provider began to exhibit strong co-movement. An investment

[1] See (Duffie 2010) for an overview.
[2] One obvious alternative interpretation is predatory trading (Brunnermeier and Pedersen 2005).

strategy that bought these stocks during supply order imbalances returned 50 percent in a single month.[3] These findings can be rationalized in a model based on Kyle (1989) that features both asymmetric information and imperfect competition. This model allows me to show that banks' market–making reduced price volatility, but increased the effect of noise trading. When a better–informed trader can provide liquidity to noise traders, overall noise becomes insignificant. However, if a market maker is unable to counteract noise trading then prices decline sharply in response to asset supply shocks.

German universal banks during the Great Depression are particularly well suited to analyze the effects of balance sheet shocks on asset prices. Nowadays it is often unclear who a natural buyer of an asset is. In contrast, in interwar Germany this role was clearly defined. Before World War II, the investment arms of only a few universal banks – the equivalent of broker-dealers – dominated German stock markets, especially the Berlin Stock Exchange. The commercial banking part of the banks supplied banking services to firms and other customers and were the main creditors for firms. At the same time, bank managers often sat on the supervisory boards of their clients. These customs established strong connections between banks and firms.[4] On the stock market, a firm typically expected the broker-dealer part of a bank to prevent large fluctuations of the firm's stock price (Wermert 1907, Prion 1929, Lehmann 2011). Broker-dealers used their capital and stock inventory to make markets. During periods of high demand, broker-dealers would sell stock; when pressure to sell was high, they would buy. Adolf Weber's 1915 manual about the German stock market describes this situation:

> ...The current demand and supply of a stock is responsible for the current market price...only a few shares, if they come to the market at the wrong time, can lead to an unreasonable price increase or decrease. It is the role of the banks to...establish an orderly price setting by buying the shares brought to the market or by adding shares to the existing supply. The underwriting bank will be able to do this better.[5]

The strong connections between banks and firms provide cross-sectional variation in a difference-in-differences framework. Each broker-dealer supplied liquidity to a different set of stocks, those of their associated firms. A sample of firms listed on the Berlin Stock Exchange is sorted into bank–specific portfolios so that each portfolio consist of stocks having a common liquidity

[3] This would amount to an annualized return of nearly 13,000 percent.

[4] Fohlin (1991) describes this situation in detail.

[5] Some of the historical sources cited in this paper pre-date the 1930s. Although the Weimar Republic witnessed important changes, the main workings of the stock exchange remained relatively constant.

provider.

The focus on German banks during the Great Depression aviods further well-known pitfalls. Marking-to market makes it difficult to study the impact of a balance sheet shock on asset prices without having confounding effects of further deterioration of the balance sheet due to falling prices. Also, for investment banks it is difficult to find shocks that are reasonably exogenous to their trading activity. A system with universal banks eliviates this problem. More specifically, German history reveals an exogenous shock to a liquidity provider's balance sheet. On 11 May 1931, one of the big banks, the Danatbank, discovered that its biggest borrower, the Norddeutsche Wollkaemmerei (Nordwolle), had for several years been forging its balance sheets; in fact, Nordwolle was close to bankruptcy. Instead of releasing this information to the public, the Danatbank decided to keep it a secret (Born 1967, Feldman 1995). The bank committed itself to providing Nordwolle with additional funds. Undetected from other market participants, these decisions severely constrained Danatbank's balance sheet. During May 1931, the bank's investment banking division was less able to provide liquidity to shares of its other connected firms.

During the period when Danatbank kept its troubles secret, stocks of affiliated firms continued to experience normal, occasional spells of selling pressure. Now, however, Danatbank was not able to smooth out the peaks. The empirical section provides evidence of an increase in illiquidity and strong price reversals during times of low funding liquidity. I use daily stock market data for 87 firms from November 1930 through June 1931. Bank–firm connections are identified through the underwriter prospectuses and firm–specific annual reports held at the German Federal Archives in Berlin. When Danatbank was unable to provide liquidity, the probability of supply order imbalances increased for connected stocks by 15–18 percent. During May 1931, the returns of Danatbank–connected firms became predictable after supply imbalances. In these cases, prices deviated substantially and more than in the case of other broker-dealers. The increasing illiquidity of stocks associated with Danatbank is not uniform across the sample and more volatile stocks show stronger reactions.

This market illiquidity had implications for pricing, summarized by Figure 1. The figure looks at return behavior of firms connected to different liquidity providers, the Danatbank and the other broker-dealers, after days of illiquidity, which is measured by the existence of supply order imbalances. Each panel plots the average cumulative return after such days. Returns of firms connected to other broker-dealers are shown in the lower two graphs, and returns of firms connected to the Danatbank are shown in the upper two. When the relevant liquidity provider is constrained, asset prices show a pronounced V-shaped pattern (upper right panel). This pattern is visible neither for stocks unassociated with Danatbank nor for Danatabank stocks prior to the funding liquidity shock. Traders who provide liquidity to stocks connected to Danatbank, earned positive expected returns. An investment strategy of investing in illiquid stocks does not lead to positive returns on average. However, returns to the same strategy were much higher for Danatbank–connected stocks during the period of constrained funding liquidity. In particular, during May 1931 a liquidity–provision strategy would have had accumulated returns in excess of 50 percent during a single month. These high returns reflect the strength of "V-shaped" price patterns in the days after order imbalances.

In the theoretical section these findings are placed in a more general context that helps explain the effects of broker-dealers' liquidity provision on both price volatility and the price impact of noise trading. There I describe a simple model, in the spirit of Kyle (1989), with asymmetric information, imperfect competition, and noise trading. Uninformed traders and an informed broker-dealer trade an asset that pays an uncertain dividend in the second period. The broker-dealer has a dual role because it trades for informational reasons, using a private signal about dividends, and also commits itself to counteracting the demand of noise traders. Thus the broker-dealer adds noise to the total demand, although this added noise is negatively correlated with noise trader demand. For reasonable parameter values, the model indicates that the negative correlation between the broker-dealer's market–making demand and noise trading results in less volatile prices. Yet this reduced volatility renders the broker-dealer less able to trade on its private information and thereby restricts its speculative demand. Under these conditions, uninformed traders will also react less to changes in prices and the price impact of noise increases. In normal times this noise is small, so the broker-dealer can successfully reduce price volatility. But if the broker-dealer is unable to act as a market maker, then prices react strongly to fluctuations in noise trader demand and so sharp price declines away from fundamentals can occur.

Relative to the existing literature I make the following contributions: Illiquidity and price reversals can stem from many sources, one of which may be a liquidity provider's balance sheet. In this paper I turn to the Great Depression to supply clear evidence that funding liquidity has the potential to affect market liquidity. This setting allows us to observe an exogenous shock to intermediation capital and also enables us to test for stock market illiquidity. Reduced funding liquidity did lead to less market liquidity, as predicted by the theoretical literature and suggested by empirical studies after the recent financial crisis. During periods of illiquidity, asset prices moved as expected and exhibited a V-shaped pattern. By documenting illiquidity and return reversals I contribute to the empirical literature on return predictability. Further, this study is complementary to the literature on price behavior after supply pressure. In contrast to these papers that focus on sudden increases in asset supply, this study looks on the effects of a sudden decrease in asset demand. While in the literature on mutual funds' outflows prices decline and take a long time to rebound, this article shows large effects on short-run volatility when the demand side is constrained. The empirical part also adds to the historical literature and tests the hypothesis of DeLong and Becht (1992) that banks actually reduced the volatility of German markets. The theoretical discussion suggests that the broker-dealers' intervention in markets came at the cost of greater price impact. In normal times, broker-dealers' market–making demand can reduce volatility, although price impact increases. In times of constrained liquidity provision, this greater reaction of prices to noise induces large price fluctuations.

Section 2 provides an overview of the related literature. Section 3 details the historical background and the shock to funding liquidity. The data is described in Section 4. Section 5 shows how the funding liquidity shock affected market liquidity and Section 6 examines the behavior of asset prices during these periods of illiquidity. The empirical findings are rationalized by the model presented in Section 7. Section 8 concludes.

2 Related literature

This article relates to several strands in the literature. It is closely connected with the literature on traders' funding conditions and asset markets. These papers are part of the research agenda on slow–moving capital that seeks to explain several asset pricing "puzzles".

Several empirical studies find a correlation between traders' balance sheets and asset price movements. Adrian and Shin (2009) and Adrian and Shin (2010) show that changes in dealers' balance sheet positions have predictive power for changes in market volatility. Coughenour and Saad (2004) examine the movements in market liquidity of stocks traded by a given market maker at the NYSE and find that market liquidity changes after mergers of market maker firms.

Coughenour and DeLi (2002) find that liquidity provision changes with the organizational form of the firm; Comerton-Forde et al. (2010) use inventory positions of NYSE specialist firms as a proxy for a market maker's funding liquidity. During times of distressed funding liquidity, illiquidity and asset volatility are positively correlated. Furthermore, specialists' inventory positions are negatively correlated with contemporaneous returns (Hendershott and Seasholes 2007). The price pressure (and reversals) are greater for smaller firms (Hendershott and Menkveld 2013). Andrade et al. (2010) show that trading imbalances on the Tokyo Stock Exchange lead to price declines and reversals. Aragon and Strahan (2012) look at the behavior of stocks connected to hedge funds after Lehman Brother's bankruptcy. They find that stocks became more illiquid if they were held by funds with Lehman as their prime broker. My study complements their finding by shutting down changes in balance sheet variables due to marking-to-market. Further, while my study looks at the effects of a decrease in the asset demand side, recent studies show the existence of price reversals during periods of supply pressure (Coval and Stafford 2007, Edmans, Goldstein, and Jiang 2012).

Several theoretical models establish a causal relationship between funding and market liquidity (Gromb and Vayanos 2002, Gromb and Vayanos 2010). Brunnermeier and Pedersen (2009) extend this line of research by introducing financiers with a value-at-risk constraint, which yields the micro foundations for fluctuations in the margin requirement. Gârleanu and Pedersen (2007) also link changes in liquidity to risk management practices.

All of these studies are part of a broader research agenda on slow–moving capital.[6] Mitchell et al. (2007) document mispricing in markets for convertible securities; Mitchell and Pulvino (2012) show that, after the bankruptcy of Lehman Brothers, several assets may have been mispriced because arbitrageurs were capital constrained.

This article is also related to the literature on commonality in liquidity. Chordia et al. (2000) show that asset-specific measures of liquidity co-move with measures of marketwide liquidity. That co-movement extends to such measures of funding liquidity as the T-bill–eurodollar (TED)

[6]Examples of this slow movement of capital are the predictable price patterns after earnings announcements (Bernard and Thomas 1989) and after index deletions or additions (Chen and Noronha 2004). Looking at the relation between order imbalances and price pressure, Kraus and Stoll (1972) find that block trades cause prices to overshoot. Early market microstructure models accounted for the deviation of prices from fundamentals either by risk-averse market makers (Grossman and Miller 1988) or asymmetric information (see Brunnermeier (2001) for an overview). DeLong et al. (1990) explain limited arbitrage with noise trader risk: the danger that mispricing increases because of uninformed traders. Shleifer and Vishny (1997) add informational frictions, while Duffie et al. (2005) and Duffie et al. (2007) show that search frictions can give rise to V-shaped price patterns. Search frictions are especially relevant for over-the-counter markets, where trade is bilateral. Another explanation offered for slow–moving capital is rational inattention (Biais et al. 2011).

spread (Brennan et al. 2009).

The investment strategy proposed here is related to return predictability and the literature on contrarian trading strategies. Nagel (2012) argues that a "return–reversal" investment strategy resembles the trading motives of a liquidity provider.[7] This strategy delivers high returns during times of illiquid markets—for example, after the collapse of Lehmann Brothers in 2008. Rinne and Suominen (2010) arrive at similar conclusions.

From a historical perspective, this article relates to the literature on interwar Germany and the German financial system.[8] Fohlin (1991) reviews the role of German banks before World War II. Several papers examine the German stock market, mostly dealing with the pre-WW I period (see, e.g., Burhop (2011), Lehmann (2011)). Comparing the German stock market with the US stock market, DeLong and Becht (1992) find that the German market was different in the first half of the twentieth century: unlike the United States, Germany did not experience excess volatility. They argue that market–making activities of banks smoothed price fluctuations. Voth (2003) is one of the few studies on the German stock market in the interwar period. He explores the pricking of a seeming "bubble" by the Reichsbank in 1927. The next large event in German financial history after the crash of 1927 was the banking crisis in 1931; a time, which I will now turn to.

3 Historical background: The Berlin Stock Exchange and the "big banks"

This section places the study in its historical context. It describes the tasks of German banks, how the Berlin Stock Exchange worked, and the shock to funding liquidity.

3.1 Liquidity provision of banks

Since the 19th century, universal banks played a prominent role in Germany's financial system. Investment banking and commercial banking are done by the same institutions. Comparing the German system to banking in England, *The Economist* of 21 October 1911 noted that:

[7]Return reversal strategies are also developed in Lo and MacKinlay (1990) and Lehmann (1990).

[8]James (1986) describes in detail the turbulent times of hyperinflation, high unemployment, rapidly changing governments, and the crisis of 1931. For discussion of whether the 1931 crisis was a currency crisis or a banking crisis (or both), see Ferguson and Temin (2001), Temin (2008) and Schnabel (2004).

> German banks have a much wider sphere of action than our English deposit banks...they are stock, bill, and exchange brokers and dealers, banker-merchants, trust, financial, and promoting companies, etc...Not only have the banks promoted most of the industrial joint-stock companies, and retain part of their share capital, but their managing directors remain members of the board of these companies for their services in that capacity. [9]

Until WW I firms could choose from a wide variety of banks (Reisser 1910). This choice narrowed during the 1920's, when Germany experienced a major consolidation of the banking industry. By the 1930s, the financial system was dominated by just a handful of big banks. Five in particular towered over all others: The Berliner Handels-Gesellschaft (BHG), the Commerzbank, the Deutsche Bank und Diskonto-Gesellschaft, the Darmstaedter und Nationalbank (Danatbank), and the Dresdner Bank. These "big Berlin banks" had connections to an extensive portfolio of firms ranging from small family businesses to large manufacturers such as Siemens.[10] A bank's CEO typically sat on the supervisory board of a firm; when the latter went public, the broker-dealer part of a connected bank was the natural choice for underwriter (Lehmann 2011).[11] In a typical equity offering, the broker-dealer bought the shares at a fixed price and placed them in the market, serving its own clients first. However, broker-dealers did not sell all shares and kept some stocks in their portfolios. This custom was meant to align the incentives of a firm and its bank, as it emphasized the connection and dedication of the bank to its client. Even without a large credit outstanding, the firm's risk was still part of the bank's balance sheet. Yet this balance sheet position was not static because banks were active on the exchange in making markets for stocks of connected firms.[12] Firms expected their broker-dealer to provide this service and to act as a market maker in their stocks. Banks used their capital and their inventory to smooth stock price fluctuations during periods of order imbalances at the Berlin stock exchange (Fohlin 1997). This "important role that banks play in the daily trading" (Prion 1929)

[9] Although these remarks were made prior to WWI, they remained valid in 1931. According to the *Wall Street Journal* of 5 May 1931: "Bank heads hold directorships in scores of companies, and the banks themselves retain holdings in shares they have issues".

[10] These banks were referred to as "big Berlin banks" because each of these banks had their headquarter in Berlin

[11] The close connections between banks and firms are well documented and lend credence to several arguments that such connections stimulated economic growth after the German Reich was founded(Gerschenkron 1962).

[12] In a country that just had experienced times of financial turmoil, investors sought security and stability. Firms seeking to accommodate this need preferred their stock prices to exhibit low volatility. Prices should not fluctuate solely because of market illiquidity and firms believed that a specific trader would keep markets liquid and establish a smoothly functioning price environment.

was an accepted fact at German stock markets and acknowledged by newspapers, books, and stock market manuals.[13] For example, Prion (1929) describes the typical broker-dealer trading behavior as follows:

> At the Berlin Stock Exchange it is impossible that supply and demand match daily. Fluctuations from one day to the other that are based on these imbalances and do not represent the fundamental value can be prevented through the intervention of the connected banker...Through this a constant possibility to sell is assured: the banker takes on excess supply to sell it over time again.

However, this "service of immediacy" (Grossman and Miller 1988) had its limitations. Market–making required broker-dealers to have deep pockets as well as immediately available capital.[14] Various other reasons hindered banks' liquidity provision in cases of occasional supply spills to the market. Mostly, the responsible broker-dealer merely required assurance that no major fundamental event was driving the order book imbalances. Until the broker-dealer was satisfied on that score, traders had to decide whether to follow its lead and thus, perhaps, miss an investment opportunity.[15] If no one provided liquidity, stocks could not be sold at the established market price; markets became illiquid. This illiquidity was reflected in order book imbalances, a measure of liquidity German newspapers reported at this time.[16] Supply order book imbalances are my main measure of illiquidity. The main part of this paper tests whether this measure of a stock's liquidity deteriorated for firms associated with Danatbank after that bank experienced a large exogenous balance sheet shock that strongly affected its broker-dealer's intermediation capital.[17]

[13] The elimination of large fluctuations may have hindered prices to fully reveal all information. But Dang et al. (2013) show that banking is inherently opaque and that this opaqueness can be welfare enhancing. See also Gorton (2013), who describes opaqueness in the US banking system.

[14] Prion notes that "the power of the banker to supervise the stocks is not unlimited. For the execution of his activity he might need considerable capital or rich clients, which are willing to buy the stocks on offer at the moment." *(Prion 1929:64)* Further, unlike specialists at the NYSE, banks were never officially appointed as market makers. They could refrain from providing liquidity or withdraw liquidity altogether without stating a reason for doing so. Their behavior could perhaps best be described as akin to that of traders following a contrarian investment strategy.

[15] "If the connected banker only buys little from a stock with excess supply...then the speculators, who normally always are on the look for an opportunity, do not dare to intervene immediately, even if they themselves think that prices are wrong. " *(Prion 1929)*

[16] Despite the overall goal to keep prices from fluctuating, order imbalances were not symmetric. Few stocks were listed as having excess supply, but excess demand was commonplace because "bankers do not like an excess supply quotation" (Wermert 1907: 636). Wermert (1907) also notes that a bank's objective was to achieve a "high quotation or the quotation of excess demand that at least the stock appears as demanded in the stock price list." In normal times, a broker-dealer would more than satisfy the supply side while taking the risk of unexpected large supply shocks.

[17] The appendix provides an overview of the microstructure of the Berlin Stock Exchange. It also gives an example of banks' interventions in case of order book imbalances.

3.2 Danatbank's shock to funding liquidity

On 11 May 1931, Danatbank discovered that its biggest creditor was on the verge of bankruptcy. The bank did not disclose this information, but its balance sheet capacity and it's trading ability as a broker-dealer were thereby severely constrained.

The Danatbank had grown in importance after its merger with the Nationalbank in 1920. It was now the main lender for several German municipalities and an active underwriter. Its CEO, Jacob Goldschmidt, sat on more than a hundred supervisory boards. He enjoyed the public spotlight, and he made the trading business a top priority when he took over as CEO. Newspaper comments on the Danatbank's active role in the stock market were frequent, and Goldschmidt himself commented on stock market issues in the bank's annual reports. On the corporate business side, the Danatbank's main client was the textile company Norddeutsche Wollkaemmerei und Kammgarnspinnerei, known as Nordwolle. This company was a family firm that had financed its expansion during the interwar period with huge credits from Danatbank. In 1931, Nordwolle had credit of 48 million Reichsmark (RM) outstanding with the bank, a sum that amounted to 80 percent of Danatbank's equity.[18]

During April 1931, Goldschmidt was alerted to the gradual withdrawal of money from German banks by foreign creditors (Ferguson and Temin 2001). If foreign withdrawals were to increase, then the liquidity of Nordwolle's credit would be crucial for Danatbank.[19] Bank employee Max Droehner therefore looked deeper into the books of Nordwolle. What was supposed to be a routine check brought disastrous news for Danatbank. Nordwolle had been falsifying its books since 1925. Most recently it had speculated on the rise of wool prices by purchasing a year's supply, after which wool prices fell. Nordwolle did not disclose the losses and it was on the edge of bankruptcy. Goldschmidt received these devastating news on 11 May 1931. A letter from Droehner confirms that Goldschmidt immediately saw the consequences of Nordwolle's likely bankruptcy: "Nordwolle goes down! Danat goes down! I go down!" The next day, that verbal response was by physical action. When the CEO of Nordwolle came to Danatbank's headquarters Goldschmidt threw a chair at him.[20]

[18] For a more detailed description of the German banking crisis in 1931, see Born (1967).

[19] This suspicion turned out to be true. After the bankruptcy of Nordwolle in June 1931, Danatbank closed its offices at 12 July; that closing set in motion a run on other banks.

[20] A detailed description of these events is given in a letter from Droehner to Georg Solmssen, in 1931 a member of the board of directors of the Deutsche Bank and Disontgesellschaft; that letter is held at the Historical Archive Deutsche Bank, file "Georg Solmssen".

Although angry and fearful, Goldschmidt hesitated to reveal his discovery.[21] In his account of the events, Droehner stresses that Goldschmidt knew immediately the possible consequences if the bad Nordwolle news were to become public. Danatbank owned a huge package of Nordwolle stock and was also extremely susceptible to creditor withdrawals. To save Nordwolle and his own bank, "during the ensuing weeks, Goldschmidt sought desperately to find means of supporting Nordwolle and refused to inform either the Dresdner Bank or the Reichsbank of the situation" (Feldman 1995). The Danatbank committed its financial resources to saving Nordwolle (Feldman 1995); in particular, a large offer of seasoned equity (some 30 million RM) was planned, with Danatbank as a major buyer of the new stock.[22] Further, Danatbank started buying its own stock. If the information about Nordwolle were to become public, Goldschmidt wanted to maintain control of his bank's stock price and prevent it from dropping. The stock price was the predominant indicator of a bank's health and that of its creditors; a precipitous decline relative to other bank stocks would have led to rumors and possibly to revelation of the bank's and Nordwolle's problems. Goldschmidt was afraid to send any kind of negative signal to the market. After informing Danatbank's managerial staff about the Nordwolle fraud, he immediately went to the Berlin Stock Exchange. Goldschmidt's intention was to assure that any panic sales by his colleagues would not be noticed.[23]

This strong commitment of funds to one firm put severe constraints on Danatbank's trading ability. After 11 May 1931, the broker-dealer part of Danatbank was unable to provide liquidity to stocks of all the other firms to which it was connected. Hence this episode provides a setting in which a major trader suffers a large and exogenous shock to its liquidity-providing capacity.

No direct evidence has survived that Danatbank restricted funds to its trading business after it found out about Nordwolle's problems. Even so Danatbank's reactions just described offer indirect evidence that the news about Nordwolle affected the bank's balance sheet and limited its market-making abilities. Furthermore, investment banking was a significant part of any large

[21] That this information was not disclosed is documented in historical sources. The main source is the afore mentioned letter from Droehner to Solmssen. A second source is the commission set up in 1933 to investigate the banking crisis. Another source is my reading of several interregional newspapers, published during this time, in which no news can be found (during May) regarding possible losses at Nordwolle.

[22] In pre-WW II Germany it was common practice for an underwriter to purchase the entire equity offering; only after some time had elapsed would the underwriter start selling the new shares on the stock market. See Fohlin (2010).

[23] The Nordwolle credit amounted to 80 percent of Danatbank's equity. Danatbank was highly leveraged, with a ratio of assets over equity of 38. Jacob Goldschmidt rightfully saw this threat to his asset side as a possible cause for bankruptcy. A further incentive for the Databank to keep the information secret was the possibility of a bank run. Markets were already in an alerted state, a negative signal could easily trigger a bank run. Once the Nordwolle news leaked in July, not only the Databank was affected by runs of depositors, but the whole German banking system.

bank's business—but it was also the most liquid part and so, if money was urgently needed, then this was the business section to supply it.[24] Other ways to finance the Danatbank's role as a liquidity provider can be ruled out. Today banks can finance their trading operations through an interbank market; however, this form of financing was not developed in interwar Germany, where most financing went through the Reichsbank. No evidence can be found of an increase in Danatbank's dealings with the Reichsbank, and neither did Danatbank ask other banks for help. Staring into the abyss in June and asked about the possibility of other banks stepping in, the proud Jacob Goldschmidt responded: "The people in the Mauerstrasse[25] would feel triumphant because they think that I am finished. I will not give them the satisfaction of this triumph."[26] Other banks would have been reluctant to help in any case. Even after the Danatbank's problems surfaced, no other bank offered to rescue it—a failure strongly criticized for example by the main banking union: "The central directorate highly disapproves that the other big banks were not willing to prevent the shortage of cash of the Danatbank and all the related miseries, even with a guarantee of the Reich."[27]

I focus on the month of May and stress that the information on Nordwolle was not disclosed. That the situation remained a secret rules out several scenarios. First, other banks could not step in and provide either credit lines to Danatbank or liquidity to the distressed stocks at the same price that Danatbank had before. The secrecy of Nordwolle's distress also rules out the possibility of other broker-dealers initiating predatory trading schemes (Brunnermeier and Pedersen 2005). With these channels shut down, I can reasonably attribute most of the findings reported here to the shock endured by Danatbank's balance sheet.

Goldschmidt did not succeed with his rescue. On 17 June, Nordwolle published a short note stating that it might face some losses in the near future. In the three weeks of June during which rumors about Danatbank were circulating, creditors withdrew 355 million RM. From this point forward, one can no longer assume that the information about Danatbank's distress was private.

Having supplied the historical background necessary for this case study, in the next section

[24]Between 1928 and 1930, German firms issued securities worth 2.87 billion RM that were intermediated by the five big banks in Berlin. In 1930, the investment banking division accounted for more than half of Danatbank's total revenue. The bank's heavy reliance on this business had its risks: in 1930, Danatbank had to write off stocks worth 10 million RM. In one of the first paragraphs in its annual report, the bank stated that "because of the development of the stock market the bank had to take large responsibilities to take care of the stock market, responsibilities we could not escape from."

[25]The Mauerstrasse was the street where the Deutsche Bank und Discontgesellschaft were located.

[26]Priester (1925), "Das Geheimnis des 13. Juli" p. 25

[27]"Letter of the Zentralvorstand des Allgemeinen Verbandes der Deutschen Bankangestellten, BAr R 43-I/646."

I describe the data used and the construction of a liquidity measure.

4 Data description

This study uses three main data sources: contemporary newspapers for stock market quotes; IPO prospectuses to establish the bank–firm connections; and contemporary books, stock trading manuals, and other archival sources for background information and anecdotal evidence.

The main data source for identifying the bank–firm connections are files from the *Reichskommissar bei der Berliner Börse*, which are held at the German Federal Archives.[28] Nearly 300 files of firms survived World War II; of these firms, 68 were still active in 1931.[29] A firm file contains all prospectuses from the initial public offering and later seasoned equity offerings. A prospectus gives information about the underwriting banks. I use this information to identify firm–bank connections, where a firm is considered to be connected to a bank if it had one or two large banks. This source yields only 14 firms connected to the Danatbank, so I employ a second source—bank annual reports—to augment the sample. From 1927 onward, all Berlin banks reported their underwriting activities of the previous year. If a firm had a public offering during the period 1927–1931, I connect it to Danatbank if that bank was the sole underwriter. This gives an additional 19 firms connected to Danatbank, resulting in a total sample of 87 firms (i.e., 33 connected and 54 not connected to Danatbank).[30] For most of the empirical analysis, bank–firm connections are used to sort stocks into liquidity–provider specific portfolios. Every stock in a given portfolio has a common underwriter bank and therefore a common liquidity provider on the Berlin Stock Exchange. Table 1 provides descriptive statistics of book values and dividends for 1930 by industry, which are taken from firms' balance sheets in 1930. Table 2 shows the number of firms connected to each of the five banks.

I use firms connected to the Danatbank as a treatment group and firms connected to other banks as a control group. Comparing these two subsets (Table 1) shows that firms of the former are slightly smaller in size, though the medians are not statistically different. Because the shock is induced by a firm in the textile industry, it is important that textile companies not be

[28]The files are listed in BAr R 3103 *Abteilung H: Aktiengesellschaften.*

[29]On 3 February 1945, Berlin was attacked by nearly 1000 B-17 bombers of the Eighth Air Force. During this one and a half hour raid, led by Lieutenant-Colonel Robert Rosenthal, the Berlin Stock Exchange burned almost completely down.

[30]Manually entering stock price data for all firms also connected to other banks was not feasible, but all the results in this paper still hold if I use only the smaller sample of firms that were identified via firm prospectuses. The larger sample offers the advantage of enabling comparisons when the sample is restricted to Danatbank–connected firms between such firms as regards their reaction to constrained liquidity provision.

overrepresented in the treatment group. The whole sample includes six textile companies, only one of which is connected to the Danatbank. Firms are disproportionately located in Berlin (in comparison with other German cities), which is reflected in the sample: about one fourth of the firms are situated there. Of the Danatbank-connected firms in the sample, 26 percent are located in Berlin; 24 percent of the other firms are located there. The remaining sample firms are situated all over Germany, with small clusters in the mining area around the river Ruhr. This distribution indicated that the firms in the treatment group are not geographically clustered in such a way that would bias the results.

Daily stock market quotes are from the evening issues of the *Berliner Börsen Zeitung* between 1 November 1930 and 4 June 1931. In addition to prices, the *Berliner Börsen Zeitung* also provides data on order imbalances: each price is followed by a "tag" describing differences in demand and supply. Table 3 summarizes the meanings of these tags.

History dictates the sample's endpoint. Early in June 1931 Danatbank declined a credit to the city of Bremen, and on 5 June a Berlin newspaper published the first negative story about Danatbank. One day later, the newspaper was forced by Danatbank to publish a retraction, but rumors persisted. This situation may have affected the stock prices of firms connected to Danatbank. In order to clearly identify the impact of a shock on the bank's balance sheet, I limit my sample period to the time before 5 June 1931.

Crucial for the analysis is a measure of liquidity. Although there exists no perfect measure, widely used ones include bid–ask spreads, measures of price impact (e.g. Kyle's λ), and negative autocorrelation of returns. Unfortunately, neither bid–ask spreads nor volume data are available for the Berlin Stock Exchange during the period under study. Yet behind all measures of liquidity stands the following question: How hard it is to sell a stock at the current price? When there are large order book imbalances, some traders are unable to fulfill their trading needs. This information is provided by the tags appended to the price quotes in German newspapers. Specifically, the existence of supply order book imbalances at the established price tells us that some sellers were unable to unwind their positions. This conclusion accord with the results of Chordia et al. (2002), who find that "changes in liquidity are strongly associated with order imbalances." My main measure of illiquidity is therefore a dummy variable set equal to 1 if there existed supply order imbalances—that is, for prices tagged "b" or "bb"—and set equal to zero otherwise.

5 A funding liquidity shock and market illiquidity

This section shows the effects of Danatbank's constrained intermediation capital on market liquidity. The frequency of supply order imbalances significantly increased for stocks connected to the Danatbank during May 1931.[31] A difference-in-differences framework provides more evidence that this relationship between constrained intermediation capital and market illiquidity is causal, after which I show that this finding is robust to a wide range of robustness checks.

5.1 Frequency of illiquidity

A first glance at the data reveals how the order book imbalances of firms connected to the Danatbank behaved over time and how this behavior compares with that of firms connected to other broker-dealers. In Table 4, stocks are sorted into portfolios whose constituents have the same liquidity provider; the table shows the percentage of supply and demand order imbalances for each portfolio. After 11 May, the frequency of illiquidity for the Danatbank portfolio nearly triples—rising from 6 percent to 23 percent—while the corresponding frequency for other banks' portfolios does not change significantly.[32] The Danatbank's frequency of demand order imbalances declines after that date from 45 to 21 percent. This decrease can be understood by recalling the quote of Wermert (1907) that "banks had a preference for excess demand." This preference is evidenced by the high frequency of excess demand before May between 21 and 45 percent. Note also that posting limit buy orders ran the risk of being picked off, and once Danatbank became wealth constrained it stopped taking that risk.

Although these descriptive statistics tell us that illiquidity increased on average during May 1931, they say nothing about the timing of that illiquidity. Figure 2 plots the proportion of illiquid stocks in the Danatbank portfolio as compared with the Deutsche Bank portfolio (plotted values are based on a three-day moving average). Although practically identical before May 1931, after that month the number of stocks becoming simultaneously illiquid is much higher for firms connected to Danatbank. This illiquidity was driven mainly by commonality after the Nordwolle–induced shock to Danatbank's balance sheet.[33]

[31] In this paper I treat the terms "illiquidity", "excess supply", and "supply order imbalances" as synonyms and use them interchangeably

[32] Before 11 May, the Danatbank portfolio actually had a slightly lower frequency of supply order imbalances than did the portfolios of other banks. To some extend, this difference reflects the importance that Danatbank CEO Jacob Goldschmidt assigned to the investment banking business.

[33] This conclusion holds also for daily frequencies and not only for three-day moving averages.

5.2 Order imbalances and market illiquidity: Baseline results

An increase in illiquidity and commonality in illiquidty deliver the initial evidence suggesting that the Danatbank's constrained funding liquidity resulted in market illiquidity. In order to undertake a proper assessment of possible causality, I employ a difference-in-differences approach; the treatment group consists of firms connected to Danatbank and the control group consists of all other firms. Were the shares of firms connected to Danatbank more likely to experience supply imbalances because of that broker-dealer's liquidity constraints?

The baseline regression tests whether stocks of firms connected to Danatbank underwent changes in May 1931 as compared with (a) preceding months and (b) the stocks of other firms. I estimate the regression

$$Imbalance_{it} = \beta_1 Danat_i + \beta_2 May_p + \beta_3 (May_p \times Danat_i) + \beta_4 X_{it} + \epsilon_{it} \quad (1)$$

Here $Imbalance_{it}$ is an indicator variable set equal to 1 if the stock of firm i has a supply order imbalance at time t (and zero otherwise). $Danat_i$ is a dummy for firms that are underwritten by no large bank(s) other than Danatbank. May_p is a dummy set to 1 for the period $p = DuringMay$ (after 11 May) and to 0 for the period $p = BeforeMay$. We are mainly interested in β_3, the coefficient for the interaction between the two preceding variables. After corrections for several fixed effects, β_3 captures the variation in illiquidity of the Danatbank portfolio over time and across other portfolios. The matrix variable X includes firm-specific dummies, industry dummies and time dummies.

The main results are reported in Table 5. Qualitatively speaking, these results confirm the findings of the descriptive statistics: the Danatbank portfolio had a significantly higher probability of being illiquid during May 1931. The simple linear probability model predicts that, during May 1931, stocks connected to Danatbank were 15 percent more likely to have supply imbalances than stocks connected to other banks. In light of studies establishing that liquidity and liquidity risk are important pricing factors (Pastor and Stambaugh 2003, Acharya and Pedersen 2005), this amount of increase would have had significant pricing implications once it became known to the market.

These results are based on comparisons of two sets of firms: those connected to the Danatbank and those connected to other banks. Yet averaging over different liquidity providers may have biased the results. If other banks all behaved differently, then the respective effects may have cancelled each other out. To address this concern, I use the complete set of bank–firm connections and create bank-specific dummies for each of the five big banks. I then estimate the following linear model:

$$Imbalance_{it} = \beta_1 \times Bank_i' + \beta_2 May_p + \beta_3 \times (May_p \times Bank_i') + \beta_4 X_{it} + \epsilon_{it}, \tag{2}$$

where $Bank_i$ is a dummy row vector that includes the indicator variables for all five big banks. The coefficients of interest are within the vector β_3, which contains the interaction coefficients of the single banks (β_3^{BHG},$\beta_3^{Commerz}$,$\beta_3^{Deu-Dis}$,β_3^{Danat},$\beta_3^{Dresdner}$). Our prior is that the probability of excess supply should increase for firms connected to Danatbank after 11 May and $\beta_3^{Danat} > 0$. Column (2) of Table 5 gives the results for the interaction terms; the other coefficients are omitted for clarity. In this linear model the point estimate is close to that from the simpler model estimated previously: the probability of imbalances increases by about 17 percent for a firm connected to Danatbank during May 1931. Controlling for firm fixed effects, industry fixed effects, and time fixed effects does not change the results; neither does clustering the standard errors across different groups or controlling for firm size (column 3).[34] Furthermore, the results stay qualitatively equal when a non-linear model is used (Table 6).

The results of the baseline regression are not affected by averaging over different liquidity providers. The same concern might arise along the time–series dimension, so we need to establish that May 1931 was the only exceptional month for the Danatbank portfolio. Towards this end, I perform a stringent test to see whether stocks connected to Danatabank behaved differently only when that bank was constrained. The baseline regression is given by

$$Imbalance_{it} = \beta_1 Bank_i + \beta_2 Month_p + \beta_3 (Month_p \times Bank_i) + \beta_4 X_{it} + \epsilon_{it} \tag{3}$$

Table 5 reports results for the case when $Bank = Danat$ and $Month = May$, but now I estimate this equation for every possible bank–month combination. The results of this placebo test are displayed in Figure 3, which plots the regression coefficient β_3 for each of the possible regressions and shows (on the x-axis) which month was used as the placebo period. In only 6 out of the 35 possible regressions was the interaction's coefficient significantly different from

[34] Because we consider only five banks, it is not feasible to cluster the standard errors at the bank level. Yet firms in the Danatbank portfolio were not clustered geographically or within a given industry, which addresses some of the concerns that make clustering at the bank level desirable.

zero. More importantly, two coefficients stand out. When the regression is performed using Danatbank firms during either May or June, the coefficients are not only significantly different from zero but also significantly larger than all other coefficients in this placebo test.

5.3 Order imbalances and illiquidity: Extensions

The baseline results have established a causal link between Danatbank's reduced funding liquidity and a decrease in market liquidity. This section discusses the robustness of these results to information on firm fundamentals and other factors. It provides a more detailed look at the illiquidity of the Danatbank portfolio and shows which of its constituent stocks inside the portfolio are mainly responsible for the observed illiquidity.

Firms differ in the number of their underwriters. Several firms had two or more large underwriting banks. Even though the lead underwriter had the most responsibility, the other banks also participated in the unofficial market making. I use these observations to strengthen further the finding of illiquidity for Danatbank–connected firms. When the Danatbank was unable to provide liquidity, stocks of firms with an additional underwriter should have exhibited a smaller increase (or none at all) in market illiquidity. To test this hypothesis, I restrict the sample to firms for which Danatbank was one of the main underwriting banks. Table 7 reports the results for a regression of imbalances on a dummy set equal to one only if the Danatbank was the sole underwriter and on the interaction of this dummy with the May dummy (Column 1). Column (2) reports a similar regression in which the dummy variable is set to 1 if a firm had two or three large underwriting banks. Column (3) reports all effects jointly. During May 1931, order imbalances increased only for cases where the Danatbank was the only underwriter; if a firm had one or two additional underwriting banks, the effect vanished. That is, other underwriters were still able to provide market–making services. These results shed light on which firms within the Danatbank portfolio drive the previously reported findings—namely, those firms that were most closely connected to Danatbank.

Brunnermeier and Pedersen (2009) provide further theoretical support for the claim that illiquidity does not affect all stocks alike. In their model, more volatile stocks are more illiquid than less volatile stocks. The reason is that providing liquidity for more volatile stocks requires more capital because the imbalances of more volatile firms are likely to be larger and more frequent. In times of capital shortage, liquidity providers might therefore prefer to concentrate on providing liquidity for less volatile stocks; Brunnermeier and Pedersen (2009) and others call this phenomenon a "flight to quality". In order to test this prediction, I estimate the conditional variance for each stock using a Garch(1,1) model. Using the average before May 1931 of the estimated variances, I separate the stocks into quartiles. Table 10 reports the results of a fixed–effects regression of supply imbalances on the May dummy—performed for each variance quartile separately. In Panel A of this table the sample is restricted to firms connected to Danatbank. The coefficients are increasing over the variance quartiles, and stocks with a higher average variance were more likely to experience illiquidity during May 1931. Neglecting the first (insignificant) coefficient, a simple t-test confirms that the May dummy coefficient for the fourth quartile is significantly different from the coefficients for the second and third quartile. This effect is not evident for firms connected to other banks (Panel B).

One main identifying assumption is that the exogenous shock to Danatbank was unknown to other market participants during May 1931. Bad news about Danatbank could influence investors' outlook about firms connected to the bank, since those firms may find it more difficult to obtain credit from that bank in the future. It is well established among historians that the shock to Danatbank's balance sheet was initially a well-kept secret; however, it is still necessary to rule out firm-specific news, rumors, and speculations. Contemporary newspapers provide at least anecdotal evidence that firm news is not driving the results. Figure 4 shows an accumulated monthly news count for Danatbank firms for the period February–May 1931. News items are counted in the national newspaper *Vossische Zeitung*.[35] No significant difference between May and other months is observed.

No newspaper or weekly publication ran any story on the Danatbank itself during the period in question, and the Danatbank's share price also indicates that the Nordwolle-induced shock was unknown to the public. Figure 5 plots the share prices of all Berlin big banks before and during May 1931. Owing to the fall of the Oesterreichische Credit-Anstalt and some foreign withdrawals, bank stocks as a group trended downward in May. But all prices moved in lockstep and, in the eyes of the market, the Danatbank was no different than other banks. Note that the Danatbank returns are not significantly different from the returns of other banks. Furthermore, Ferguson and Temin (2001) examine bank balance sheets and argue that deposit outflows were

[35] Although the news count is performed on only one newspaper, the resulting graph is representative of other leading national newspapers such as the *Frankfurter Zeitung*, the *Berliner Börsen Zeitung* and the *Berliner Börsen Courier*.

no cause for concern even during May. Early summer 1931 was a turbulent period in Germany. Although Danatbank was the focus of the banking crisis that emerged in June, during May 1931 it was not receiving any special attention. And neither was Nordwolle. The behavior of Nordwolle's stock price was on par with other stocks. Daily returns during May 1931 are not significantly different than returns of other stocks around this time.

Absent firm–specific news, fire sales by Danatbank itself could have been the source of the order imbalances. A huge literature on asset fire sales indicates that a distressed trader might sell his assets at depressed prices.[36] Did the Danatbank sell stocks from its own portfolio, thus making the bank itself the source of the order imbalances? Unfortunately, detailed portfolio data before the 1931 bank crisis is not available.[37] However, the following test suggests that fire sales are not the main cause of the order imbalances.

Accounting standards gave banks ample room to choose which stock price to report in their balance sheets. If a stock price was higher than the nominal value, banks could at most value the stock at its nominal value. But if a price was lower than the nominal value, banks could opt for the lower value or any other price up to the nominal value. Banks normally accounted stocks at their nominal value and devalued them only in extreme cases (as in 1932, after all stocks had severely fallen in value during the second half of 1931). If a bank sold assets below their nominal value, its balance sheet declined; a practice used very rarely. Danatbank's 1930 annual report stresses the bank's reluctance to sell assets at prices below nominal value: "The unusually strong decline at the stock market...prohibited the liquidation of a big part of ongoing transactions." Inspecting the monthly balance sheets of Danatbank establishes that the equity position hardly changed during the first half of 1931.

Assuming that assets were booked at their nominal value, Danatbank should have sold any assets with prices above their nominal value because doing so would have improved their balance sheet position. Conversely, sales of assets at prices below their nominal value would have resulted in balance sheet deterioration. A distressed trader does not want to send such a signal to the market. Given these suppositions, we can test indirectly for the occurrence of fire sales by checking for whether assets priced above their fundamental value exhibited greater imbalances than did other assets in the Danatbank portfolio. For this test, the sample is restricted to stocks

[36] For a recent review of the literature on fire sales, see Shleifer and Vishny (2011).

[37] After 1931, the *Deutsche Revisionsgesellschaft* examined Danatbank more closely, providing a detailed list of the portfolio as of December 1931. One third of the firms connected to the Danatbank were still in the portfolio and so, for two-thirds of the stocks, the possibility of fire sales cannot be ruled out with certainty.

connected to Danatbank. I create a firm–specific dummy set to 1 if the price on 1 November 1930 is greater than the nominal value; the regression results are reported in column (1) of Table 8. The interaction term with the May dummy shows that stocks with higher prices were less likely to see imbalances during the period of financial distress. This result holds also when the price at the beginning of the sample is directly interacted with the May dummy (Column 2). Hence there were nor fire sales of the stocks Danatbank most likely would have sold first.

In view of this indirect test and anecdotal evidence, it is doubtful that fire sales originating with Danatbank were the main drivers of the observed supply imbalances. Order imbalances seem rather to have been driven by demand-side considerations (i.e., funding liquidity). The next section addresses the behavior of asset returns during these times of market illiquidity.

6 Funding liquidity and price reversals

Illiquidity is of substantial interest because of its possible asset pricing implications (see, e.g., Acharya and Pedersen (2005)). This section examines asset price behavior during the period of Danatbank's constrained intermediation capital. Section 6.1 describes the behavior of prices and return volatility of firms connected to the Danatbank and compares this behavior with that of other firms. In Section 5.2 I show that the returns on stocks in the Danatbank portfolio exhibited a high degree of co–movement. Section 5.3 assesses return predictability and demonstrates that when Danatbank was constrained, returns became predictable after days of order imbalances; this is when V-shaped price patterns emerged. Finally, Section 5.4 describes an investment strategy for investing in illiquid stocks. I show that if restricted to Danatbank–connected firms this strategy would have yielded substantial returns during May 1931.

6.1 Prices and volatility

When prices deviate from fundamentals and rebound, volatility increases. This raises investors' uncertainty and renders liquidity risk a main pricing factor (Acharya and Pedersen 2005). After describing the average stock price behavior, this section establishes that in response to increased market illiquidity, stocks connected to the Danatbank became more volatile during May 1931.

Figure 6 displays price indices for two portfolios. One portfolio consists of Danatbank–connected firms; the other portfolio consists of firms connected to other banks. After being normalized to unity as of 11 May, both indices show the same movements. These price indices add to the evidence that the bad news about Nordwolle and Danatbank was unknown at this time. However, an important aspect of prices is not clearly visible in the graph. Whereas the average daily returns during May of stocks within the two portfolios was the same (0.07 percent), the standard deviation differed significantly. For the portfolio of non–Danatbank firms it increased from 0.029 before May to 0.033 during May. In contrast, the standard deviation of returns for the portfolio of Danatbank firms increased from 0.029 to 0.041 during the same time span. Yet it is not only the volatility of the overall portfolio returns that changes; a more important and meaningful statistic is the volatility of returns for a single firm. I therefore calculate the standard deviation for each firm during the periods before May and during May and then compare the averages of Danatbank–connected firms versus other firms. Prior to May, the average standard deviation of daily returns was 0.026 for Danatbank firms and 0.028 for other firms. During May, however, this statistic increases to 0.035 for Danatbank firms but to only 0.029 for other firms.

This volatility is portrayed in more detail by Figure 7, which plots the average firm-specific variance between March and June 1931. The variance is calculated for each firm separately using a Garch(1,1) model, after which averages are taken across the two sets of firms. The graph shows that the return variance of Danatbank–connected and other firms is similar before May 1931. But when the Danatbank is liquidity constrained, the return variance of its connected firms spikes. This sudden increase in short-run volatility is in sharp contrast to papers that look at supply pressure. In papers of index deletions or mutual fund redemptions, prices show V-shaped patterns in the medium run; prices decline and rebound within several months. However, in the short-run prices do not fluctuate as they do in this historical case study.

6.2 Co-movement of returns and the flight to quality

Before moving to the average price behavior of single stocks, this part takes a closer look at how returns co-move. Several empirical studies have shown that, in times of illiquidity, returns co-move across assets and sometimes even across asset classes (Chordia et al. 2000, Chordia et al. 2002, Coughenour and Saad 2004). These findings can be explained via the introduction of a wealth-constrained liquidity provider (Brunnermeier and Pedersen 2009). If the same trader provides liquidity to several assets, they will all be affected by a binding wealth-constraint.

To test for co-movement of stock prices, I estimate firm–specific time–series regressions of excess returns on bank-portfolio returns:

$$r_{i,t} = \alpha + \beta \sum_{j=N_b, j\neq i} r_{j,t} + \epsilon_{i,t} \tag{4}$$

Here $r_{i,t}$ is the excess return of stock i at time t, and N_b is the set of all firms connected to bank b.[38] After obtaining the firm–specific values of β, I calculate the mean across all firms connected to each bank. Table 9 reports the average β–values for two separate periods—namely, before and after 11 May 1931. Stocks connected to Danatbank co-move more so in May than before, a sign of commonality with respect to liquidity. This effect is not present for stocks connected to other banks.

6.3 Return reversals and V-shaped price patterns

The literature on slow–moving capital revolves around the question of why capital sometimes seems reluctant to move immediately to investment opportunities. Empirical studies describe this slow movement of capital in terms of a V-shaped price pattern: prices decline, only to revert after some time (Mitchell et al. 2007). Reversals can occur within minutes, as with the so–called Flash Crash of May 2010, or prices can take months to bounce back (Coval and Stafford 2007, Mitchell et al. 2007, Mitchell and Pulvino 2012).[39] This section establishes that V-shaped price patterns were present in the historical case investigated here. During May 1931, returns of Danatbank firms showed (on average) significant return reversals after days of illiquidity. Order imbalances allowed returns of Danatbank firms to be predictable. That predictability was not possible before May.

Figure 8 shows that, in general, imbalances cannot predict returns. The figure plots the predicted returns after market illiquidity by regressing excess returns r_{it} on a set of lags of the dummy for imbalances; it also shows the parameter estimates and the confidence intervals from the predictive regression. Returns from providing liquidity after supply imbalances are not significantly different from zero. As noted in the introduction, the same conclusion can be drawn for firms not connected to the Danatbank before and after 11 May 1931. However, the shock to the Danatbank's funding liquidity therefore had important pricing implications. Specifically, a

[38] See appendix for the calculation of excess returns.

[39] 6 May 2010, the S&P 500 declined 6 percent within six minutes; it regained its previous level in less than half an hour.

trader could expect on average a daily return of almost 2.5 percent (assuming no trading costs) by purchasing shares of a firm connected to Danatbank after an imbalance was reported.

This predictability persists when the regressions are refined. I estimate the following equation:

$$r_{it} = \alpha + \beta_1(Imbalance_{t-j} \times Danat_i \times May_t) + \beta_2 X_{it} + \epsilon_{it} \quad (5)$$

The term $(Imbalance_{t-j} \times Danat_i \times May_t)$ is the interaction of the supply order imbalance dummy with the Danatbank and the May dummy; it includes several lags. Here X_{it} is a vector that includes all other interactions of the three dummies and also the dummies as single variables. The question is : Are returns are significantly different for firms connected to the Danatbank after a day of order imbalances? Column (1) of Table 11 reports the results. Lagged excess supply predicts significantly negative returns for all stocks. During May, only the stocks of firms connected to Danatbank have more strongly negative returns, which are reversed later on.

So far, I have shown the effects only of supply–side order imbalances. Column (2) of Table 11 reports the predictive regression with excess demand interactions. Unlike the case of supply imbalances, information on demand imbalances cannot be used to predict returns.

6.4 Investing in illiquidity: A contrarian trading strategy

An immediate question that arises from the predictability of returns is how much an investor could have earned by providing liquidity to stocks associated with the Danatbank. Nagel (2012) shows that a contrarian long–short strategy would have yielded high returns during the long-term capital management crisis of 1998 and around the time of the breakdown of Lehman Brothers in 2008. Nagel (2012) argues that a contrarian trading strategy is the natural equivalent of market–making activities, and the returns to such a strategy can be viewed as returns to providing liquidity.[40] This section shows that May 1931 delivered high excess returns to a trader that followed such a strategy.

I construct an "Illiquidity" investment strategy as follows. Buy all stocks one day after a supply imbalance is noted and hold them for one day. The portfolio weight of a single stock is related to the price behavior directly after excess supply was present. The greater the decline in price, the higher the positive weight in the portfolio. Following Nagel (2012), the weight w_{it}

[40] Lehmann (1990) and Lo and MacKinlay (1990) have shown that a contrarian trading strategy delivers positive excess returns.

for stock i at day t is given by

$$w_{it} = -\frac{(R_{i,t}|t-1:\text{Imbalance})}{(\sum_i |(R_{i,t}|t-1:\text{Imbalance})|} \tag{6}$$

Given a supply imbalance, the strategy will go long on a stock after its price declined. The weight is increasing in the absolute size of the price decline.[41]

Figure 9 shows the daily returns and accumulated returns to this strategy for all stocks during the time of the sample. Using the whole sample, the strategy has a mean daily return of minus 0.0013 and a standard deviation of 0.0287. Overall, following such a strategy was not the best investment advice: between November 1930 and June 1931, an investor would have lost about 30 percent of his initial investment. When return reversals occurred for Danatbank firms, I showed that on average a daily return of 2.5 percent could be obtained. Following the "Illiquidity" investment strategy, such daily returns would be rare. Spikes are larger on the downside, so an investor would most likely have lost money following this kind of strategy.

Figure 10 shows the cumulative returns to a more refined version of this investment strategy. Cumulative returns are plotted only for May 1931, and the strategy is now limited to stocks connected to a given liquidity provider. For most bank-specific portfolios, accumulated returns during May are small. But an investor who restricted himself to Danatbank–connected stocks would have made large gains. Following the "Illiquidity" strategy in May and investing only in stocks connected to Danatbank, an investor would have enjoyed a return in excess of 50 percent during a single month.

Given these huge returns and several episodes of price reversals, it is noteworthy that traders failed to deduce that Danatbank was in trouble. However, it was not unusual for banks to refrain from smoothing order imbalances. There were situations before May 1931 where a bank did not provide immediate liquidity, and a number of reasons could explain that behavior. In such cases, "speculators do not always dare to intervene, even if they think the price is not correct" (Prion 1929). Return reversals sometimes occurred for other stocks and also before May 1931. On average, however, returns did not reverse. Therefore, the "Illiquidity" investment strategy will usually deliver negative returns. The situation is different for stocks connected to the

[41] Constructing a weight that depends on the price on day t is feasible because the price discussion was public before the final price was set. Yet when calculating returns to this strategy, I assume that the contrarian trader who follows it has no price impact—in other words, that trader is not the marginal buyer action drives the price up.

Danatbank in May 1931 because many more cases of return reversals can be observed. To show this, I look at those episodes where stocks exhibited supply imbalances and prices declined afterwards; then I group stocks according to the size of their initial price decline. Figure 11 shows box plots of the returns over the two days following such a price decline for each group. All panels show that, after price declines, price reversals did occur. However, in three of the figure's four panels, prices did not reverse on average. Thus a general "Illiquidity" investment strategy yields negative returns. For firms connected to the Danatbank during May 1931, price reversals were much more common. For price decline's of less than 1 percent, prices always rebounded. For price declines of up to 5 percent, prices rebounded in about half of the cases.

A closer look at the official market makers provides further evidence that traders did not learn very fast about the higher frequency of V-shaped price patterns. Official market makers stayed in close contact to bank employees. When banks abstained from liquidity provision, they were the first to know. If price behavior seemed suspicious or the news about Nordwolle had leaked, we would suspect market makers to take larger positions in stocks connected to Danatbank. However, this was not the case during May 1931. After connecting all stocks to their market makers, I use the auditing reports by the Berlin Stock Exchange of the market makers. These reports especially commented on large proprietary trading by market makers. None of the market makers trading Danatbank-firms was suspected to trade heavily for his own account during May 1931.[42]

In sum: this section showed has established that, on average, more supply order imbalances existed for firms connected to the constrained liquidity provider. During times of illiquidity in May 1931, there were significant price reversals. The next section takes a look at the price behavior once traders expected some problems at the Danatbank.

6.5 The aftermath: Order imbalances and price behavior during June 1931

On June 4, Danatbank denied additional credit lines to the city of Bremen. This decision was rapidly picked up by the Basler Zeitung, a Swiss newspaper that stated that Danatbank must be in trouble. Although the editors had to revise their statement under Goldschmidt's pressure, rumors remained. Even excessive buying of own stock by the Danatbank could not prevent the price from decreasing 10 percent during the following two weeks. This section looks at the frequency of oder book imbalances and price behavior of firms connected to the Danatbank during

[42] BAr/R3103-58

June 1931.

After June 4, the frequency of supply order book imbalances for Danat firms declined to 13 percent. This sharp drop in supply imbalances went along with an increase in demand imbalances, which bounced back to 43 percent. These differences in order imbalances are statistically significant, as Table 12 shows. The table reports the results for the baseline regression with supply order imbalances as dependent variable. However, the sample period is restricted to May and June 1931. The dummy for May takes on a value of 1 while the information was private and takes a value of 0 once rumors spread about Danat's problems. For firm connected to Danat, supply order imbalances are significantly higher during May as compared to June. Stocks connected to other banks experienced during June the same frequency of supply spills as before.

Not only did days of illiquidity became less frequent for firms connected to Danatbank, also return reversals disappeared. Figure 12 depicts the average returns after the days with supply order imbalances. On average, returns are upward sloping during the following days. This is in contrast to other firms, which continue to see falling returns after days of illiquidity.

Summarizing, the main effects of Danatbank's constrained liquidity provision disappear once traders have better information about the nature of the imbalances. The next section lays out a simple theoretical model that rationalizes the price behavior during the different regimes – when banks do not face constraints to liquidity provision and when banks are unable to provide this service.

7 A theory of noise trader risk and banks as liquidity providers

The empirical results suggest that during the turbulent times of the Great Depression, a constrained liquidity provider led to greater order book imbalances; prices responded with V-shaped price patterns. While the study shows the causal influence of funding liquidity on market liquidity, it does not show how broker-dealers' market–making service interacted other variables—their own informational trading, and the effect on price volatility and price impact. Based on Kyle (1989), this section therefore describes a static model of asymmetric information and strategic traders. This provides guidance on the effects of the institutional setup in interwar Germany and rationalizes the empirical findings. In the model, better informed broker-dealers trade a risky asset with uninformed traders. Asset supply is random, since noise traders are present. This presence allows banks to hide part of their informational advantage. A broker-dealer demands a risky asset for two reasons: informational trading and market–making. A broker-dealer receives an informative signal about the asset's future dividend before it submits its demand schedule. With this information, a bank makes its informational trading decision. But a broker-dealer also trades for market–making reasons. It is able to extract the noise trading component from prices and intervenes in the market by adding own noise. However, this noise is negatively correlated to noise traders' demand. This intervention is intended to smooth price fluctuations due to noise trading. Over a range of reasonable parameter values, this results in a lower price volatility. However, banks restrict their information-based trading since they take on more demand for market making reasons. Furthermore, the noise component in prices decreases, making banks less able to hide their informational advantage. Information–driven trading decreases further. Examining the reaction of uninformed investors, one can notice that they react less to movements in prices when banks make markets. Prices reflect less noise; a price decrease is more likely to come from bad news about fundamentals. Price impact of noise shocks is higher as compared to a situation where banks do not make markets. Nevertheless, in normal times broker-dealers can effectively counter-balance supply from noise traders and total noise is small. Yet when a broker-dealer cannot intervene in the market, noise trading is not reduced and prices react strongly. Prices are more likely to decrease because of supply shocks, and in repeated trading rounds this effect will vanish and give rise to V-shaped price patterns. The next section describes the model formally. Following the setup, expectation formation is characterized and I provide the definition of the equilibrium in the model. Section 7.2 then shows a numerical example of the behavior of price impact and price volatility and relates the model to the historical case study of the Danatbank in 1931.

7.1 Setup

The model consists of two periods. There are i informed bankers (borker-dealers), o other, uninformed, traders, and noise traders that trade a risky and a risk–less asset in the first period. The risk–less asset pays interest r, normalized to one. The risky asset pays an uncertain dividend d in the second period. d is normally distributed with mean $\overline{d}$ and variance $(\tau_d)^{-1}$. In the first period, trading takes place by a unit price auction. Bankers and traders submit complete demand schedules which depend on their respective information. Noise traders submit aggregate random demand u with $u \sim N(0, \tau_u^{-1})$. The price p of the risky asset is set such that the market clears.

The asset was issued by a specific firm and bankers have a close connection to that firm. This gives them an informational advantage. Before they choose their trading, they observe a signal s about the dividend: $s = d + \epsilon$, where $\epsilon \sim N(0, \tau_\epsilon^{-1})$. Each banker observes the same signal. The close firm–connection introduces the market–making role of broker-dealers (Dang et al. (2013) provide a theoretical reasoning why it can be welfare enhancing that banks with private information try to keep their information secret). While broker-dealers have their own speculative demand (the optimal solution to their utility maximization problem), they commit themselves to decrease the impact of noise trading on prices. This service leads to a market–making demand, which is exogenously given by αz. z follows a normal distribution with $N(0, \tau_z^{-1})$. However, the added noise by the broker-dealer is negatively correlated with noise trader demand u and the correlation is given by the correlation coefficient ρ_{uz}. Given the signal s and the additional market making demand, a broker-dealer's demand function x_i is the sum of the speculative demand x_i^{spec} and the market making demand x_i^{mm}:

$$x_i = x_i^{spec} + x_i^{mm} \tag{7}$$

$$= as + b_i - c_i p + \alpha z \tag{8}$$

Each broker-dealer uses his private signal about the dividend, but takes into account that he has market power and his own trading moves the price against him.

Uninformed traders do not observe the informative signal s. Nevertheless, before submitting a demand schedule x_o, an uninformed trader o observes the price and bases his best estimate of d on the market price p. However, also uninformed traders take their market power into account. Their demand is therefore linear in p:

$$x_o = b_o - c_o p \tag{9}$$

Equipped with the linear demand functions, market clearing closes the model and enables us to derive the following proposition:

Proposition 1 *In equilibrium, the price function is given by* $p = \lambda(bas + ib_i + ob_o + u + i\alpha z)$

and the linear demand functions are given by $x_i = as + b_i - c_i p + \alpha z$ *and* $x_o = b_o - c_o p$.

The appendix derives the exact parameter conditions. However, the proposition shows that the price is a function of $(u + i\alpha z)$. Since u and z are negatively correlated, broker-dealers' market making had the desired effect in normal times: It reduces price impact due to noise trading. The next section however shows that it can also have unintended consequences in terms of price fluctuations when a bank is not able to intervene.

7.2 Price volatility and price impact

This section shows how price impact and market volatility change when broker-dealers not only trade on their information, but also provide liquidity–services. I look at the case of a monopolistic informed trader and set $i = 1$.

Two important parameters influence a broker-dealer's decision to trade for informational reasons. ρ_z determines the correlation between a bank's market making demand and noise trading. α determines how strongly a broker-dealer reacts to noise trading. When a broker-dealer adds additional noise to the market, the effect on a broker-dealer's informational trading (and therefore the informativeness of prices) may be ambiguous. When the additional noise is negatively correlated with u and decreases overall noise $(u - \alpha z)$, a better informed bank is less able to hide its private information since less noise is reflected in prices. This restricts a broker-dealer's informational trading. However, if the correlation is low or the bank's reaction to noise trading is very strong, overall noise in the market increases due to the broker-dealer's market–making service. In this case, the broker-dealer can hide behind noise and trades more aggressive. Whether a broker-dealer's market–making demand increases or decreases informational trading depends therefore on the combination of α and ρ_z. How strong uninformed investors react to movements in prices also depends on the overall level of noise in the market. When a broker-dealer's market–making activity effectively decreases overall noise and price volatility, price fluctuations are more likely to reflect changes in fundamentals; uninformed traders will react less to fluctuations in prices. It is more risky to take on additional stocks and uninformed investors must be compensated by higher expected returns.

The interplay of these effect on price volatility and price impact can be seen in Figure 13. The figure plots price volatility and price impact in equilibrium as functions of α. The functions are plotted for different values of ρ_z, and the left panel shows price volatility as a function of

α, the right panel shows price impact as a function of α. The bank is better able to decrease volatility for a large range of its taste parameter α if the negative correlation between u and z is stronger. But this decreases its incentives to trade on the basis of private information. The broker-dealer decreases its informational demand and uninformed traders react less to fluctuations in the price—the price impact of noise trading increases. In normal times, however, fluctuations due to noise trading are still low because overall noise, the difference between u and αz, is small. A problem arises if a broker-dealer is suddenly unable to provide its market–making services. In this case ,z is equal to zero, and a noise shock hits the market in its full size because liquidity provision is absent. As a result, prices react strongly. Other market participants are unaware of the real reason why banking demand is so low and attribute most of the price decline to a decline in fundamentals. Prices have to fall strongly since traders need to be compensated for the increase in risk with high expected returns.

What do these results mean in light of the German stock market before WW II? The decrease in price volatility rationalizes the findings of DeLong et al. (1990). Unlike the US market, excess volatility was not present on the German stock market. DeLong et al. (1990) already speculated that the low volatility is related to the banks' role in trading. The model shows that for a reasonable range of parameters, banks were able to provide liquidity to noise traders; they could reduce volatility because they were better informed. Yet this increased the price impact of noise shocks, and when a bank is suddenly unable to counteract noise trading, this effect becomes relevant. The shock to Danatbank's funding liquidity was such a situation. The model predicts that during the period when Danatbank is unable to provide marke–making services, price impact and price volatility are high. It can rationalize why Danatbank–connected stocks were more illiquid during May 1931. Prices were mainly driven by noise trading, but for other investors to buy them, expected returns had to increase. In a repeated trading game, V-shaped price patterns were more likely to occur.

8 Conclusion

Although V-shaped price patterns came into the spotlight during the recent financial crisis, they are hardly novel. One explanation for the slow–movement of capital is limited funding liquidity – a hypothesis that is difficult to test in today's markets. This paper turns to the Great Depression where a large, exogenous shock to a liquidity provider's balance sheet can be cleanly identified. Furthermore, in this particular context the role of liquidity providers is clearly assigned. One of them, the Danatbank, faced a major shock to its capacity to provide liquidity. I show that this shock directly affected the market liquidity of the stocks of firms connected to Danatbank. During the period of constrained intermediation capital, these stocks were highly likely to experience supply order book imbalances, and it is around these times that we observe V-shaped price patterns. The findings are rationalized by a model, which follows Kyle (1989), where informed traders exploit their informational advantage. Such traders also provide market–making services for a specific stock and thereby reduce the noise that prices reflect. At the same time price impact increases. When the market–making function cannot be performed, the effect of noise trading on prices increases and leads to sharp price declines.

The study provides a clear example of funding illiquidity causing market illiquidity. Of course, today's markets are different from the Berlin Stock Exchange during the interwar period. The rise of algorithmic trading, the emergence of several trading venues, and other differences limit the applicability of this study's quantitative results to the present. Even so, this paper contributes to the discussion of whether funding liquidity is important for asset pricing by showing that such liquidity did matter in an institutional setting with universal banks and a well–developed stock exchange. The research reported here supplements the suggestive evidence from the recent financial crisis and provides further support for the view that liquidity providers' balance sheets can influence asset markets.

The study speaks also to the current debate over the dangers of universal banking. The Danatbank experienced a balance sheet shock because a creditor was in distress. Although not related to the bank's trading business, this shock led to illiquidity and price fluctuations on the stock market. Nowadays, JP Morgan Chase's CEO Jamie Dimon wants his bank to be "like Wal-Mart", [43] and Bank of America's CEO Brian Moynihan believes that universal banking is the "most important model there is because it gives consumers access to global information, capital markets, investment advice, and basic banking activities all in one place."[44] Neither CEO addresses the risks of these "financial supermarkets." The arguments in favor of the Glass-Steagall Act were based on conflicts of interest (Kroszner and Rajan 1994). When commercial banks are involved in securities trading, their financial advice might be driven by prospects of high profits for the investment department. As Glass-Steagall eroded, discussion

[43] "America's Least Hated Banker." New York Times,1 December 2010
[44] Forbes.com (21 May 2012)

about the dangers of universal banks was conspicuously absent. However, the recent financial crisis has brought it back to life. Reports on banking reform by Sir John Vickers[45] and Erkki Liikanen[46] suggest "ring-fencing" the deposit taking business of a universal bank. Others, like former Bank of England Governor Mervin King, go one step further. They advocate breaking up investment banking and deposit banking. The experience of Danatbank is one example of these concerns. This paper shows that the arguments in favor of universal banking come with certain risks attached. Economies of scope and diversification are useful only as long as cash flows remains relatively uncorrelated. In the German stock market, banks traded actively in stocks of connected firms; hence payoffs from the investment business and corporate credit business were highly correlated. Private information is also often advanced as an argument in favor of large financial intermediaries. In the context in this paper, private information enables the bank to reduce price volatility. Yet the presence of information asymmetries increases the price effect and restrains the activities of uninformed traders. This dynamic calls into question whether universal banking is actually welfare improving. Note also that the mixture of deposit taking, mortgage business, corporate loan business, and investment banking entails more risk that a bank's funding liquidity will be constrained. A bank's balance sheet can deteriorate for myriad reasons, any of which can lead to asset price fluctuations.

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Tables and Figures

Table 1: **Sample balancedness** This table gives summary statistics and an overview of the composition of the sample. The sample is divided in two groups: firms connected to the Danatbank (Danat firms) and firms connected to other banks (Other firms). For each industry, the tables provides the number and percentage of firms within a group, and the median total book value. For firms in the finance industry, book values are not available. The differences in median book value are tested for statistical significance using a Wilcoxon rank sum test. None of the tests shows statistically significant differences between the two groups.

	Danat firms	Other firms	Difference
		Manufacturing	
No .of firms	19	37	-18
% in group sample	57.58	68.52	-10.94
Median book value (Mio RM)	34.1	52.4	-18.3
		Mining	
No. of firms	6	10	-4
% in group sample	18.18	18.52	-0.34
Median book value (Mio RM)	83.8	56.1	27.7
		Utilities	
No. of firms	4	5	-1
% in group sample	12.12	9.26	2.86
Median book value (Mio RM)	44.2	79.3	-35.1
		Finance	
No. of firms	4	0	4
% in group sample	12.12	0	12.12
Median book value (Mio RM)	n.a.	n.a.	
		Geographical location	
No. of firms located in Berlin	9	13	-4
% in group sample	26	24	2

Table 2: **Number of bank-firm connections.** This table provides an overview of how many firms in the sample are matched to one of the five big banks located in Berlin. A firm is connected to a bank when the latest equity issue before 1930 was done by this bank. A firm-bank connection is only established when the firm had at most two big underwriting banks. The big underwriting banks are the Berliner Handels Gesellschaft (BHG), Commerzbank (Commerz), Deutsche Bank und Discontogesellschaft (Deu-Dis), Darmstaedter und Nationalbank (Danatbank), and Dresdner Bank (Dresdner). Data to establish firm-bank connections comes from firm prospectuses and annual reports held at the German Federal Archives.

	BHG	Commerz	Deu-Dis	Danat	Dresdner
Firms	6	5	25	33	6

Table 3: **Price tags about order imbalances.** This table provides an overview of the possible price tags about order imbalances. The official stock price list printed in newspapers reported whether supply or demand order imbalances existed after the stock price had been set by the official market maker.

Abbreviation	Explanation
bz	no imbalances between demand and supply
bz B	supply was higher than demand
bz G	demand was higher than supply
B	supply was much higher than demand
G	demand was much higher than supply

Table 4: **Market illiquidity: Frequency of order book imbalances.** This table provides the average percentage of stocks having supply or demand order imbalances for a given bank-portfolio. A bank-portfolio consists of firms connected to the bank. Averages are taken over all firms and the time period between 1 November 1930 and 11 May 1931 (Before May 11) and between 11 May 1931 and 4 June 1931 (After May 11). Supply (demand) order imbalance is measured by a dummy which is one if the stock price list indicates supply (demand) order imbalances.

	Supply order imbalance		Demand order imbalance	
	Before May 11	After May 11	Before May 11	After May 11
BHG	0.09	0.11	0.21	0.14
Commerz	0.13	0.13	0.38	0.35
Deu-Dis	0.10	0.15	0.31	0.30
Danat	0.06	0.23	0.45	0.28
Dresdner	0.10	0.16	0.29	0.33

Table 5: **Baseline results.** This table provides the results for OLS regressions of the imbalance dummy as dependent variable on a set of dummy variables. The regression for the linear model is

$$Imbalance_{it} = \beta_1 \times Bank_i' + \beta_2 \times May_p + \beta_3 \times (May_p \times Bank_i') + \beta_4 X_{it} + \epsilon_{it}$$

$Imbalance_{it}$ is a dummy set to 1 if firm i has a supply order imbalance at day t and set to 0 otherwise. $Bank_i$ is a row vector including all bank dummies. In the specifications in Column (1), $Bank_i = Danat_i$, which is an indicator variable equal to 1 if firm i is connected to the Danatbank. In the other specifications, $Bank_i$ includes dummies for all five big banks. May_p is a dummy set to 1 after 11 May. The dummy varies over the periods $p \in \{BeforeMay, DuringMay\}$. The coefficients of interest are within the vector β_3. For the specification in column one, $\beta_3 = \beta_3^{Danat}$. For all other specifications $\beta_3 = (\beta_3^{BHG}, \beta_3^{Commerz}, \beta_3^{Deu-Dis}, \beta_3^{Danat}, \beta_3^{Dresdner})$. All standard errors are clustered at the firm level.

	(1)	(2)	(3)
May×*Danat*	0.158***	0.167***	0.181***
	(0.0438)	(0.0470)	(0.0507)
May×*BHG*		-0.0147	-0.0162
		(0.0319)	(0.0394)
May×*Commerz*		-0.00133	-0.0131
		(0.0423)	(0.0553)
May×*DeuDis*		0.0227	0.0300
		(0.0380)	(0.0386)
May×*Dresdner*		0.0342	0.0410
		(0.0449)	(0.0441)
Time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Size			Yes
Size×*May*			Yes
N	15138	15138	15138
R^2	0.128	0.128	0.130

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 6: **Logit results.** This table provides the results for logit regressions of the imbalance dummy on a set of dummy variables. The dependent variable of the logit model is $Imbalance_{it}$, a dummy set to 1 if firm i has a supply order imbalance at day t. Independent variables are $Bank_i$, a dummy row vector including bank dummies. In the specification in Column (1), $Bank_i = Danat_i$, which is a dummy equal to 1 if firm i is connected to the Danatbank. In the other specifications, $Bank_i$ includes dummies for all five big banks. May_p is a dummy that is one after 11 May. The dummy varies over the periods $p \in \{BeforeMay, DuringMay\}$. The coefficients of interest are within the vector β_3. For the specification in column one, $\beta_3 = \beta_3^{Danat}$. For all other specifications $\beta_3 = (\beta_3^{BHG}, \beta_3^{Commerz}, \beta_3^{Deu-Dis}, \beta_3^{Danat}, \beta_3^{Dresdner})$. The same variable description applies for the non-linear regression results. All standard errors are clustered at the firm level.

	(1)	(2)	(3)
May×$Danat$	1.662***	1.887***	2.029***
	(0.327)	(0.472)	(0.494)
May×BHG		-0.269	-0.314
		(0.223)	(0.313)
May×$Commerz$		0.0581	0.0172
		(0.470)	(0.485)
May×$DeuDis$		0.472	0.501
		(0.443)	(0.466)
May×$Dresdner$		0.180	0.219
		(0.367)	(0.391)
Time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Size			Yes
Size×May			Yes
N	14616	14616	14616
Pseudo R^2	0.158	0.159	0.159

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 7: **Danat-firms: Single underwriter vs. additional underwriters.** This table provides OLS results for regressions using the imbalance dummy as dependent variable:

$$Imbalance_{it} = \beta_1 OnlyDanat_i + \beta_2 May_p + \beta_3 (May_p \times OnlyDanat_i) + \beta_4 X_{it} + \epsilon_{it}$$

$Imbalance_{it}$ is a dummy set to 1 if firm i has a supply order imbalance at day t. In Column (1), the dummy $OnlyDanat_i$ is equal to 1 if the Danatbank is the single underwriter of a given firm and is equal to 0 otherwise. Column (2) shows the results of the same regression, but using the variable $Danat + other_i$ instead of $OnlyDanat_i$ as explanatory variable. The variable $Danat + other$ is 1 if the Danatbank is part of an underwriter team of two or three big banks. All standard errors are clustered on the firm level.

	(1)	(2)	(3)
May×*OnlyDanat*	0.166***		0.167***
	(0.0227)		(0.0289)
OnlyDanat	0.0173		0.0172
	(0.0260)		(0.0261)
May	-0.00886	0.109*	-0.00969
	(0.0626)	(0.0637)	(0.0665)
May×$Danat + Other$		-0.117***	0.00140
		(0.0220)	(0.0275)
Danat+other		-0.0224	-0.000144
		(0.0259)	(0.0228)
N	9396	9396	9396
R^2	0.101	0.095	0.101

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 8: **Danat-firms: Imbalances and initial price level.** This table provides the results of OLS regressions of the imbalance dummy as dependent variable on price variables at the beginning of the sample:

$$Imbalance_{it} = \beta_1 Pricevar_i + \beta_2 May_p + \beta_3 (May_p \times Pricevar_i)$$

$Imbalance_{it}$ is a dummy set to 1 if firm i has a supply order imbalance at day t, $Pricevar_i$ is either the variable *Price above nom. value* or the variable *Price at* t_0. The variable *Price above nom. value* is a dummy equal to 1 if a firm had a price at the beginning of the sample that was above 100 percent and equal to 0 otherwise. The variable *Price at* t_0 is the price at the beginning of the sample. The sample is restricted to firms connected to the Danatbank. All standard errors are clustered on the firm level.

	(1)	(2)
Price above nom. value	0.0138*	
	(0.00752)	
May×(Price above nom. value)	-0.133*	
	(0.0727)	
May	0.151	0.227*
	(0.118)	(0.130)
Price at t_0		-0.00145***
		(0.0000520)
May×(Price at t_0)		-0.00131**
		(0.000503)
N	5742	5742
R^2	0.150	0.155

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 9: **Return co-movement.** This table provides the average β of firm-specific regressions of supply imbalances on bank-portfolio returns:

$$r_{it}^{exc} = \alpha + \beta r_{bt}^{exc}$$

r_{it}^{exc} are excess returns of firm i at time t and r_{bt}^{exc} are the excess returns of all other stocks connected to the same liquidity provider at day t. This regression is done for all firms i separately. All regressions are done for each firm once using the sample before 11 May 1931 and once using the sample after 11 May 1931. β's are then averaged across all firms connected to the same liquidity provider.

	β (Before May 11)	β (After May 11)
BHG	0.708	0.768
Commerz	0.595	0.362
Deu-Dis	0.934	0.815
Danat	0.774	0.983
All (except Danat)	0.964	0.917

Table 10: **Imbalances across variance quartiles.** This table provides the results for the following regression using the imbalance dummy as dependent variable:

$$Imbalance_{it} = \beta_1 May_p + \beta_2 X_{it} + \epsilon_{it}$$

$Imbalance_{it}$ is a dummy set to 1 if firm i has a supply order imbalance at day t. May_p is a dummy equal to 1 after 11 May. The dummy varies over the periods $p \in \{BeforeMay, DuringMay\}$. The sample changes across the columns: For each stock, the variance up to May 1931 is calculated using a Garch(1,1) model and taking the average over the conditional variances. Stocks are then sorted into quartiles according to their average conditional variance. Panel A provides the results for firms connected to the Danatbank, Panel B for other banks.

	(1) First quantile	(2) Second quantile	(3) Third quantile	(4) Fourth quantile
Panel A: Firms connected to the Danatbank				
May	0.154	0.0991**	0.101	0.319**
	(0.0885)	(0.0345)	(0.0555)	(0.102)
Constant	0.0434***	0.0329***	0.0585***	0.104***
	(0.00915)	(0.00357)	(0.00574)	(0.0106)
N	1566	1392	1392	1392
R^2	0.048	0.022	0.016	0.083
Panel B: Firms connected to other banks				
May	-0.00290	0.0166	0.0704**	-0.0460
	(0.0320)	(0.0274)	(0.0273)	(0.0567)
Constant	0.0902***	0.0646***	0.0884***	0.166***
	(0.00331)	(0.00283)	(0.00282)	(0.00587)
N	2436	2262	2436	2262
R^2	0.000	0.000	0.005	0.002

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 11: **Return predictions.** This table presents the results for predictive return regressions of excess returns as dependent variable on a liquidity provider dummy, May dummy, various lags of the supply or demand order imbalance dummy, and the interactions:

$$r_{it}^{exc} = \beta_1 Danat_i + \sum_{s=t-4}^{t-1} (\beta_{2,s}(Imbalance.X_{i,s}) + \beta_{3,s}(Imbalance.X_{i,s} \times Danat_i \times May_p)) + \beta_4 \times May_p$$

r_{it}^{exc} is the excess return of firm i at day t, $Danat_i$ is a dummy that is 1 if firm i is connected to the Danatbank, and May_t is 1 after 11 May. The dummy varies over the periods $p \in \{BeforeMay, DuringMay\}$. $Imbalance.X$ is a dummy for order imbalances, where X is equal to supply in the first specification and X is equal to demand in the second specification. For better readability not all coefficients are reported.

	(1)	(2)
	X=Supply	X=Demand
Imbalance.X$\times May \times Danat(t-1)$	-0.0191	0.0117
	(0.0207)	(0.0130)
Imbalance.X$\times May \times Danat(t-2)$	0.0249	-0.0156
	(0.0159)	(0.0122)
Imbalance.X$\times May \times Danat(t-3)$	0.0196	-0.00790
	(0.0190)	(0.0137)
Imbalance.X$\times May \times Danat(t-4)$	-0.0266*	0.00883
	(0.0155)	(0.0110)
Imbalance.X (t-1)	-0.00314	0.00572***
	(0.00236)	(0.00146)
Imbalance.X (t-2)	0.00135	-0.00160
	(0.00254)	(0.00137)
Imbalance.X (t-3)	-0.00172	0.000104
	(0.00220)	(0.00141)
Imbalance.X (t-4)	0.00152	-0.00224
	(0.00236)	(0.00141)
N	3639	3639
R^2	0.009	0.013

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 12: **Supply order imbalances during May/June.** This table provides the results for OLS and Logit regressions of the supply imbalance dummy as dependent variable on a set of dummy variables. The regression for the linear model is

$$Imbalance_{it} = \beta_1 \times Bank_i' + \beta_2 \times May_p + \beta_3 \times (May_p \times Bank_i') + \beta_4 X_{it} + \epsilon_{it}$$

$Imbalance_{it}$ is a dummy set to 1 if firm i has a supply order imbalance at day t and set to 0 otherwise. $Bank_i$ is a row vector including all bank dummies. In the specifications in Column (1), $Bank_i = Danat_i$, which is an indicator variable equal to 1 if firm i is connected to the Danatbank. In the other specifications, $Bank_i$ includes dummies for all five big banks. May_p is a dummy set to 1 between May 11 and June 4 and set to 0 between June 5 and June 28. The dummy varies over the periods $p \in \{May, June\}$. The coefficients of interest are within the vector β_3. For the specification in column one, $\beta_3 = \beta_3^{Danat}$. For all other specifications $\beta_3 = (\beta_3^{BHG}, \beta_3^{Commerz}, \beta_3^{Deu-Dis}, \beta_3^{Danat}, \beta_3^{Dresdner})$. All standard errors are clustered at the firm level.

	(1) OLS	(2) OLS	(3) Logit	(4) Logit
May*Danat	0.0922**	0.0921**	0.903**	0.920*
	(0.0435)	(0.0431)	(0.411)	(0.477)
May*BHG		0.0355		0.442
		(0.0442)		(0.466)
May*Commerz		0.00691		0.0632
		(0.0733)		(0.702)
May*DeuDis		-0.0109		-0.0376
		(0.0350)		(0.415)
May*Dresdner		0.0256		0.176
		(0.0830)		(0.670)
Time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
N	3306	3306	2964	2964
R^2	0.205	0.205		

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Figure 1: **Average returns after order imbalances: Danatbank firms and other firms** This graph plots the average excess returns after days of supply order imbalances. The sample is split in firms connected to the Danatbank (upper panels) and firms connected to other liquidity providers (lower panels). For each sample, expected returns are shown for the period before May (1 November 1930–10 May 1931) and after 11 May (11 May 1931–4 June 1931).

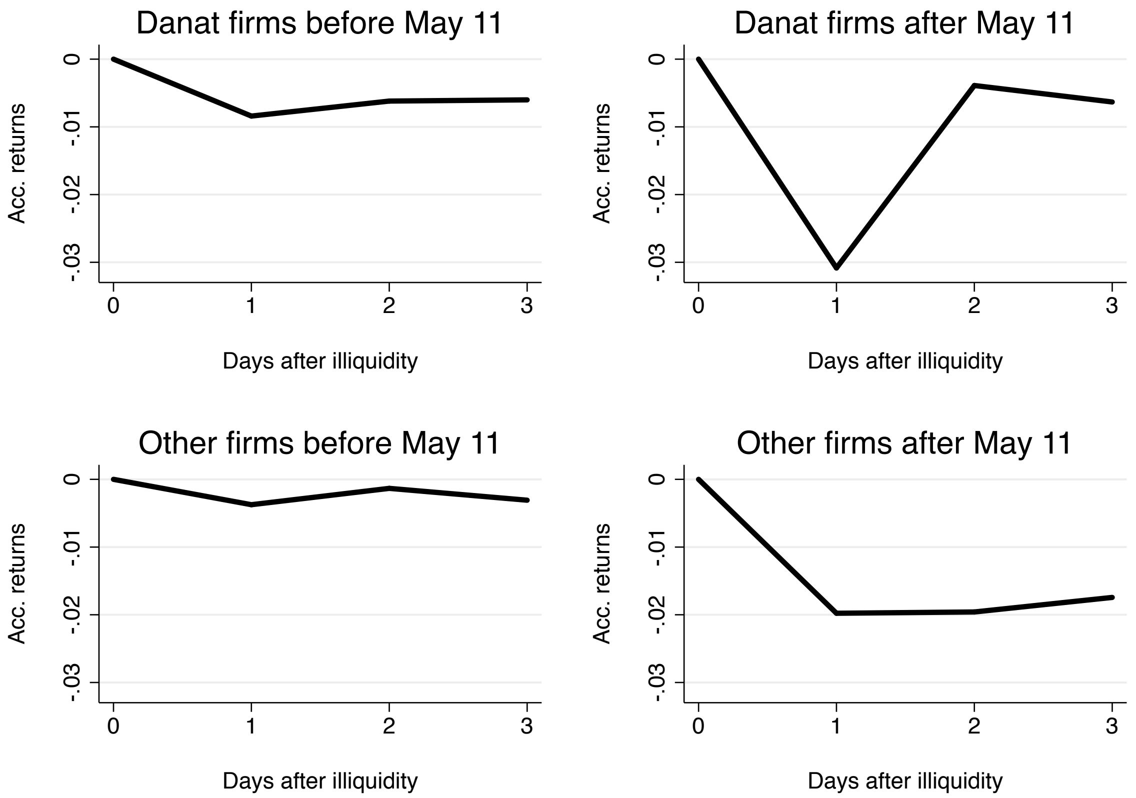


Figure 2: **Order imbalances: Deutsche Bank vs. Danatbank firms.** This graph plots the average percentage of stocks with supply order imbalances for the current and the last two days between 1 November 1930 and 1 June 1931. Stocks are either from firms connected to the Deutsche Bank or firms connected to the Danatbank. The vertical line represents 11 May 1931.

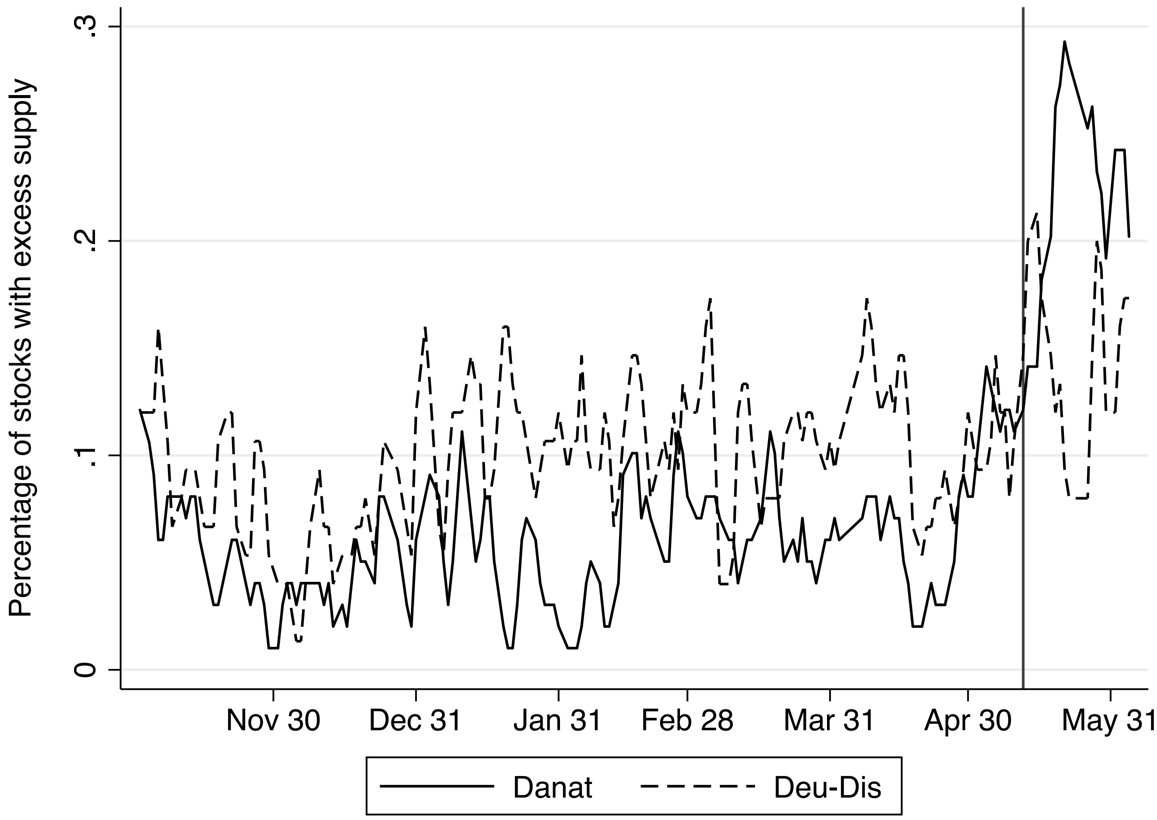


Figure 3: **Order imbalances: Placebo test.** This graph plots the coefficient of the interaction term of the following regressions:

$$Imbalance_{it} = \beta_1 Bank_i + \beta_2 Month_p + \beta_3 (Month_p \times Bank_i) + \beta_4 X_{it} + \epsilon_{it}$$

$Imbalance_{it}$ is a dummy that is 1 if firm i has a supply order imbalance at day t. $Bank_i$ is a dummy that is 1 if firm i is connected to the specific $Bank$. May_p is a dummy that is 1 after 11 May. The dummy varies over the periods $p \in \{BeforeMay, DuringMay\}$. The regression is performed for each combination of $Month \in \{Nov1930, \ldots, May1931\}$ and $Bank \in \{BHG, Commerz, Deu-Dis, Danat, Dresdner\}$. The graph plots β_3 for each bank–month combination.

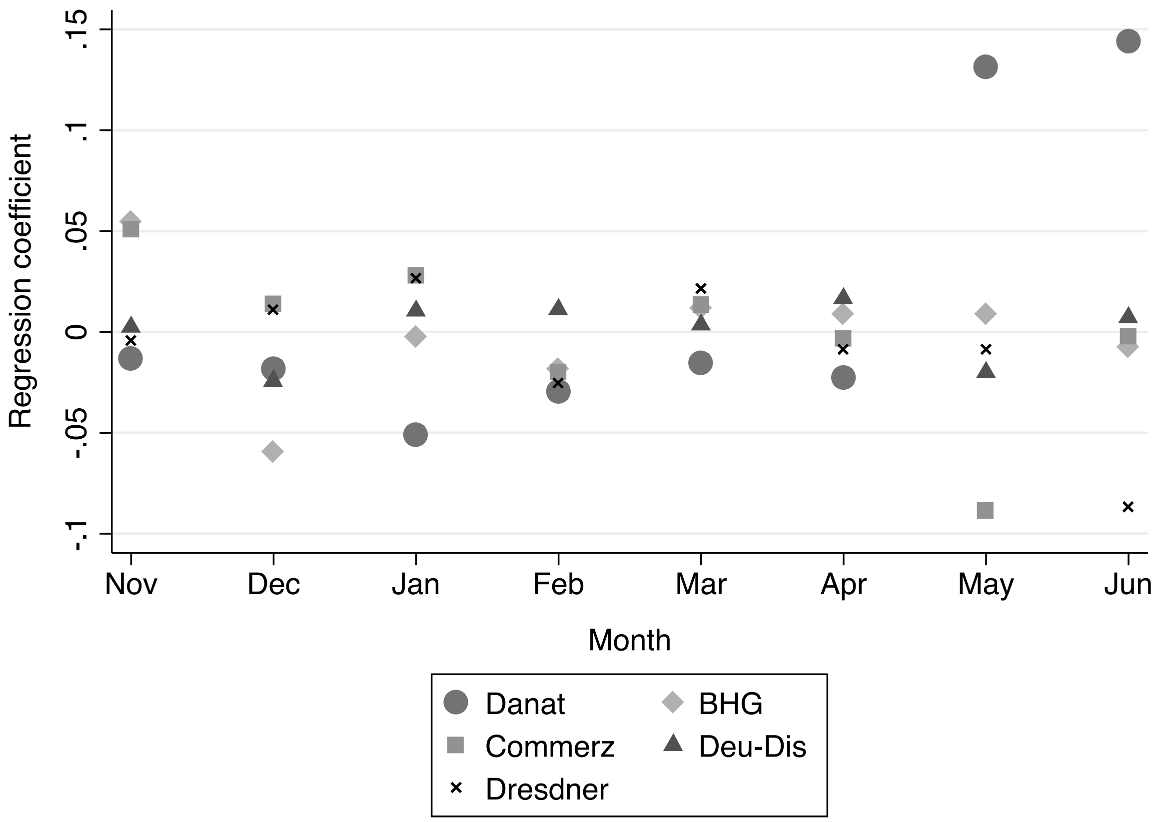


Figure 4: **News about Danatbank-firms.** This graph plots a news count for Danatbank–connected firms during a given month, performed using the *Vossische Zeitung*. The number of news items is shown as a ratio over the total number of Danatbank–firms in the sample.

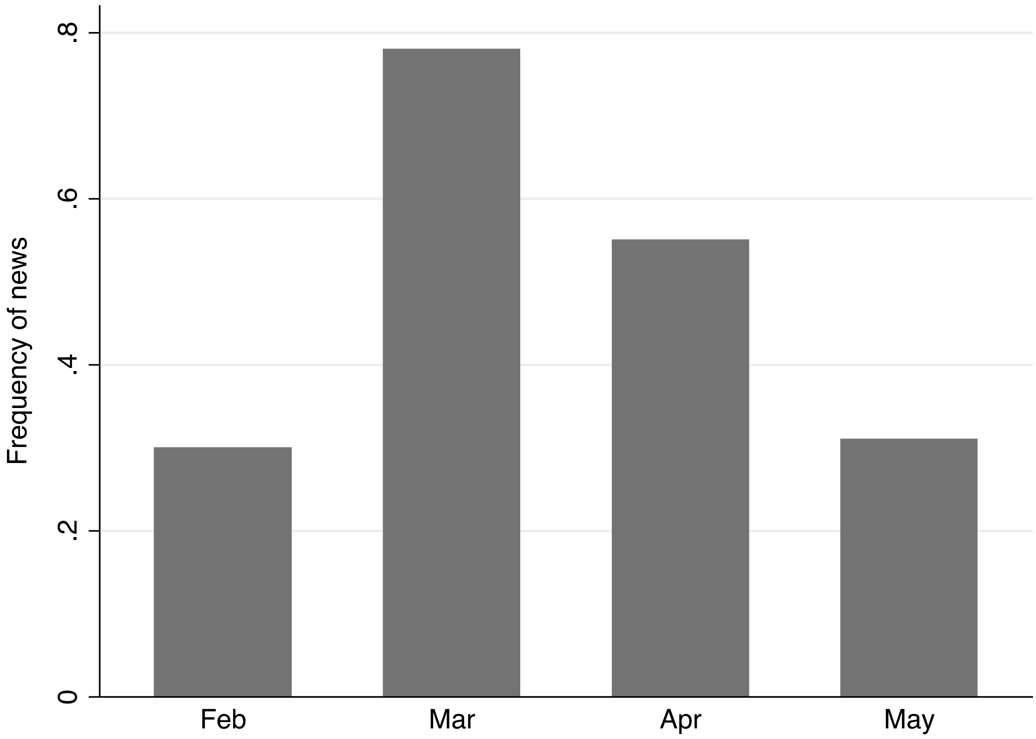


Figure 5: **Banks' stock prices.** This graph shows the evolution of the stock prices of the big Berlin banks between 1 February 1931–4 June 1931. Stock prices are normalized to 100 at 11 May 1931. Data is taken from the official stock price list published daily in the *Berliner Boersen Zeitung*. The vertical line represents 11 May 1931.

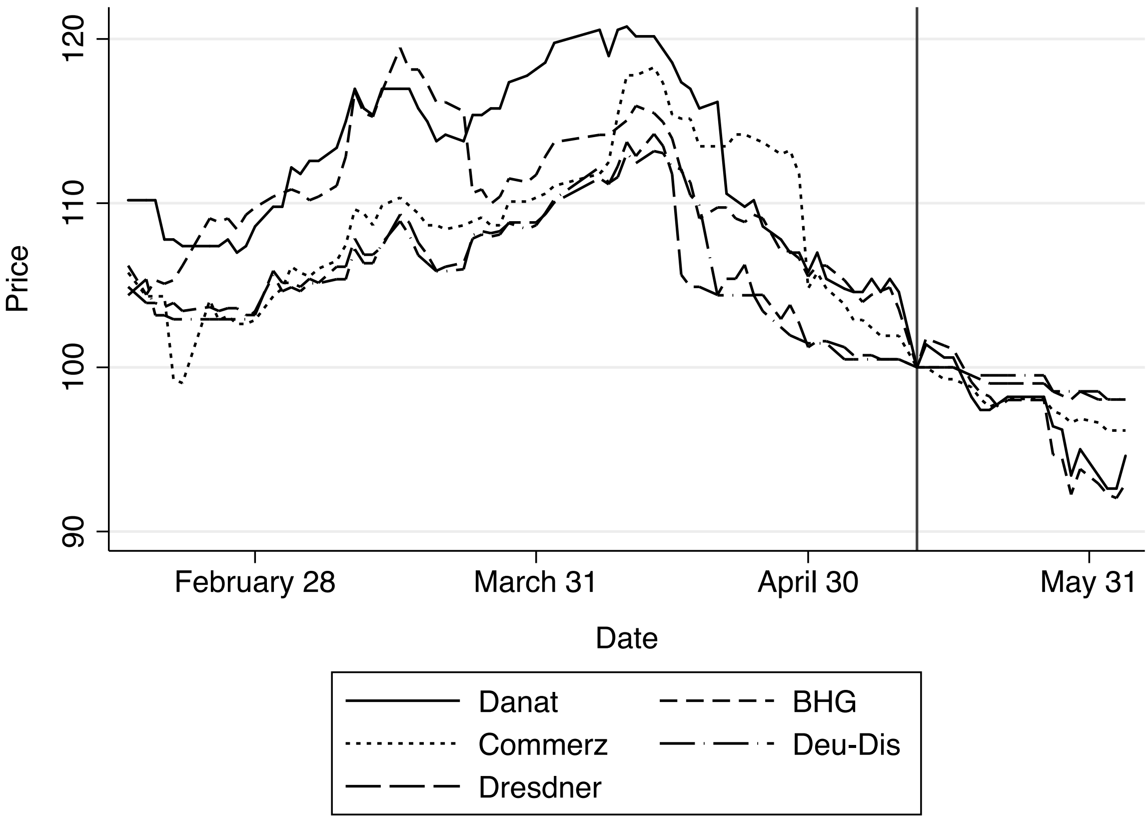


Figure 6: **Price indices.** This graph shows price indices for a portfolio of Danatbank firms and a portfolio of other firms. Daily portfolio returns are calculated as the average return across firms. The indices are normalized to 100 at 11 May 1931. The vertical line represents this date.

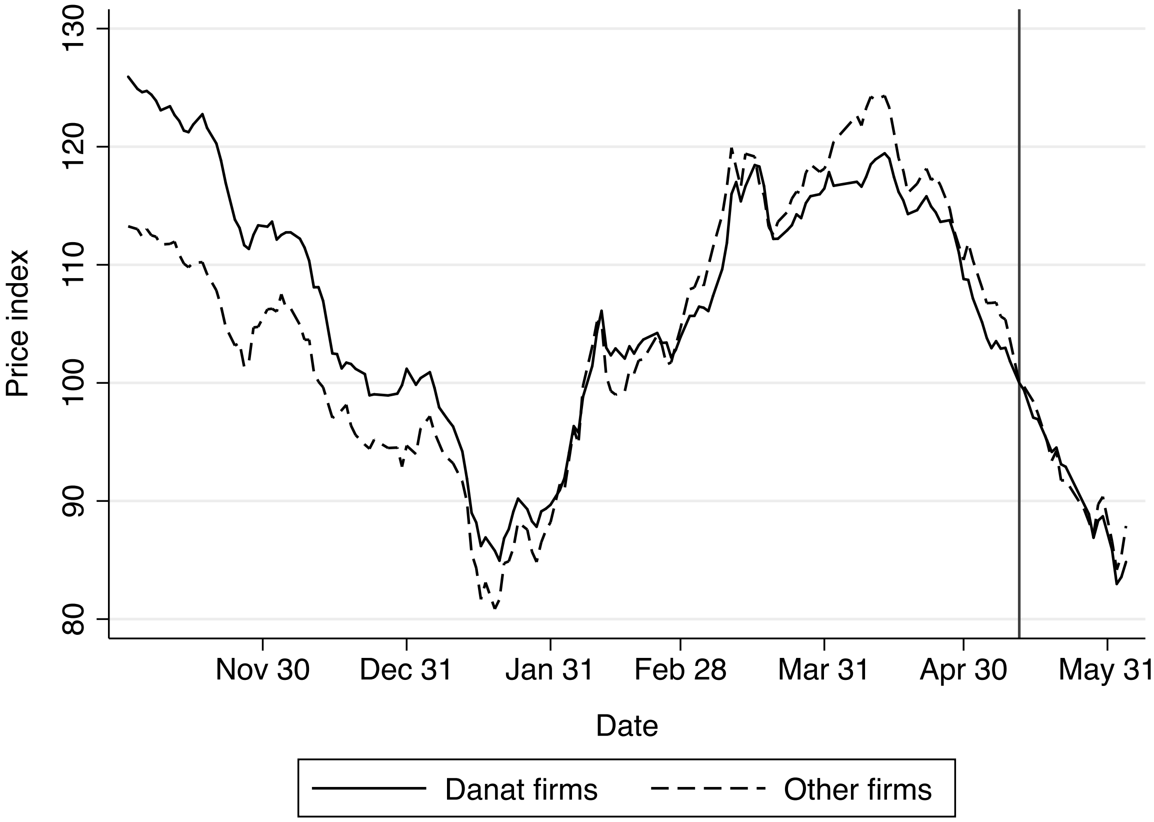


Figure 7: **Volatility.** This graph plots the average variance of firm-specific returns for firms connected to the Danatbank and for other firms. For each firm, the variances are calculated using the residual of a Garch(1,1) model. Then averages are taken across firms, once across firms connected to the Danatbank and once across other firms. The vertical line represents 11 May 1931.

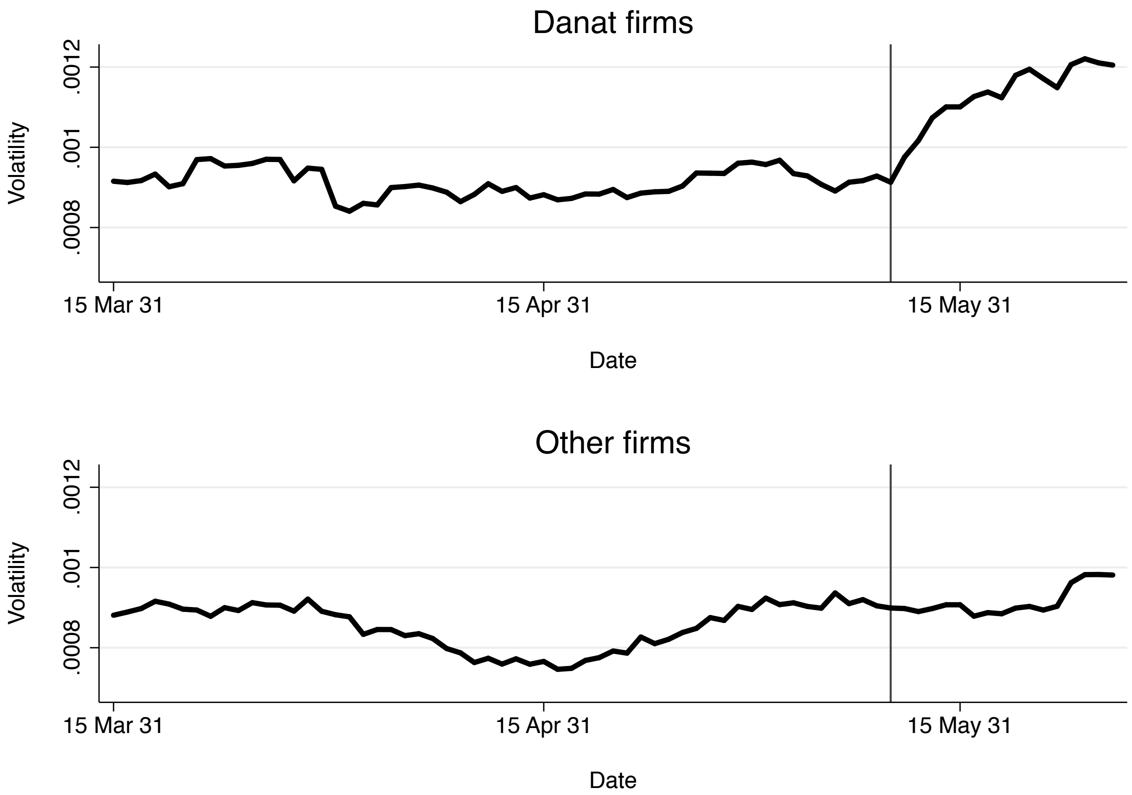


Figure 8: **Expected returns after order imbalances: General case** This graph plots the coefficients from a regression of excess returns on several lags of the supply order imbalance dummy together with a 90 percent confidence interval.

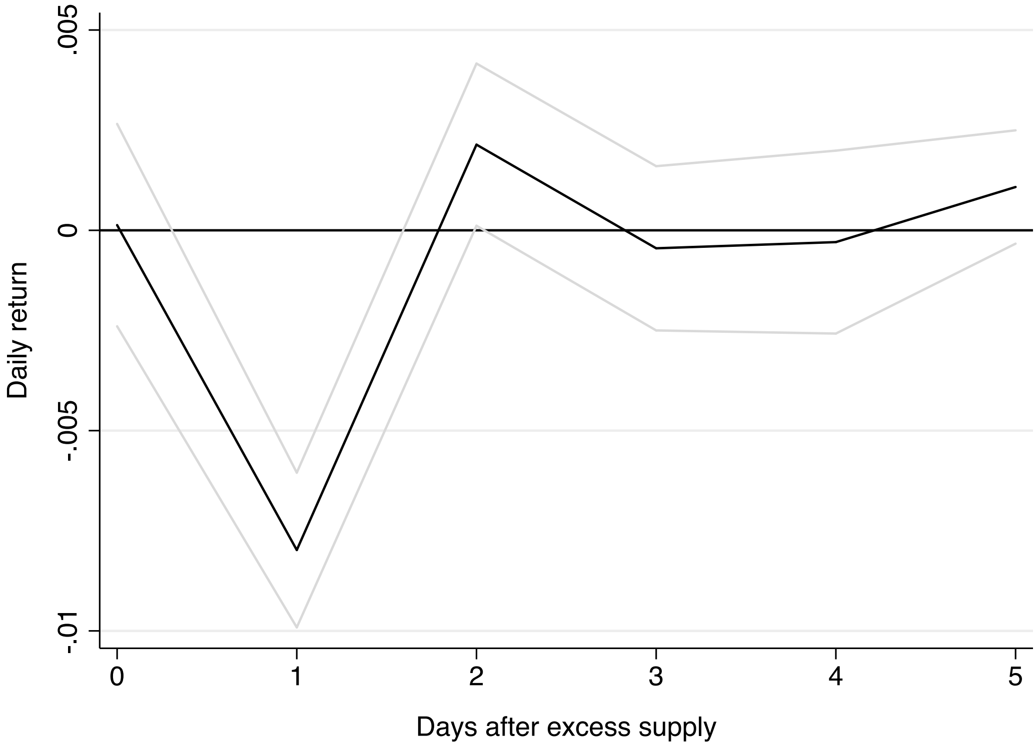


Figure 9: **Investing in illiquid stocks: Daily returns.** This figure plots the daily returns to a strategy that invests in stocks that saw a supply order imbalance the previous day. The weight of the stock in the daily portfolio is proportional to the decrease or increase in the stock: The larger the price change, the larger the weight of the stock in the portfolio.

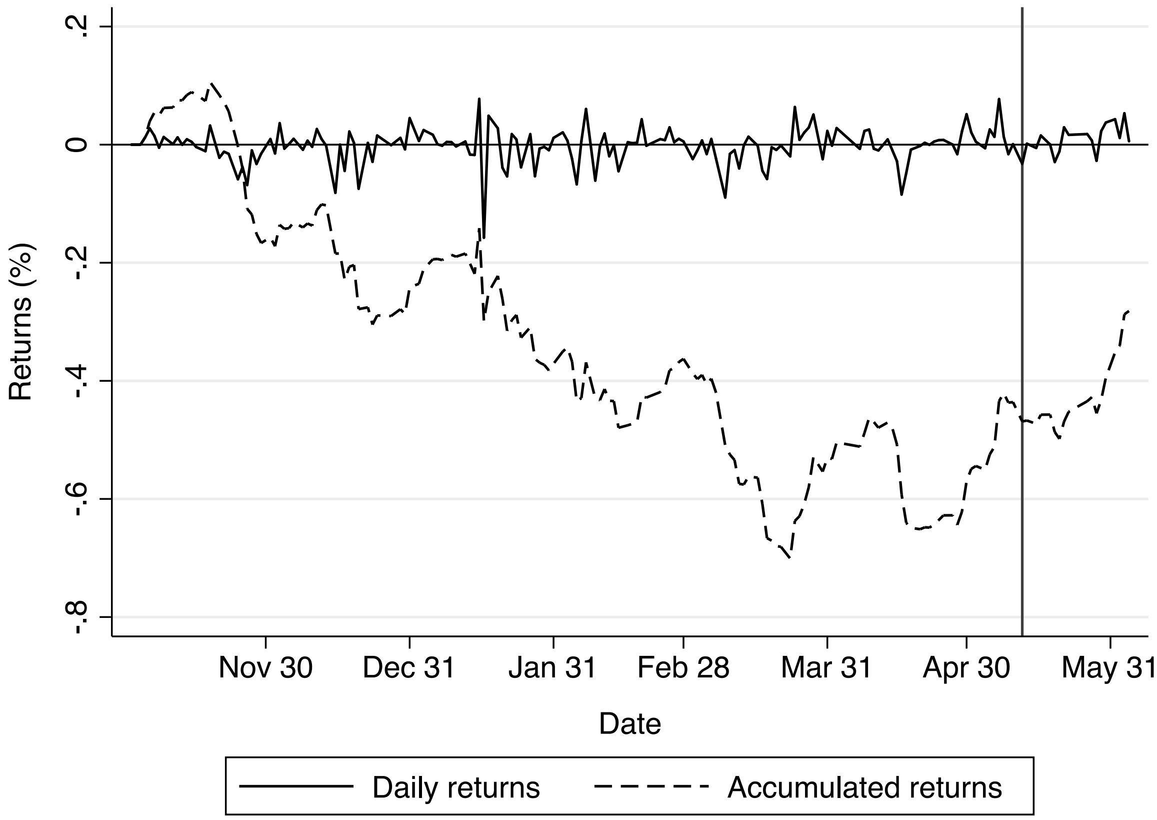


Figure 10: **Investing in illiquid stocks: Cumulative returns.** This figure plots the accumulated returns to a strategy that invests in stocks that saw a supply order imbalance the previous day. Stocks available for investment are grouped by liquidity provider. The weight of the stock in the daily portfolio is proportional to the decrease or increase in the stock: The larger the price change, the larger the weight of the stock in the portfolio.

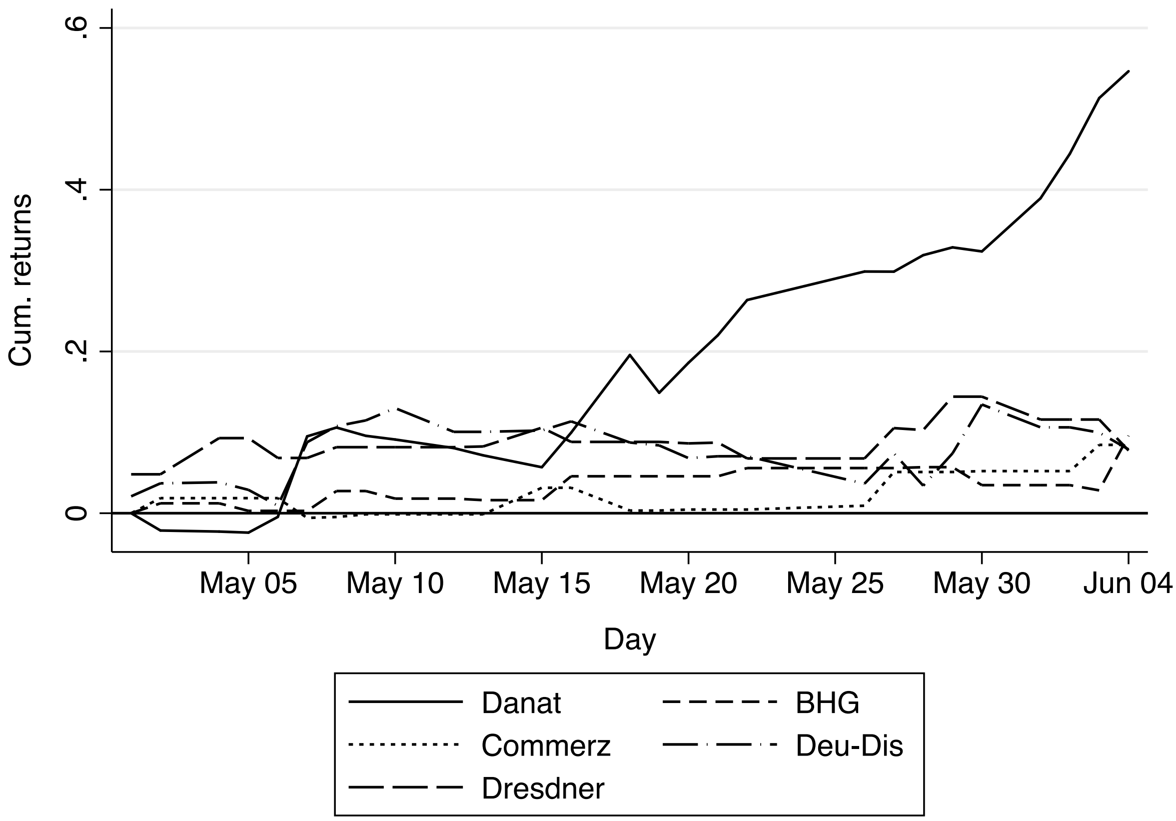


Figure 11: **Returns after order imbalances.** The graphs show the returns over the two days following a day with a supply order imbalance. Two-day returns are differentiated by the initial price drop at the time of the order imbalance. The x-axis shows the initial price drop when a supply order imbalance exists and the y-axis shows the two-day average return following this price drop. The figure shows that price reversals happened also for firms not connected to the Danatbank and also for Danatbank-firms before May. But on average, returns reversals are only observed for firms connected to the Danatbank during May 1931.

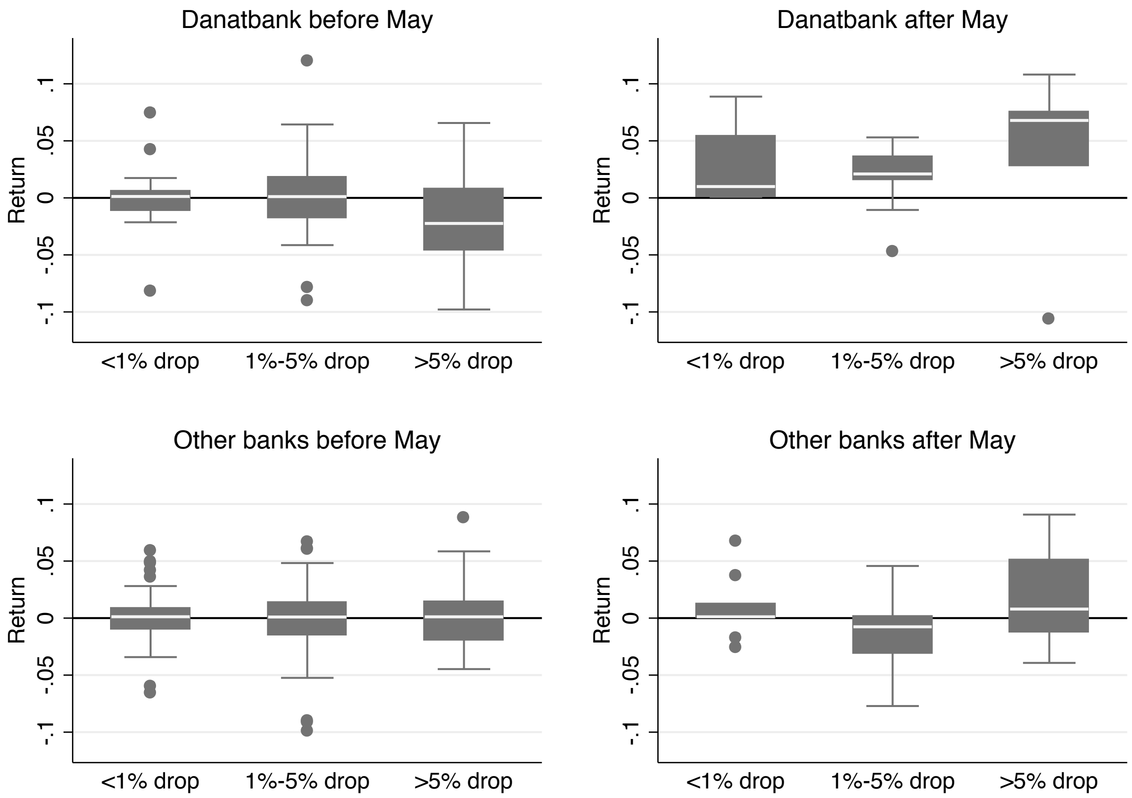


Figure 12: **Expected returns after order imbalances: June.** This graph plots the average excess returns after days of supply order imbalances. The sample consists of firms connected to Danatbank between June 4 and June 28.

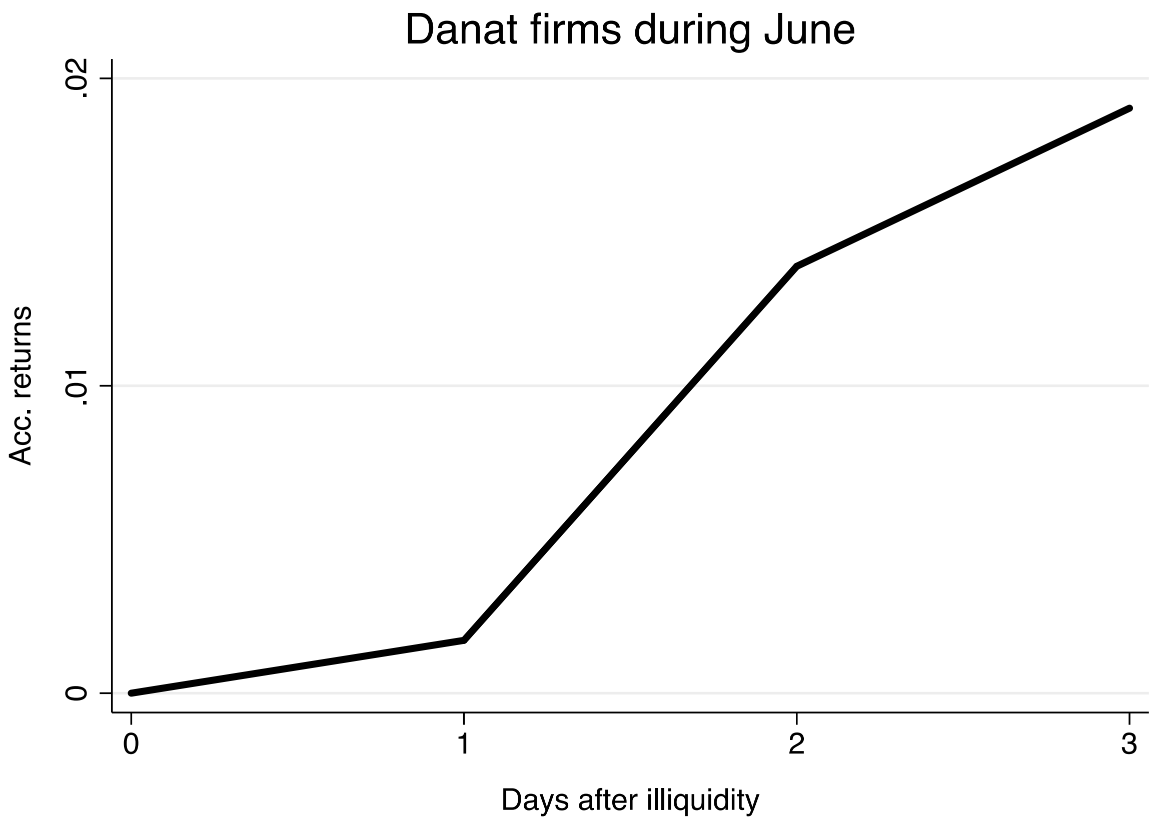
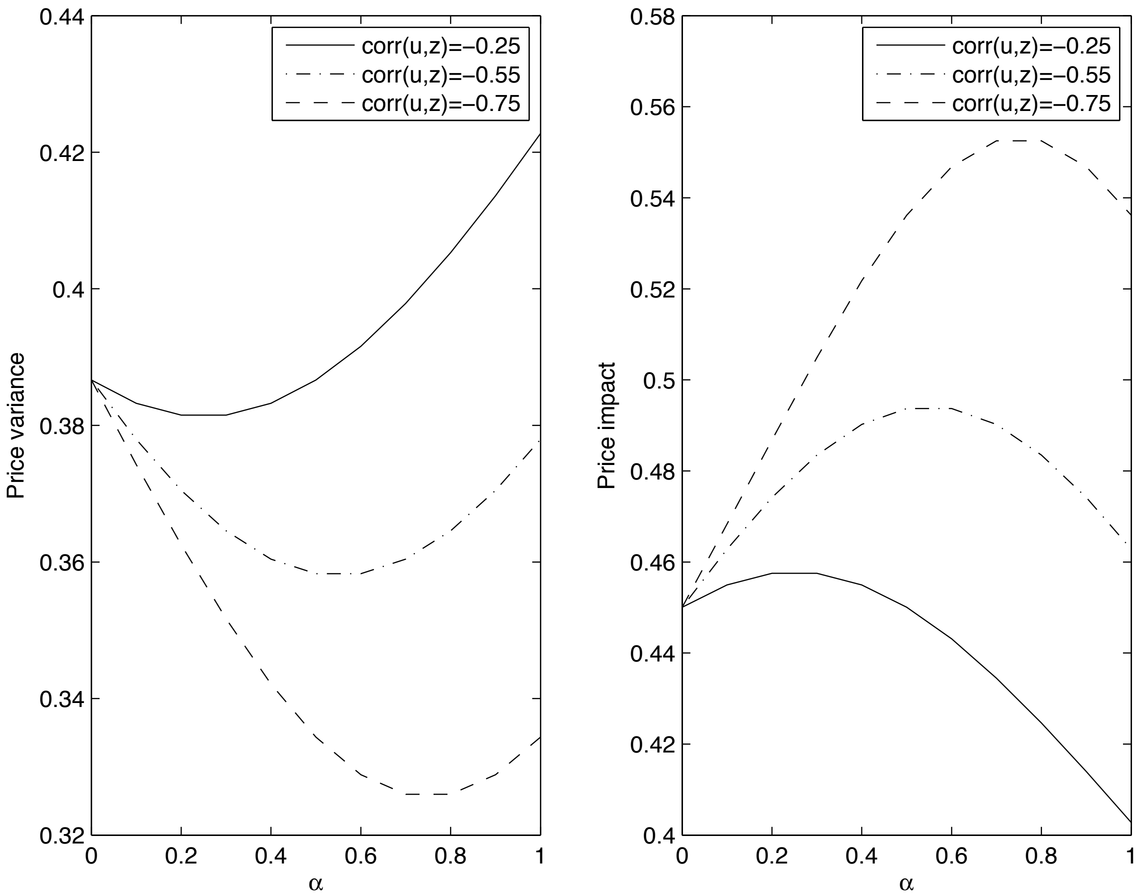


Figure 13: **Price variance and price impact.** These graphs plot the unconditional price variance and price impact. The first graph plots plots the price variance against α for different values of ρ_{uz}. The second graph plots plots price impact against α for different values of ρ_{uz}. The parameter values for the simulations are: $\tau_d = 1, \tau_u = 1, \tau_z = 1, \tau_\epsilon = 10, i = 1, o = 20, \rho_i = \rho_o = 2, \overline{d} = 1$.



Appendix A: Data sources

Stock prices:

Stock prices and order imbalance information are taken the evening issue of the *Berliner Boersen Zeitung*. Scans of the newspaper are held at the newspaper archive of the Staatsbibliothek Berlin.

IPO prospectuses:

IPO prospectuses and firms' balance sheets are held at the German Federal Archives in Berlin. Both are part of firm-specific files within the documents about the Berlin stock exchange (Signature R3103). I used the files R3103/300 to R3103/600.

Bank balance sheets:

Banks' balance sheets are held at the German Federal Archives in Berlin. I used the signatures R2501/1131 and R2501/1132.

Other data:

For background information and anecdotal data, I used scans of national newspapers held at the newspaper archive of the Staatsbibliothek Berlin. Information about the Berlin Stock Exchange can be found in several documents at the German Federal Archives in Berlin. These documents are mainly part of the signature R3103. I further used several statistical publications of the German Reich, all held at the Staatsbibliothek Berlin.

Appendix B: The microstructure of the Berlin Stock Exchange

A closer look at the Berlin Stock Exchange's microstructure helps explain exactly how banks made markets in stocks of connected firms. After the founding of the German Reich in 1871 the Berlin Stock Exchange became one of the world's major exchanges and during the 1920s it was the only stock exchange in Germany with notable volume.[47] Only the Berlin Stock Exchange drew the attention of politicians, the Reichsbank, the banks, and the media.

Each trading day, the exchange held a single call auction. A single stock had two official market makers or *Kursmakler*, which were located at a designated post inside the stock exchange. Similar to specialists at the NYSE, these official market makers could trade on their own account

[47] See Davis et al. (2003)

to ensure price continuity, but this procedure was seldom used.[48] For one and a half hours, orders could be submitted to the official market maker either as limit orders or as market orders. Afterward, the process of price setting began. The market makers brought together their order books, and a public discussion about the unique market-clearing price followed. Meanwhile, traders were still able to submit bids and offers until a single price was set that maximized trading volume. As a minimum requirement, all market orders had to be filled.[49] The last step was acceptance of the price by a committee, which was mainly concerned about large price swings. Sometimes prices were rejected in order to keep volatility within certain bounds.[50] All possible trades were settled at the established price.

If markets did not clear at the settled price then the market was left with supply or demand order imbalances. In extreme cases, order book imbalances were too great to enable trades and so it was not possible to establish a price quote. The official share price list reported the existence of order book imbalances. A lowercase letter appended to the price quote figure informed traders about any imbalances and also their direction. Table 13 gives an example of the price setting and shows a stylized order book. In this example, matching all sell orders without limit requires the auctioneer to go deep into the order book. The price drops, and there remains unmatched supply at the established price.

Often in cases of such imbalance, the connected bank intervened to prevent prices from fluctuating too widely. The bank placed an employee at the post of each market maker for its associated firms; that employee followed the price-setting process, ready to step in whenever order imbalances arose. In normal times he had the means to satisfy all orders without limits and to keep price fluctuations low. Trading then proceeded without major price effects and the market remained liquid.[51]

[48] Trading on their own account was risky for official market makers. Stock exchange officials constantly checked the order books; if a market maker held a stock inventory for more than one day, he was suspected of insider trading and had to pay a large fine.

[49] The price set by the auctioneer is described by Prion (1930) as "the price, which reflects demand and supply...the price, which, given the limits on the orders, maximizes the number of trades."

[50] These bounds were not officially established, but it was accepted that before WW I a 5–10 percent change was viewed as an upper bound on price swings. During the 1920s this bound was expanded to 15–20 percent.

[51] If banks were to maximize trading gains, a low price would be optimal. But as Lehmann (2011) shows, underwriter switching was not unusual and can be explained by a stock's post-IPO performance. If it maximized trading gains, the bank risked losing its connected firm and the future revenues from it equity offerings.

Table 13: **A dealer's order book.** This table provides an example of a dealer's order book and the possibility of bank intervention. The previous day's price was 100. Maximizing volume, the price would drop to 90, still leaving a supply order imbalance at this price. Newspapers would quote a price of 90 and the existence of excess supply. A bank could step in between 90 and 100 to prevent a sharp price drop and eliminate order imbalances.

Price	Bid	Offer	Imbalance
w/o limit	5	50	45
100	10		35
90	15		20
50	20		0

Appendix C: Excess returns

A classical correction of daily returns using the Fama-French factors (Fama and French 1993) is not possible for all the usual factors, because the data at hand do not provide a long time series on variables like book value. I correct for return factors in the following way:

- Market beta: I run simple time-series regressions separately for all firms i of returns on a constant and the returns of an unweighted portfolio holding all firms in my sample. This gives a firm's market beta β^M.
- I divide all stocks into 10 size classes. Within each size class I regress returns on the log of equity to obtain size betas β^{SIZE}.
- Finally, I regress returns on firm's market betas and size betas and use the residual as excess returns:

$$r_{it}^{exc} = r_{it} - \lambda_1 \beta_i^M - \lambda \beta_i^{SIZE} \tag{10}$$

Appendix D: Model setup and solution

Given the signal s and the additional market making demand, one can conjecture a linear demand function x_i for banker i, which is the sum of the speculative demand x_i^{spec} and the market making demand x_i^{mm}:

$$x_i = x_i^{spec} + x_i^{mm} \tag{11}$$

$$= as + b_i - c_i p + \alpha z \tag{12}$$

Each banker uses his private signal about the dividend, but takes into account that he has market power and his own trading moves the price against him.

Uninformed traders do not observe the informative signal s. Nevertheless, before submitting a demand schedule x_o, an uninformed trader o observes the price and bases his best estimate of d on the market price p. For an uninformed trader o the conjectured demand function is

$$x_o = b_o - c_o p \tag{13}$$

Uninformed traders base their demand only on the price signal, but they also take their market power into account.

All traders submit their demand schedules and the market clearing condition is given by

$$i(x_i^{spec} + x_i^{mm}) + ox_o + u = 0 \tag{14}$$

Using the conjectured linear demand functions, the market clearing condition can be solved for the market clearing price. The trading mechanism is a unit price auction, where all stocks are traded at the same price. This price is given by

$$p = \lambda(ias + ib_i + ob_o + u + i\alpha z) \tag{15}$$

where $\lambda = (ic_i + oc_o)^{-1}$. λ is a measure of price impact: The greater λ the more do prices react to noise trader demand.

All investors maximize second period utility according to a CARA utility function. Bankers have risk aversion ρ_i and uninformed speculators have risk aversion ρ_o. Investors derive utility from the gains from trading $\pi_m = (d-p)x_m$ and the problem of investor m is

$$\max_{x_m} E_m(-e^{-\rho_m \pi_m}) \tag{16}$$

$$\Rightarrow \max_{x_m} E_m(d-p)x_m - \frac{1}{2}\rho_m Var_m(\pi_m) \tag{17}$$

All moments are conditional on investor m's information set. The second line follows because prices and dividends are normally distributed and

$$E_m(-e^{-\rho\pi_m}) = -e^{\rho_m E_m(\pi_m) - \frac{1}{2}\rho_m Var_m(\pi_m)} \tag{18}$$

The original optimization problem is equivalent to maximizing the last expression in the stated problem. As shown by Kyle (1989), investors face a residual supply curve and the optimal solution to their problem takes the form

$$x_i = \frac{E_i(d) - p}{\lambda_i + \rho_i Var_i(d)} \tag{19}$$

$$x_o = \frac{E_o(d) - p}{\lambda_o + \rho_o Var_o(d)} \tag{20}$$

where $\lambda_i = ((i-1)c_i + oc_o)^{-1}$ and $\lambda_o = (ic_c + (o-1)c_o)^{-1}$. When trading, each trader takes his price impact into account. Because the market's microstructure is a unit price auction, the marginal increase in the price due to a trader's demand increases the price of all stocks for this trader. As a result, investors react less aggressively to price fluctuations or new information. Apart from restricting trading due to market power (λ_m), an investor trades less if he is more risk averse or if the conditional price variance is higher. To complete the description of the model, I now describe the formation of expectations and provide a definition of the equilibrium.

Before observing signals or prices, all traders have the prior expectation that dividends will be equal to $\overline{d}$. Informed bankers observe a signal s and will update their prior belief about the dividend d. Using Bayes rule, their optimal forecast of d and the conditional variance are given by

$$E_i(d|s) = \overline{d} + \frac{\tau_\epsilon}{\tau_\epsilon + \tau_d}(s - \overline{d}) \tag{21}$$

$$Var_i(d|s) = (\tau_\epsilon + \tau_d)^{-1} \tag{22}$$

Uninformed traders do not observe a private signal, but are able to observe the price. They will condition their estimate of d on this noisy signal. The price p is informationally equivalent to the variable $\tilde{p}$:

$$\tilde{p} = \frac{1}{ia}(p\lambda^{-1} - ib_i - ob_o) \tag{23}$$

$$= d + \epsilon + \frac{1}{ia}(u + i\alpha z) \tag{24}$$

We can use this equivalence to derive the conditional moments, because $E_o(d|p) = E_o(d|\tilde{p})$ and $Var_o(d|p) = Var_o(d|\tilde{p})$. The conditional variance is the inverse of the precision of the prior, τ_d, and the precision of the price signal, $\tau_{\tilde{p}}$. Using this, the conditional moments are given by

$$E_o(d|p) = \frac{\tau_{\tilde{p}}}{\tau_d}\tilde{p} + (1 - \frac{\tau_{\tilde{p}}}{\tau_d})\overline{d} \tag{25}$$

$$Var_o(d|p) = (\tau_d + \tau_{\tilde{p}})^{-1} \tag{26}$$

The precision of the price signal is given by

$$\tau_{\tilde{p}} = \tau_\epsilon \frac{i^2 a^2 \tau_u}{i^2 a^2 \tau_u + \tau_\epsilon(1+\gamma)} \tag{27}$$

with $\gamma = i^2\tau_u\alpha(\alpha\tau_z^{-1} + \frac{2}{i}\rho_{uz}(\sqrt{\tau_u\tau_z})^{-1})$. For the remainder of the section, I will denote by $E_m(x)$ the expectation of x conditional on trader m's information set.

The unconditional price variance is given by

$$Var(p) = \lambda^2 i^2 a^2(\tau_d^{-1} + \tau_\epsilon^{-1}) + \lambda^2(\tau_u^{-1} + \alpha^2\tau_z^{-1} + 2\alpha\rho_{uz}(\sqrt{\tau_u\tau_z})^{-1}) \tag{28}$$

Having described the optimization problem of traders and their optimal expectation formation, we can now define an equilibrium in this trading game. The equilibrium concept is that of a symmetric linear Bayesian equilibrium. Kyle (1989) states the conditions for existence of such an equilibrium in this model of rational expectations with imperfect competition.

Definition 1 *A symmetric linear Bayesian equilibrium is a set of demands $x_i(s,p)$ and $x_o(p)$ and a price function $p(s,u,z)$ such that*

1. *Traders optimize:*

$$x_i(s,p) \in \arg\max_{x_i} E_i(U(\pi_i))$$

$$x_o(p) \in \arg\max_{x_o} E_o(U(\pi_o))$$

2. *Markets clear:*

$$ix_i(s,p) + ox_o(p) + i\alpha z + u = 0$$

The definition of an equilibrium, the optimal demand functions, and the price function derived from the market clearing condition, allows us to verify the conjecture of the linear demand functions. Proposition 1 together with the conditional moments, the price function, the demand functions, and with the system of equations for the coefficients provides a complete description of the equilibrium.

In equilibrium, the price function is given by $p = \lambda(bas + ib_i + ob_o + u + i\alpha z)$ and the linear demand functions are given by $x_i = as + b_i - c_i p + \alpha z$ and $x_o = b_o - c_o p$. The coefficients are the solution to the following system of equations:

$$a = \left(\frac{\tau_\epsilon}{\tau_d + \tau_\epsilon}\right)\left(\frac{1}{(\lambda_i + \rho_i(\tau_d + \tau_\epsilon)^{-1})}\right) \tag{29}$$

$$b_i = \overline{d}\left(1 - \frac{\tau_\epsilon}{\tau_d + \tau_\epsilon}\right)\left(\frac{1}{(\lambda_i + \rho_i(\tau_d + \tau_\epsilon)^{-1})}\right) \tag{30}$$

$$c_i = \left(\frac{1}{(\lambda_i + \rho_i(\tau_d + \tau_\epsilon)^{-1})}\right) \tag{31}$$

$$b_o = \left(\overline{d}\left(1 - \frac{\tau_{\tilde{p}}}{\tau_d + \tau_{\tilde{p}}}\right) - \frac{\tau_{\tilde{p}}}{\tau_d + \tau_{\tilde{p}}}(ib_i + ob_o)\frac{1}{ia}\right)\left(\frac{1}{\lambda_o + \rho_o(\tau_d + \tau\tilde{p})^{-1}}\right) \tag{32}$$

$$c_o = \left(1 - \frac{\tau_{\tilde{p}}}{\lambda(\tau_d + \tau_{\tilde{p}})}\right)\left(\frac{1}{\lambda_o + \rho_o(\tau_d + \tau\tilde{p})^{-1}}\right) \tag{33}$$

The conditional moments are given by

$$E_i(d|s) = \overline{d} + \frac{\tau_\epsilon}{\tau_\epsilon + \tau_d}(s - \overline{d}) \tag{34}$$

$$Var_b(d|s) = (\tau_\epsilon + \tau_d)^{-1} \tag{35}$$

$$E_o(d|p) = \frac{\tau_{\tilde{p}}}{\tau_d}\tilde{p} + (1 - \frac{\tau_{\tilde{p}}}{\tau_d})\overline{d} \tag{36}$$

$$Var_u(d|p) = (\tau_d + \tau_{\tilde{p}})^{-1} \tag{37}$$

and the precision of the price signal is given by

$$\tau_{\tilde{p}} = \tau_\epsilon \frac{i^2 a^2 \tau_u}{i^2 a^2 \tau_u + \tau_\epsilon(1 + \gamma)} \tag{38}$$

and $\gamma = i^2 \tau_u \alpha(\alpha \tau_z^{-1} + \frac{2}{i}\rho_{uz}(\sqrt{\tau_u \tau_z})^{-1})$.