Market efficiency and limits to arbitrage: Evidence from the biggest short squeeze in history*

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Abstract

On October 26, 2008, Porsche announced its domination plan for Volkswagen. This announcement came as a surprise to investors shorting Volkswagen stock, and caused the biggest short squeeze ever. We use the Porsche-VW short squeeze and the German financial market system as a unique experimental setting to argue that regulation is important for market quality and informational risk in modern, fast-paced, yet opaque financial markets. We provide the first forensic academic study of this squeeze and show that it significantly impaired price discovery, increased informational risk, and impeded market efficiency. These limits to shorting arbitrage imply significant costs to the arbitrageurs involved.

Keywords: Limits to arbitrage, short selling, stock cornering

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1 Introduction

At the height of the financial crisis on Monday, October 27, 2008, Volkswagen’s (VW) stock price started skyrocketing and surged past EUR 1,005 per share on Tuesday, October 28, 2008, from a close the previous Friday of EUR 210 per share. As a result, VW briefly became the most valuable company in the world in terms of market capitalization. In this paper we analyze what happened in these tumultuous days. In particular, we examine the incentives of Porsche in the week before their press announcement of Sunday, 26 October, concerning their holdings of VW stock. We argue they had an incentive to create a short squeeze to drive up the price to save Porsche from bankruptcy. Moreover, we provide evidence that the release did in fact lead to a short squeeze. This consists of the movement of the price and its volatility in the two trading days following the announcement. Also, the fact that the press release on Wednesday, October 29, 2008, that Porsche would increase liquidity in the market by making available 5 percent of Volkswagen shares was followed by a fall in the price is also evidence of a short squeeze in the previous two days.

These events are not only of interest in their own right. Capital market efficiency relies to a large extent on the principle of arbitrage. If the price of an asset is too low relative to its discounted future cash flows then arbitrageurs will buy it and drive the price up; if the price is too high they will short sell it and drive the price down. Among the most important limits to this process is the possibility of squeezes and corners. In a squeeze, short sellers find it difficult to acquire the securities they need to cover their short position because of a shortage of supply and drive up the price with their purchases. A corner is an extreme form of short squeeze, when the buy side has almost complete control of all floating shares.

While stock price manipulations such as squeezes and corners have been outlawed in the United States of America (US) since the Securities and Exchange (SEC) Act of 1934, legal limitations have only been introduced and enforced in many European countries in recent years. We use the relative opaqueness of the German stock market to investigate how a short squeeze impacts informational risk and market quality in modern, fast paced stock markets in which information is in many circumstances incorporated quickly but in others, such as when there is asymmetric information, this process can take some time. We provide evidence that in case of stock manipulation in semi-regulated markets, these markets are incapable of remaining efficient despite fast-paced trading technology, continuous news streams, and continuous information processing.
Allen et al. (2006) document that in the nineteenth and early twentieth century squeezes and corners did occur with some regularity in the US stock markets. A classic example is the 1863 Harlem corner. Commodore Cornelius Vanderbilt bought stock in the Harlem Railway Company at around $8 to $9 a share at the beginning of 1863. He became involved in managing the company and its stock price rose to $50 per share. The New York City Council passed an ordinance allowing the Harlem Railway to build a streetcar system the length of Broadway in April 1863. As a result, the stock price rose to $75. Daniel Drew who was a director of the company conspired with members of the council to sell the stock short, repeal the ordinance, and thus force the price down. However, events did not turn out this way as Vanderbilt discovered the plan and secretly managed to buy the entire stock of the company. After the repeal of the ordinance, the members of the council tried to cover their short positions but they soon discovered that none of the stock could be purchased. They were forced to settle with Vanderbilt at $179 per share.

In 1920 the New York Stock Exchange passed rules to discourage market squeezes and corners. The only intentional attempt at a corner reported after that was the Piggly-Wiggly corner in 1923. This provides an illustration of how authorities can intervene to stop the damaging effects of squeezes and corners. Piggly Wiggly was a grocery chain in the Midwest US. The firm wished to make a seasoned equity offering. The firm’s president, Clarence Saunders, hired a well-known stock manipulator, Jesse Livermore, to raise the price of the stock in anticipation of the offering. The price started to rise and this resulted in substantial short sales as it was perceived to be overvalued. This led to a market squeeze in mid-March. Clarence Saunders thought that he could make more money by cancelling his previous plan to issue more stocks and make the short sellers pay even more. The price soared 50 points in a single day on 23 March. However, the Governing Council of the New York Stock Exchange decided to delist Piggly Wiggly the next day, and let the short sellers buy the stock at a nominal price.

The Securities Exchange Act of 1934 contained extensive provisions to eliminate stock price manipulation. The Act effectively outlawed two categories of manipulation. The first is action-based manipulation. This is based on actions that change the actual or perceived value of the assets. An example is provided by the managers of the American Steel and Wire Company (the forerunner of US Steel). In 1901, they shorted the firm’s stock and then closed some of its steel mills. The announcement of the closures caused

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¹See Allen and Gale (1992a), Chancellor (2000, Chapter 6) and Allen et al. (2006) for more details.
²See Brooks (1969), Markham (2001) and Allen et al. (2006).
the firm’s stock price to fall from around $60 to around $40 per share. The managers covered their short positions at these low prices, then reopened the mills, at which point the stock price rose to its previous level.³

The second category the Act outlawed can be described as information-based manipulation. This involves providing false information or spreading false rumors. Examples of this kind of manipulation are provided by trading pools consisting of groups of investors acting in concert who would work with journalists in return for a share of the profits. For instance, a pool manager John J. Levinson worked with Raleigh T. Curtis who wrote a column entitled The Trader in the *New York Daily News*. They made profits of over $1 million per year in this way.⁴

The Securities Exchange Act made it illegal for directors and officers to sell short the securities of their own firm. This and various other restrictions it introduced made action-based manipulation much more difficult. To remove information-based manipulation, the Act required firms to issue information to the public on a regular basis to, among other things, make the spreading of rumors more difficult. It also became illegal for anybody to attempt to raise or depress stock prices by making statements which they knew to be false. The Act is actively enforced and with a number of well-publicized exceptions it has been fairly successful in eradicating action-based and information-based manipulation.

In contrast, in Europe securities regulation and in particular the regulations against manipulation of stock prices came much later than in the US. In Germany, US-style securities law to protect investors did not exist until the mid-1990s. Before then, rules and regulations concerning the issuance and trading of securities were to be found in various parts of the law, particularly in stock corporation law, securities exchange law, and banking law. Market manipulation is now part of the Securities Trading Act and the Market Manipulation Definition Regulation (WpHG (or *WertpapierHandelsGesetz*) and MakonV (or *Verordnung zur Konkretisierung des Verbotes der Marktmanipulation*)). An intentional false statement about a fact significant to the valuation of a security, as well as every other deliberate deceptive measure that influences the valuation, is punishable as a criminal act according to Section 20a of German securities law.

In 1997, according to La Porta et al. (1997) (LLSV), Germany scored only one out of five possible points on an aggregated index of shareholder protection, less than the score

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³See Wycoff (1968, pp. 72-78) for an account of this episode.
for the US (5.0) and the UK (5.0), less than the average score of the 49 countries considered (3.0), and less even than the scores for Thailand (2.0), Greece (2.0), or Ecuador (2.0). In 2015, the Doing Business report of the World Bank’s International Finance Corporation, which follows the revised LLSV methodology of Djankov et al. (2008) ranked Germany as 103rd of 189 countries for investor protection in between the Dominican Republic and Kenya. So the level of investor protection seems to have not much improved in the last 20 years.

Enforcement of securities laws is carried out by the German equivalent of the SEC known as “Bundesananstalt für Finanzdienstleistungsauufsicht” (BaFin), which is located in Frankfurt and Bonn. It is a federal institution governed by public law, and is affiliated to the Federal Ministry of Finance. Under the Securities Trading Act, the BaFin investigates all possible cases of market manipulation and monitors the collection and evaluation of all securities and derivatives transactions. If a case of market abuse or market manipulation is suspected, the BaFin has to pass the case on to a public prosecutor, who may (or may not) conduct further investigations and criminal prosecution. The lack of enforcement powers on the part of the BaFin has long been criticized, and it is cited by Nowak (2004) as the reason why there have been so few insider trading prosecutions to date. For market manipulation cases, from 2013 to 2015, the BaFin (Annual Report 2015) started 698 investigations, and passed on 458 cases to public prosecutors. Of those, only 14 final judgements were made with a conviction following a full public trial. The prosecutors turned all the other cases down or settled them with down payments or administrative fines, so the risk of being convicted of market manipulation in Germany - conditional on having been investigated by the BaFin - is only two percent. BaFin does not mention any incidents of short squeezes or corners as special cases of market abuse in their annual reports. In the case of the Porsche announcement of October 26, 2008, it first started investigations of market manipulation, then dropped those charges, only to later pass on the case to the public prosecution office in Stuttgart where Porsche is headquartered.

In this paper, we argue that there is a great deal of evidence that Porsche created a short squeeze in VW’s stock. We combine this with the relative lack of enforcement of securities laws in Germany to investigate the impact that such a large short squeeze had on stock market quality and informational risk. We find that the short squeeze significantly altered the process of price discovery. Whereas on average 40 percent of price discovery happens in the very first hour of an official trading day, this decreased significantly by 28 percent during the days of Porsche’s short squeeze. For realized spreads and informational

\footnote{http://www.doingbusiness.org/methodology/protecting-minority-investors}
risk we find an increase of 200 percent during the days of the short squeeze. Finally, we document an abnormally high dispersion in analysts’ price target opinions indicating that besides the increased risk aversion among all traders, also professional analysts were uncertain and confused about how to properly value VW’s shares during the short squeeze of Porsche.


Aggarwal and Wu (2003) present a theory and empirical evidence on stock price manipulation in the United States. By extending the framework of Allen and Gale (1992b), they show that more information seekers imply greater competition for shares in a market with manipulators, making it easier for a manipulator to enter the market and potentially worsen market efficiency. Using a unique dataset from SEC actions in cases of stock manipulation, they find that more illiquid stocks are more likely to be manipulated and manipulation increases stock volatility. Merrick et al. (2005) provide empirical evidence on learning in the market place and on the strategic behavior of market participants by studying an attempted delivery squeeze in the March 1998 long-term UK government bond futures contract traded on the London International Financial Futures and Options Exchange (LIFFE). Three recent papers empirically examine short selling in relation to particular manipulative or abusive trading strategies. Shkilko et al. (2012) examine stocks that experience large negative intraday price moves followed by a reversal before the end of the day. They find aggressive short sales during the price decline period, though non-short sellers behave even more aggressively. Shkilko et al. (2012) conclude that the influence of short sellers on prices is secondary to that of non-short sellers. Fotak et al. (2014) investigate the effects of naked short selling on markets using the level of fails to deliver during settlement. Similarly to the findings of this paper, they document that (naked) short sellers have positive effects on market quality and market efficiency, such as reducing price error and volatility. How even failed attempts to manipulate stocks can cause a surge in informational risk and a deterioration of market quality is shown in Fohlin et al.
They provide evidence of how the failure of a short squeeze in the opaque trading environment of US stock markets in 1907 caused an increase in informational risk, which ultimately led to a freezing of funding and market liquidity.

The remainder of this paper is organized as follows: Section 2 of the paper reviews the events leading up to the short squeeze of VW. Section 3 describes the underlying data. The incentive of Porsche to manipulate VW’s stock price is considered in Section 4. Section 5 and 6 analyze the extent to which market participants anticipated Porsche’s press release and whether the press release lead to a short squeeze. Section 7 documents the effects of the short squeeze on market quality and informational risk. Section 8 concludes.

2 Porsche’s Plan to Take Over Volkswagen

Porsche SE is a car manufacturer with its headquarter in Stuttgart, Germany. Its product line mainly consists of high performance sports cars such as the 911 and Boxster series, and the SUV series of Cayman and Cayenne. In 2005, the company’s sales were focused mainly on the U.S. and German markets, with both markets combined accounting for about two thirds of total sales. Volkswagen Group is the largest car manufacturer worldwide with its headquarter in Wolfsburg, Germany. Volkswagen manufactures passenger and commercial vehicles, motorcycles, engines, and turbomachinery. As of 2005, Volkswagen Group’s automotive unit combined the brands of Audi, Bentley, Bugatti, Lamborghini, SEAT, Skoda and Volkswagen.

On September 26, 2005, Porsche officially announced plans to acquire a 20 percent stake in Volkswagen. On or about July 15, 2005, the shareholders’ committee of Dr. Ing. h.c. F. Porsche AG (now Porsche Automobil Holding SE), in the presence of Porsche executives including Wendelin Wiedeking and his head of strategy Michael Harmening unanimously passed a resolution authorizing the acquisition of more than 80 percent of VW. This resolution was not publicly announced. As Porsche lacked the necessary funds to take over VW, the car manufacturer developed a take-over plan. The plan included the building up of derivative positions consisting of a synthetic combination of cash-settled call and put options. As Dr. Ing. h.c. F. Porsche AG (later Porsche Automobil Holding SE) would unable to pay back the facility through its own business cash flows, they were planning to use the cash reserves of VW - then roughly EUR 12 bn - as the main source of

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liquidity of Porsche SE once it had taken over VW and could conclude a domination and profit transfer agreement.\(^8\) Porsche did not announce any of this. Their communication was marked by gradual information relevant to misinformation through denials and subsequent “confessions’. For example, in 2006 Porsche first denied intentions to increase their stake in VW to over 22 percent and then later in the year announced an increase in their VW stake to 25.1 percent.\(^9\) Similarly, in late November 2007, they denied any intentions to increase this stake to 30 percent. Yet, on March 24, 2007, Porsche SE announced their plans to increase their stake in VW to a 30.9 percent of the VW ordinary shares.\(^10\)

Again, on October 3, 2008, they denied media reports about Porsche’s take over plans as the following press release shows:

“Stuttgart, 10 March 2008. Porsche Automobil Holding SE, Stuttgart, denies reports in the media which claim that the enterprise intends to increase its stake in VW to 75 percent. The speculation about going up to 75 percent does not consider the realities of VW’s shareholder structure. In view of the fact that the German Federal State of Lower Saxony, as the second major shareholder, holds a stake of more than 20 percent in Volkswagen, the probability of acquiring the necessary shares from the remaining free float is very small indeed. The background of the current media reports is obviously provided by rumors on the Stock Exchange which can be traced back to the speculative mind games of analysts and investors.”\(^11\)

Despite their denial, by the fall of 2008, Porsche SE and Porsche GmbH, Salzburg had already acquired a combined physical and synthetic position in VW exceeding 74.1 percent of the issued voting stock. More than 40 percent of this position was held in economic ownership, i.e., through a combination of cash settled call and put options with identical strike prices in different strategies.\(^12\)

When the financial crisis hit markets around the globe in September 2008 following the collapse of Lehman Brothers, the margin requirements on their derivative positions started to threaten Porsche’s existence.\(^13\) The derivative position Porsche had built up

\(^9\)http://www.faz.net/aktuell/wirtschaft/automobile-porsche-vor-vw-uebernahme-1254863.html
\(^10\)https://www.welt.de/wirtschaft/article777486/Provokanter-Volksheld-Wiedeking.html
\(^12\)For a detailed timeline of all announcements relating to the attempted takeover of VW by Porsche, see Figure ??.
\(^13\)Der Spiegel 04/2015, Der 100-Millionen Mann, p. 66 et seq.; Indictment of the public prosecutor, 10.06.2015, LG Stuttgart 13 KRs 159 69207/09
included the cash settled put options in VW ordinary shares that factually resembled an insurance policy for the benefit of the option counterparties insuring them against falling stock prices. On top of the more than 30 percent put options that were combined with cash settled call options at identical strike prices, Porsche had sold naked put options for another 20 percent of VW ordinary shares in order to generate the liquidity necessary to finance the building up of its position in VW. Therefore, the small car manufacturer with an EBITDA of less than EUR 2 billion per year had issued insurance policies to market participants insuring more than 50 percent of DAX heavyweight VW against falling stock prices. Under its agreements with the conduit investment bank Maple Bank GmbH, Porsche was subject to margin calls on a daily basis. After the Lehman collapse in September 2008, banks began to run into difficulties and along with the bearish market hitting all major titles forced the stock price of VW ordinary shares into a rapid fall.

Due to its small size and the nature of its derivative position, the downdraft in stock prices drove Porsche to the brink of insolvency in a matter of little more than one week. The trading week starting Monday, October 19, 2008, alone resulted in cash losses of approximately EUR 4 billion and caused them to fully max out its EUR 10 billion loan facility provided by a consortium headed by Merrill Lynch. The P&L effective loss of Porsche Automobil Holding SE on Friday, October 24, 2008, alone amounted to EUR 2.6 billion. As the price-earnings ratio of VW still amounted to a large multiple in comparison to peers on Friday, October 24, 2008, a further massive decline for the trading days to come was imminent. On Sunday, October 26, 2008, Porsche announced for the first time the full size of its combined physical and synthetic position in VW - but it did not disclose the fact that it had also issued cash settled naked put options.

In past announcements prior to October 26, 2008, Porsche had excluded any intention to increase its stake in VW above slightly more than 50 percent. Market participants including all Porsche entities were fully aware that a short position of about twelve percent of the ordinary stock in VW had been built up. The announcement of October 26, 2008 - a combined holding of 74.1 percent that together with Lower Saxony’s 20 percent meant that less than six percent of VW voting stock was available on the market - shocked the market and resulted in the largest short squeeze in history.

On October 27, 2008, the price of VW ordinary shares opened at EUR 350 per share,
a 66 percent increase over the previous Fridays closing price of EUR 210. The shares closed at EUR 520, almost a 150 percent increase over the previous day close. While there was a lot of intraday volatility in the VW stock price due to uncertainty about what the press release really meant, short sellers realized that they were caught in a squeeze. They started buying VW’s stock to cover their positions.

On October 28, 2008, VW became the most valuable company in the world measured by market capitalization, the stock price rose to more than EUR 1,000 per share. While the board of VW could have exercised its authorized capital to cash in billions of Euros in mark-ups to their share price and ward off aggressor Porsche, it passed on this opportunity. On October 29, 2008, Porsche made a further press release announcing the closing of derivative positions of up to 5 percent of VW voting stock and thereby releasing shares that short sellers of VWs stock could use to cover their positions. As a result, Porsche cashed in liquidity of roughly EUR 5 billion (call option premiums resulting from the short squeeze).\textsuperscript{18} This helped Porsche to restock its liquidity reserves and to roll over its derivative positions at more digestible prices before the end of the week.

3 Data

Our data is obtained from a variety of sources. Our unique and primary data source is the evidence presented in the public criminal case held at the regional Criminal Court of Stuttgart (LG Stuttgart) on alleged market manipulation. We obtained and forensically analyzed the material publicly presented in the courtroom, such as the indictment and speech of the public prosecutor. This forensic approach enables us to reconstruct the timeline of events as well as the complex derivative strategies of Porsche, and to analyze the case in unmatched detail and completeness.

For accounting and stock price information we use Compustat Global as well as the annual reports of Porsche and VW and their investor relations websites. Data on the number of analysts following a company and analysts’ target price forecasts and dispersion are retrieved from the I/B/E/S database. High-frequency (intra-daily) trades and quotes data are obtained from Tick Data, Inc. and the capital markets database of the Karlsruhe Institute of Technology (KKMDB). Data for the securities lending market is obtained from Markit. The data sample includes VW and Porsche, and their main German automotive

competitors Daimler and BMW for the period from 2005 to 2009. In the next sections we outline the econometric methodology and results relating to the above mentioned questions.

4 Porsche’s incentive to manipulate Volkswagen’s stock price

This section investigates possible motives of Porsche to short squeeze VW’s stock. Specifically, this section analyzes if Porsche tried to prevent its own default by manipulating an increase in Volkswagen’s stock price. In order to establish if a pending insolvency was indeed a viable motive for the publication of the press release, a variety of econometric tests for potential liquidity shortages and increased default probability are performed. The press release Porsche SE issued disclosed a market position covering 74.1 percent of the voting stock of VW and announced a plan to acquire more than 75 percent of the company paving the way for a domination agreement. The press release did not mention the losses in margin calls Porsche had endured in the previous trading week nor the fact that a two-digit million amount of put options had been in the money on the last trading day preceding the release. The press release gave the impression that Porsche was hedged against rising stock prices and would welcome lower prices as these would allow them to complete the takeover at a lower cost. The synthetic forward position in VW voting shares was not mentioned, nor the risks they were facing as a result of this position - and the naked cash settled puts they had sold short (covering some 20 percent of VW’s stock). By (not) doing so, Porsche disguised its own interest in VW stock in its entirety and hid an obviously viable motive for the publication of the press release.

4.1 Liquidity analyses

As a first step in assessing possible motives that Porsche might have had for manipulating the stock price of Volkswagen, we analyze Porsche’s liquidity level. A tight liquidity situation can serve as a motive for the alleged manipulation. Hence, the following analysis concentrates on Porsche’s ability to pay its short-term liabilities. We perform a time series and a cross-sectional comparison between Porsche and its competitors based on ratios such as the current ratio (current assets/current liabilities); the quick ratio ((cash+marketable securities+receivables)/current liabilities); and the cash ratio ((cash+marketable securities)/current liabilities).

Figure 1 documents the evolution of the three measures of firms’ liquidity over the
time period from January 2005 to December 2009. Specifically, these figures document the evolution over time of the current ratio, the quick ratio, and the cash ratio. We observe that Porsche had the highest liquidity levels in the German automotive industry until 2007. From 2007 onwards, Porsche’s liquidity level - as measured by all three ratios described above - starts to deteriorate significantly. This trend stops after the publication of their press release on October 26, 2008, but continues in the second half of 2009. Liquidity levels of Porsche’s competitors do not experience this trend. In fact, the liquidity levels of Porsche’s competitors do not change at all or at most with a positive change over the course of 2005 to 2009. This in turn suggests that Porsche’s downward trend in liquidity was not a system-wide phenomenon, but rather firm-specific. This evidence suggests that Porsche did not have enough liquidity in the third quarter of 2008 to eventually cover both potential margin calls and potential rollover losses related to its option strategies triggered by the continuously declining price of Volkswagen. Yet again, the fact remains that Porsche had a strong incentive to manipulate Volkswagen’s stock price upwards in order to prevent a further draining of liquidity.

4.2 Default analyses

A second step in the assessment of motives for manipulation, involves a default analysis for Porsche and its main competitors. For the default analyses, we first study standard, academically-established measures of probability of default. In addition, we construct our own measure of the probability of default of Porsche by comparing the liabilities that Porsche was facing in the form of margin requirements and potential rollover losses due to their outstanding derivative positions in Volkswagen’s stocks to their liquidity position at the same time.

We start by discussing the academically-established distance to default measure of Bharath and Shumway (2008) and the so-called “Altman’s Z score”, which also measures the probability of default and was introduced by Altman et al. (2000). Following the approach of Bharath and Shumway (2008), which is based on the model of Merton (1974), the distance to default (DD) over the following quarter is defined as

\[
DD = \frac{\ln[(E + F)/F] + r_{t-1} - 0.5\sigma^2}{\sigma}
\]

where E equals the market value of the company’s equity (prccd×cshoc), F equals the sum of the debt in current liabilities and one-half long-term debt (dlcq+0.5dlttq), r is the firm’s quarterly stock return computed by using end of quarter prices, and \( \sigma^2 \) captures the volatility of the firm’s assets. \( \sigma \) is approximated by \( (E/(E+F))\sigma_E + (F/(E+F))\sigma_F \).
\[
(0.05 + 0.25 \sigma_E), \text{ where } \sigma_E \text{ is the quarterly percent standard deviation based on the past } 12 \text{ monthly returns (see e.g., Bharath and Shumway (2008)). A firm’s probability of default is then defined as } N(-DD), \text{ where } N \text{ is the cumulative standard normal distribution function.}
\]

Altman’s Z (see Altman et al. (2000)) is defined as:

\[
Altman’'s Z = 1.2T1 + 1.4T2 + 3.3T3 + 0.6T4 + 1T5 \tag{2}
\]

where: \( T1 = \) Working Capital/Total Assets, \( T2 = \) Retained Earnings/Total Assets, \( T3 = \) Earnings Before Interest and Taxes/Total Assets, \( T4 = \) Market Value of Equity/Book Value of Total Liabilities, \( T5 = \) Sales/Total Assets.

The first panel of figure 2 depicts the evolution of the probability of default of Porsche and its competitors from 2007 until the third quarter 2009 on a quarterly basis. In 2007 Porsche had the lowest probability of default as compared to its competitors. However, this situation changed in 2008 in which we observe a steep upwards movement in the probability of default in the second and third quarter of 2008, with an unprecedented increase from zero to almost 90 percent. In an unreported analysis we further evaluate the main drivers of this sudden increase, and conclude that this increase is mainly due to the decrease in the market value of Porsche’s equity, and - more importantly - due to the huge increase in Porsche’s short-term financial debt.\(^{19}\)

This evidence is also supported by the second panel of Figure 2, which documents the evolution of the additional default measure, Altman’s Z, over the time period of January 2007 to December 2008. High values of Altman’s Z-Score (i.e., larger than 1.8) indicate a low probability of default. It becomes clear from Figure 2 that Porsche had the lowest probability of default in the German automotive sector throughout the year of 2007 and up until the second quarter of 2008. However, from the second quarter of 2008 onwards, this division significantly shifted leaving Porsche with the highest probability of default among all German automotive producers. In fact, the bankruptcy probability of Porsche tripled when measured by Altman’s Z-Score. This was not the case with Porsche’s competitors for which we find at most slightly positive changes in the probability of default from the second quarter of 2008 onwards. Hence, the increase in Porsche’s bankruptcy likelihood

\(^{19}\)In the first half of 2008 Porsche increased its short-term debt by 10 billion from a pre-committed credit-line facility. The credit line originally comprised 35 billion euros and was arranged to finance a potential takeover of Volkswagen, for which Porsche had to make a mandatory offer. Porsche made the lowest offer for Volkswagen allowed and, after the bid failed, agreed with lenders to reduce the amount to 10 billion euros and was allowed to use the money for “general corporate purposes”.
is not a system-wide phenomenon, but rather firm-specific to Porsche. Further analyses confirm that the increase in the probability of default, as measured by Altman’s Z, is mainly due to the fact that Porsche’s market value of equity compared to its liabilities was lower with respect to both its past and also its peers. This analysis confirms the above-mentioned probability of default results. Moreover, the analysis confirms that Porsche had a clear incentive to manipulate Volkswagen’s stock price in order to prevent a pending insolvency.

4.3 Value at Risk Analysis

We then proceed by discussing another well-established measure, namely the Value at Risk (VaR). VaR states at some probability (often 1 percent or 5 percent) the worst-case loss during a specified time period. The percentage selected will affect the VaR, e.g., a 1 percent VaR would be expected to show a greater risk than a 5 percent VaR. In our analysis we apply the less-conservative 5 percent threshold, which represents a lower bound of Porsche’s losses. Furthermore the VaR time period should relate to the nature of the situation, we therefore concentrate on the period around the event date.

Since Porsche had both positions in long call options and short put options on Volkswagen, they likely faced significant liabilities when Volkswagen’s stock price continuously decreased in Mid-October 2008. These liabilities relate to margin calls as well as to the rollover risk faced at maturity of each option strategy. Hence, the idea of this section is to determine how long Porsche could have kept the options strategy alive and secured its own financial survival given the available information of October 24, 2008.

We apply an analytical VaR method, which is based on the normal distribution and the concept of one-tailed confidence intervals. In particular, we apply the following formula:

\[ p_i + (\sigma_i p_i \sqrt{t} (−1.645)) \]

where \( p_i \) denotes the price of either the ordinary or the preferred shares and \( t \) denotes the time horizon. The standard deviation \( \sigma_i \) is computed as the standard deviation of the returns of the thirty days preceding and including October 24, 2008. The 5 percent value in a single tail is associated with 1.645 standard deviations from the mean.

Table 1 portrays the evolution of Porsche’s VaR prices for its ordinary and preferred shares during the days immediately after the announcement. It also shows Porsche’s total margin calls figure, which is based on the sum of the individual margin requirements on
each of its option strategies, as well as the net liquidity on each day. Porsche’s net liquidity on each day is computed as the difference between Porsche’s total available liquidity as of October 24, 2008 and the cumulative total margin requirements. For example, Porsche’s available liquidity on October 24, 2008 is EUR 2,635 million, the total margin calls on the same day are EUR 3,462 million and the resulting liquidity net of margin calls is EUR -827 million (2,635 million - 3,462 million). Based on the VaR analysis it is clear that Porsche would have been in default on October 28, i.e., its net liquidity on that day would have been negative. Given that Porsche itself utilizes VaR methods according to their own annual report, they must have been fully aware of this fact.

The advantage of the analysis described above is that it is easy to calculate and interpret, and it can be also easily applied to shorter periods of time. The main disadvantage is that it concentrates on losses due to margin calls and disregards the rollover losses, and it also does not take into account the covariance between the ordinary and preferred shares. We therefore construct and describe a further measure of default in the next section that takes into account simulated price paths as well as rollover losses, and the covariance between the ordinary and preferred shares.

4.4 Simulated probability of default

In this section we analyze Porsche defaulting at a more granular level. Specifically, we analyze the probability of default of Porsche on a daily level by focusing on Porsche’s option strategy by taking into account different price paths, rollover losses, and the covariance between the ordinary and preferred shares. In order to take these points into account we apply a so-called “simulated probability of default” analysis in which we generate many potential daily price paths for the Volkswagen ordinary and preferred shares using a Monte Carlo simulation combined with Geometric Brownian motion. More precisely, we focus on the days after October 24, 2008 and simulate potential Volkswagen stock price paths for the coming trading days (i.e., we put ourselves in the shoes of Porsche’s management on October 24, 2008, and consider various Volkswagen price scenarios for the following trading days of October 27, 2008, October 28, 2008, etc.) Given these simulated price paths, we compute a probability of default which is based on the number of defaults incurred by the Monte Carlo simulated price paths on each trading day. Default is defined as Porsche having margin calls or paying rollover losses in excess of their existing liquid-

\[20\text{We estimate Porsche’s total available liquidity as of October 24, 2008 to be } 2,635,097,229 = 326,222,639 \times \left[(4,594,122,639 \text{ cash} - 4,267,900,000 \text{ locked in margins}) + 1,020,874,590 \text{ remainder from an existing 10-billion credit line} + 88,000,000 \text{ securities of other companies held by Porsche AG (short term assets)} + 1,200,000,000 \text{ Investment funds of Porsche AG}.\]

\[21\text{See the Porsche SE Annual Report 2007/08, p. 177}\]
ity. The number of defaults on each day divided by the total number of simulated price
paths gives us the simulated probability of default. If we find that Porsche defaults for
example in the fifth price path of October 28, 2008, then we assume that Porsche remains
in default on this particular price path also for the remaining days i.e., if Porsche defaults
in a given path, it is not able to renegotiate or reopen the strategy at a later day.

The first step involves simulating 100,000 price paths using the Monte Carlo simula-
tion methodology with Geometric Brownian motion. We simulate 100,000 price paths.
Note that the Geometric Brownian motion has two important parameters: the drift and
the variance-covariance matrix of Volkswagen’s ordinary and preferred shares. For the
drift we assume two different scenarios. In the first scenario, the drift is set to zero. This
should mimic the situation where prices do not follow any trend. In the second scenario,
the drift is set as the average return of the last six trading days. This is designed to mimic
the fact that during the months preceding October 24, 2008, there was downward pressure
on Volkswagen’s ordinary and preferred shares. This should mimic the fact that during
the months preceding October 24, 2008, there was a downward pressure on Volkswagen’s
ordinary and preferred shares.

The second important parameter is the variance-covariance matrix. In order to com-
pute this matrix, we use the multivariate GARCH-model following Ledoit and Wolf (2003).

In the third step of this analysis, we compute the accumulated margin calls and rollover
losses that Porsche faced in the days following October 24, 2008. In order to compute
gains and losses at every rollover date we proceed as follows: We take the price at the
current rollover date and subtract the price at the previous rollover. This difference is
multiplied by the quantity of the respective open option strategy.

Besides rollover gains and losses, Porsche also faced margin calls. These were acti-
vated by Porsche’s option counterparty when Volkswagen’s stock price fell below a certain
threshold.\footnote{Detailed information about the respective thresholds of Porsche’s different option strategies can be
found in the Stenographic Protocol, Plea of State Attorney, LG Stuttgart 18.02.2016 and in the Indictment
of the public prosecutor, 10.06.2015, LG Stuttgart 13 KLs 159 69207/09.} We assume that the margins are freed up at the rollover dates. The margin
calls themselves are then computed as follows. On each date following October 24, 2008,
we verify if Volkswagen’s stock price on that date is below the pre-defined threshold of
the respective option strategy. If so, then we take the stock price of that specific trading
day and subtract the stock price of October 24, 2008. This difference is multiplied by the
quantity of options used in the respective strategy. This procedure is continued until the
Finally, the last step in our simulation involves computing the probability of default. We check for each path and date if the liquidity is negative. If this is not the case, then we assign a value of zero. If this is the case, we assign a value of one to this day and also to the remaining part of this path. For example, if for the fifth path on the third simulated trading day the liquidity is negative, then we assign a value of zero to the two days preceding this specific trading day and a value of one to all simulated trading days after and including the third trading day. This way we ensure that Porsche is in default on all trading days in this particular price path.

Table 2 documents the simulated probability of default. We summarize the results for the two cases: 1.) price simulations assuming zero drift, and the more realistic 2.) price simulations assuming a drift equal to the average return over the last six trading days. We can clearly see that from the perspective of October 24, 2008, Porsche would have been in default with a probability of 55 percent on October 29, and with a probability of 100 percent on the next day in the scenario in which we apply as a drift the average return over the last six trading days. The scenario with price simulations assuming zero drift delivers very similar results with two days delay in complete default. These results indicate that taking into account the prevailing market conditions at that time and Porsche’s available liquidity, Porsche’s management must have expected a highly likely default resulting from their existing option strategies.

5 Market’s anticipation of press release

In this section we turn to assessing how market participants perceived the situation of Porsche and Volkswagen before the press release of October 26, 2008. Specifically, this section focuses on the question whether market participants could have anticipated the publication of this press announcement. Did they expect Porsche to be heavily invested in Volkswagen or to have concrete domination plans for the very short-term future? In order to understand market participants’ anticipation and perception of the market situation before the press release, we analyze a variety of measures. We start with experts’ opinions, namely analysts’ price target estimates and expectations as well as the dispersion in experts’ opinions about the fundamental value of Volkswagen. We then expand this analysis to include the perception and anticipation of all market participants and analyze the fundamental value of Volkswagen and Porsche by focusing on preferred shares and the respective wedge to ordinary shares. Finally, we analyze measures of informational risk
and trading pressure in order to understand in which direction the market was heading before the press release and if informational risk was at rather elevated levels.

### 5.1 Analysts’ price targets

In order to understand the dispersion in reactions of market participants and experts specifically, we screen analyst reports to find out what the majority of analysts expected the fundamental price of Volkswagen to be in late October 2008. We document the time series evolution of both means and standard deviations of stock analysts’ opinions about the fundamental value of Volkswagen relative to those of Volkswagen’s competitors such as BMW, Daimler, or Porsche. We interpret an increase in standard deviations of stock analysts’ opinions as an increase in the experts’ opinions dispersion. Higher dispersion in turn indicates higher uncertainty among experts about what the fundamental value of Volkswagen should be.

Panel one of Figure 3 plots the evolution of the average price target opinions of financial analysts (worldwide) for both Volkswagen’s ordinary and preferred shares as well as the highest target price given in an analyst’s forecast. As this figure documents, the mean estimates for the target price of Volkswagen were at about EUR 130. The outlier opinion of the upper part of the distribution was at a target price of EUR 204.75 (see the dashed line in panel one of Figure 3) still below the closing price of EUR 210.85 on October 24, 2008. The mean price target estimates were gradually decreasing from the end of September to the third week of October.

Panel two of Figure 3 plots the standard deviation in price target opinions of analysts for Volkswagen (ordinary and preferred), Daimler Chrysler, and BMW. This figure documents that experts’ opinions were very much aligned before the press release and all were pointing in the same direction, which was that Volkswagen was overvalued and Porsche was unlikely to dominate Volkswagen any time soon. From the evidence presented here, we conclude that experts did not expect Porsche to announce a domination plan for Volkswagen in the near future. Instead, the majority of experts perceived Volkswagen to be overvalued and recommended to sell the stock.

### 5.2 Voting premium

We compare both the preferred and common shares of Volkswagen over time in order to understand, whether the stark increase in prices of Volkswagen’s ordinary shares was due to a fundamental change in Volkswagen’s value or rather due to the heavy investment
of Porsche, in which case the increase is due to a voting premium. Preferred shares, which offer no voting rights in Germany, can be seen as those shares that represent the fundamental value of a company. Ordinary shares on the other hand have voting rights embedded in their contract features and hence usually carry a so-called voting premium. When buying shares in a publicly traded company, investors often pay a premium for voting shares because it gives them a stake in the control of the company they are investing in. Differentiating the voting premium from the fundamental value of a company can thereby help to better understand the nature of a stock market reaction such as the one observable in late October 2008 in Germany.

Figure 4 depicts the evolution of the prices of ordinary and preferred stocks of Volkswagen. There exists a statistically significant wedge in these two respective groups of share prices both before the press release of Porsche and after. (for coefficients of statistical significance please see Table 3). Most interestingly, this figure documents that the wedge was continuously increasing the closer time got to the announcement date. However, from the second week of October onwards, the wedge suddenly started to narrow, which gives the impression that less and less investors found it attractive to invest in voting shares of Volkswagen. This might be due to Porsche already being a major shareholder of Volkswagen. This, in turn, suggests that other investors assigned lower value to the option of having voting power, since Porsche already controlled a significant stake in Volkswagen, which explains why the voting premium was narrowing.

5.3 Insider trading

In order to establish whether there was informed trading in Volkswagen shares before the press release, we first apply a test based on the dynamic return-trading volume relation in the corner period. This test was introduced by Llorente et al. (2002) and later adapted by the study of Allen et al. (2006) to short squeezes and market corners.

We define the corner date as the date when the short sellers supposedly decided to close their short positions\(^{23}\), which in the case of Volkswagen is October 27, 2008, the first trading day after Porsche’s press release. We also define two corner sub-periods as well as a pre-corner period. The two corner sub-periods are: the so-called corner period

\(^{23}\)Short-sellers might decide to close their positions either because the shares that were sold short are called by the manipulator (see e.g., Allen et al. (2006)) or because the short-sellers realized that there is not enough free-float to cover their shorts. We regard the day of the announcement, Sunday, October 26, 2008, as a triggering event day because Porsche’s surprising holdings basically forced short sellers to cover their positions during the next trading days, even though they might not have received a margin call from their prime brokers immediately.
one, which is ten days before the corner date to the corner date (included), followed by a so-called corner period two, which is the day after the corner date to ten days following it. As a pre-corner period, we define 55 trading days before the first corner period, i.e., \([t-65, t-10]\). To test for whether there is trading on private information going on in the corner period we use the setup in Allen et al. (2006). Specifically, we estimate the following regression:

\[
R_{i,t+1} = \alpha_i + \beta_1 R_{i,t} + \beta_2 R_{i,t} \times V_{i,t} + \beta_3 R_{i,t} \times V_{i,t} \times D_i + \epsilon_{i,t+1} \tag{4}
\]

where \(i\) indexes the stock of Volkswagen, \(R_{i,t}\) is the continuously compounded return based on the closing price, \(V_{i,t}\) is the natural logarithm of the total number of shares traded, and \(D_i\) is an indicator variable with value one in the \([t-10, t]\) period around the corner date \(t\). We are interested in testing whether the coefficient \(\beta_3\) of the interaction term, \(R_{i,t} \times V_{i,t} \times D_i\), is positive and statistically significant\(^{24}\). If trading on private information was prevalent in the first corner period, then we expect to find that the \(\beta_3\) coefficient is positive and statistically significant. We perform our estimation in three different specifications. Each of the specifications considers different lengths of the first corner period: period \([t-10, t]\), period \([t-5, t]\), and period \([t-20, t]\).

Panels I and II in Table 4 summarize the results of the dynamic return-trading volume tests for common and preferred shares, respectively. As described in the methodology section above, if trading on private information, hence the risk of trading with better informed market participants, was high in the first corner period, then we expect to find that the \(\beta_3\) coefficient is positive and statistically significant. We perform our estimation in three different specifications. Each of the specifications considers different lengths of the first corner period: period \([t-10, t]\), period \([t-5, t]\), and period \([t-20, t]\). We find indeed that the coefficient of the interaction term \(Volume \times Return \times D\) is positive and statistically significant in all three specifications for ordinary shares. These results suggest strong evidence of informed trading in the period leading up to the short squeeze. Interestingly, we do not find any evidence for informed trading in preferred shares of Volkswagen. The reason for this lack of informed trading in preferred shares might relate to the voting premium (to which we will return in the next section). As preferred shares offer no voting rights, they might not be of interest to insider parties who are trying to gain voting control of Volkswagen.

\(^{24}\)This setup is adopted from Llorente et al. (2002), who hypothesize that conditional on high trading volume, positive \(\beta_2\) coefficients are evidence of private information trading in the market. To apply their framework to our analysis we test whether the \(\beta_2\) coefficient is increasing in the \([t-10, t]\) period, therefore we concentrate on \(\beta_3\) (see Allen et al. (2006)).
To establish robustness of the previously described results, we follow the latest literature on informed trading in stocks. More specifically, we follow the paper of Hendershott et al. (2011), who use a measure of informed trading in the framework of modern financial markets, in which trading happens both very quickly and in an automated manner (e.g., high frequency trading and algorithmic trading). Following Hendershott et al. (2011) we measure liquidity of Volkswagen’s shares and Volkswagen’s competitors using effective half-spreads, 5-minute realized spreads, and 5-minute price impacts. All of these proxies of liquidity and price impact (i.e., informed trading) are share volume-weighted to account for the differences in trading volumes across the different automobile stocks.

Effective spreads are measured as follows for stock $i$ and trade $t$:

$$ espread_{i,t} = \frac{q_{i,t}(p_{i,t} - m_{i,t})}{m_{i,t}} $$

$q_{i,t}$ is the so-called trade direction variable (estimated following Lee and Ready (1991)), where $q_{i,t}$ equals $+1$ for buyer-initiated and $-1$ for seller-initiated trades), $p_{i,t}$ is the transaction price, and $m_{i,t}$ is the mid price (i.e., the average between ask and bid quote).

Revenues to liquidity providers are estimated using (5-minute) realized spreads. We follow Hendershott et al. (2011) in using the 5-minute interval. The reason for using specifically this time interval is that liquidity providers should be able to close their position at the quote midpoint five minutes after the respective trade. The realized spread is then defined as follows:

$$ rspread_{i,t} = \frac{q_{i,t}(p_{i,t} - m_{i,t+5\text{min}})}{m_{i,t}} $$

Gross losses to liquidity demanders due to adverse selection are measured as:

$$ advselection_{i,t} = \frac{q_{i,t}(m_{i,t+5\text{min}} - m_{i,t})}{m_{i,t}} $$

In case a liquidity demander does not suffer from adverse selection and estimates the price movement correctly, the wedge between $m_{i,t+5\text{min}}$ and $m_{i,t}$ is zero. In the case that the liquidity demander is less well informed than the liquidity supplier, this difference will be larger (smaller) than zero in case of a sell-side (buy-side) trade.

Figure 5 plots the four measures of liquidity and adverse selection, respectively. Generally, before the press release of Porsche, our measures of illiquidity and adverse selection costs are in line with what Hendershott et al. (2011) find for modern financial markets.
Effective spreads are on average at less than one basis point; the same is true for realized spreads (i.e., profits to liquidity suppliers) and adverse selection losses (to liquidity demanders). All of the companies’ illiquidity measures react to the (in its history the largest) drop of the Dow Jones Index on October 7, 2008. On this day, Daimler experiences the steepest increase in all types of illiquidity and adverse selection costs. For Daimler we find a significant increase in effective spreads and adverse selection costs (about a 300 percent increase); for all other companies we find a non-significant increase. For the press release of Porsche with respect to the domination of Volkswagen shares, we find a significant increase in effective spreads, realized spreads, and adverse selection costs for Volkswagen and Porsche. Effective spreads at Volkswagen increase significantly - about 400 percent on the two days after the press release of Porsche. Porsche’s effective spread, most interestingly, is on a severely elevated level already before they announced the press release. Here we find a significant increase of about 600 percent already in the week of October 24, 2008. Note that adverse selection cost was already on an elevated level for Volkswagen before the press release. In fact, in the two weeks before the press release we observe an increase in Volkswagen’s adverse selection cost of 40 percent on average, which lends robustness to the above described findings, which are based on the measure of Llorente et al. (2002). We do not observe this to happen at any of the other companies.

5.4 Buying vs. selling pressure

Another indicator of market participant’s perception of how the price process and/or the situation of a certain stock will evolve relates to the so-called trading pressure. This variable indicates whether market participants from both sides of a market (i.e., demand and supply sides) are perceiving certain situations to be positively or negatively evolving, which either makes them turn to buy or sell orders. Specifically, by differentiating general trading volume (in this case measured as the number of shares traded) into buy-side and sell-side trading volume, we are able to better understand whether the demand side was rather selling or buying Volkswagen stocks. Similarly, by analyzing the number of shares offered at the ask side vs. offered at the bid side of the order book, we are able to better understand whether the supply side (i.e., market makers and liquidity suppliers in general) was trying to sell or buy Volkswagen stocks. In order to differentiate the number of shares traded into buy-side and sell-side trading volume, we apply the algorithm proposed by Lee and Ready (1991) as described in the previous subsection.

Figure 6 plots the evolution of the signed trading volume of Volkswagen (buy side and sell side). Interestingly, buy orders were significantly less frequent than sell orders during the weeks before the press release. In fact, buy orders were traded at approximately 0.4
million shares per day, sell orders were traded at approximately 0.7 million shares per day during the two weeks before the press release. This evidence is consistent with the significant decrease that Volkswagen’s share price experienced in the weeks before the announcement.

Figure 6 documents the behavior of the supply side of the equity market in Volkswagen stocks. Here the volume offered at the ask and bid sides, respectively, are plotted. Similarly to the behavior of the demand side of the market, also the supply side of the market tried to decrease Volkswagen’s shares in their portfolios. In the two weeks before the press release, the volume offered at the ask side of the market (hence available for sale) is significantly higher than the volume offered at the bid side of the market. This reinforces the impression that both sides of the market - demand and supply - tried to decrease Volkswagen’s shares in their holdings and were hence not expecting Porsche to make an announcement and gain additional control in Volkswagen.

6 Did the press release lead to a short squeeze?

Given the just established fact that Porsche had a motive to manipulate the stock price of Volkswagen (namely its pending insolvency, see Section 4) and the fact that market participants seemingly did not anticipate this kind of press release (see Section 5), it is important to consider the evidence that Porsche’s press release did indeed lead to a short squeeze in Volkswagen’s stock and hence damaged market participants. Allen et al. (2006) suggests a series of tests of market corners, which occurred between 1863 and 1980. Their paper provides a valuable summary of the consequences of market cornering and suggests a series of tests that can help in evaluating the market impact of a short squeeze. Specifically, they concentrate on daily returns, volatility, illiquidity, price dispersion, and trading volume around the corner events. Importantly, they find in their sample that in the days following a short squeeze cumulative daily returns, volatility, illiquidity, price dispersion, and volume increase to abnormally high levels. We therefore concentrate on the behavior of Volkswagen’s stock after the press release. We test for an abnormal increase in cumulative returns, cumulative trading volume, illiquidity, price dispersion, and volatility, in order to determine whether Volkswagen’s stock behaved as if it was short-squeezed.

As already discussed, we regard as the triggering event day the first trading day after

\footnote{Kyle and Viswanathan (2008) also contribute to this stream of literature by giving a definition for illegal price manipulation: “A trading strategy that undermines both pricing accuracy and market liquidity.” Therefore, we can see a stock squeeze or corner as specific forms of market manipulation.}
Porsche’s press release, Monday, October 27, 2008. For the analysis we define two corner sub-periods as well as a pre-corner period. The two corner sub-periods are: the corner period one, which is ten days before the corner date to the corner date (included), followed by corner period two, which is the day after the corner date to ten days following it. As a pre-corner period, we define 55 trading days before the first corner period, i.e., [t-65, t-10].

Abnormal returns are defined as the difference between the daily return in the corner period and the pre-corner [t-65, t-10] average daily return. In the figures, that we will describe below, we have accumulated the abnormal return across the corner period, i.e., at date t-10 we have plotted the abnormal return at that date, at date t-9 we have plotted the sum of the variable values at dates t-10 and t-9, etc. We furthermore computed a measure of abnormal returns, defined as the daily return in the corner period in excess of the average daily return for the German automotive industry.

Abnormal trading volume is defined as the difference between daily trading volume in the corner period and the pre-corner [t-65, t-10] average daily trading volume. We standardize this variable with the standard deviation of the pre-corner period daily volume. In the figures, that we will plot and describe below, we have accumulated the abnormal trading volume across the corner period, i.e., at date t-10 we have plotted the abnormal trading volume at that date, at date t-9 we have plotted the sum of the variable values at dates t-10 and t-9, etc.

We define the daily illiquidity measure for Volkswagen’s stock as $\text{ILLIQ}_{i,t} = \frac{|R_{i,t}|}{\text{VOLD}_{i,t}},$ where $\text{VOLD}_{i,t}$ is the daily dollar trading volume (in millions of dollars), and $R_{i,t}$ is the daily absolute stock return (see Amihud (2002)). We further compute a measure of abnormal illiquidity, defined as the daily illiquidity measure in the corner period in excess of the average daily illiquidity measure for the German automotive industry.

Daily price dispersion for Volkswagen’s stock is the difference between the high and low prices within a given trading day as a percentage of the closing price. We further compute a measure of abnormal price dispersion, defined as the daily price dispersion measure in the corner period in excess of the average daily price dispersion measure for the German automotive industry.

We define the daily volatility measure for Volkswagen’s stock as the standard deviation of intra-daily returns (on a minute by minute basis). Abnormal volatility is defined as the difference between daily volatility in the corner period and the pre-corner [t-65,
average daily volatility. We compute also a measure of abnormal volatility, defined as the daily volatility measure in the corner period in excess of the average daily volatility measure for the German automotive industry.

In addition to these stock market quality and trading measures, we analyze the securities lending market. Presumably, if the hypothesis of a short squeeze is to be accepted, we should find a freezing of trading activity in the securities lending market as depicted, for example, by increasing fees on loans, decreasing utilization, increasing average tenure of outstanding loans, and decreasing demand for securities loans for short selling purposes of Volkswagen’s stock.

The behavior of the cumulative abnormal return (CAR) for Volkswagen’s ordinary and preferred shares are depicted in Figure 7. The CAR for the common shares peaked at the day of the corner by more than 100 percent in absolute values (from -52 percent on Friday, October 24, to 71 percent on Monday, October 27) and increased slightly further throughout the days of October 28 and 29. During the remaining trading days of the second corner period the cumulative average return steadily declined by more than a third of its previous high. One concern with this procedure, is that the pre-corner period may contain abnormal (e.g., manipulation) activity. We would expect that this would bias our estimates since we use the pre-corner period to compute the average expected return, which we then subtract from the daily return in the corner period. To address this concern, we also computed market adjusted returns. These are computed by subtracting the German automotive market return from the raw returns of Volkswagen in the corner period. The results are very similar. In addition, Volkswagen’s preferred shares are analyzed in the right-hand side graph of Figure 7. There is a continuous downward trend throughout the examination period, with only a small peak after the press release of Porsche. This evidence confirms that the attention was concentrated on Volkswagen’s common shares.

Next, we examine the cumulative abnormal trading volume for Volkswagen’s shares in Figure 7. As above, on the left-hand side we display the common shares and on the right-hand side we display the preferred shares. For the common shares a clear pattern of a sudden increase in trading volume and subsequent gradual decrease is displayed. Interestingly, for the preferred shares there is an upward trend throughout the whole period after the press release of Porsche. We also compute abnormal trading volume based on subtracting the standardized German automotive market trading volume. The results are similar.
The next variable of interest in determining whether Porsche’s press release lead to Volkswagen’s short squeeze, is daily illiquidity. Illiquidity is measured by the Amihud measure (Amihud (2002)). Figure 7 shows the evolution of illiquidity over the corner period for both ordinary and preferred shares. The respective results indicate that there is an increase in the illiquidity right before the corner date, which in turn is in line with the evidence above on declining trading volume and returns. After the corner date we observe a slight improvement in illiquidity throughout the days of October 28 and 29. During the remaining trading days of the second corner period illiquidity steadily increased and reached its highest point on the last day of the second corner period. This evidence is in line with the evidence for cornered stocks, presented by Allen et al. (2006), and lends support to the idea that the manipulator can withhold the acquired free-float before and after the corner date while at the same time making it available during the corner day(s).

We further compute a measure of abnormal illiquidity, defined as the average of the daily illiquidity measure in the corner period in excess of the average daily illiquidity measure in the pre-corner period, or in excess of the average daily illiquidity of the entire German automotive industry. The results are similar.

Next, we turn to the concept of price dispersion, which is measured by the difference between a day’s highest price to the lowest price divided by the closing price of that day. Figure 7 plots the evolution of this measure across the corner periods for both ordinary and preferred shares. Price dispersion is lower in the first corner period as compared to the second. Price dispersion spikes at the corner date and decreases following the corner. Still, price dispersion remains at elevated levels in the second corner period as compared to the first corner period. This pattern of increasing price dispersion is indicative of the presence of information trading and reflects the volatile nature of the market corner. Again, results are robust when compared to the entire German automotive industry.

Finally, with respect to the reaction in stock markets, we turn to daily abnormal volatility. Figure 8 plots the evolution of this measure across the corner periods for both ordinary and preferred shares. Abnormal volatility suddenly increases at the corner date for the ordinary shares and slightly decays thereafter. Interestingly, volatility in the preferred shares spikes three to four days before the announcement and reverts back to the pre-corner level much faster. As before, results are robust when compared to the entire German automotive industry.

Before concluding this section, we turn to the reaction of traders in the securities
lending market (i.e., short sellers). Specifically, we analyze variables such as fees on loans, utilization (which is the value of open loans relative to the total offered lendable value), average tenure of outstanding loans, and demand for securities loans for short selling purposes of Volkswagen’s stock. The respective evolution of each of these variables is depicted in Figure 9. The short squeeze in Volkswagen’s stock is confirmed by the reaction of traders and trading behavior in the securities lending market: fees increase steeply by 47 percent; the utilization drops by 17 percent of the day of the press release and the day thereafter, tenure increases by 44 percent, and the demand for securities loans decreases by one percent on the day of the press release.

So, did Porsche’s press release trigger the short-squeeze or was it a mere accident? In summary, the evidence outlined in this section suggests that after Porsche made the press release on October 26, 2008, cumulative abnormal returns and trading volume drastically increased at the corner date and gradually decreased afterwards. Price dispersion jumped, remaining at an elevated level as compared to the pre-press release period. Furthermore, illiquidity improved immediately after the corner date and gradually increases in the next couple of days. Moreover, abnormal volatility jumps at the corner date and remains at elevated levels throughout the corner days of October 28 and 29. This evidence is consistent with the behavior of cornered stocks described in detail by Allen et al. (2006) and suggests that Porsche’s press-release seemed to have triggered the Volkswagen’s short squeeze. The fact that the press release on Wednesday, October 29, that Porsche would increase liquidity in the market by making available 5 percent of Volkswagen shares was followed by a fall in the price is also evidence of a short squeeze in the previous two days. In the next section, we evaluate the impact of Volkswagen’s short squeeze on price discovery and market efficiency of Volkswagen and the overall German automotive market.

7 Did the short squeeze distort price discovery and market efficiency?

In this section we aim at quantifying what the short squeeze - which resulted from Porsche’s press release of October 26, 2008 - meant in terms of market quality for Volkswagen’s stock. Did the short squeeze distort price discovery and market efficiency for Volkswagen? How does this relate to the overall market for German automobile manufacturer’s stock? Were Volkswagen’s competitors impacted as well?

The literature on repeated trading and herding in efficient markets explains how difficult it is for market participants of all kinds (unsophisticated and experts) to evaluate
surprising news. Specifically, this literature describes that usually some market participants are faster in evaluating certain surprising news than others. Because others then fear to lose on trades if they do not react quickly enough, they herd and follow the crowd rather than lose time with the evaluation of the information. More specifically, following the theories of Foster and Viswanathan (1996), Park and Sabourian (2011), and Park and Sgroi (2012), we should observe price discovery to happen in stages. These theories predict that we should observe high speed of price discovery first (i.e., right after the press release) as traders with extreme information tend to trade the earliest. They should then be followed by those with information conducive to contrarianism, which we should observe with price discovery slowing down and price setting even working in the opposite direction. Finally, the true “herders” should follow in a third stage, which do not trade on information but follow the crowd. Hence, in this last stage, price discovery should slow down significantly.

7.1 Price discovery

We can test for the behavior of price discovery and market efficiency by analyzing the abnormal change in speed of price discovery right after press release for Volkswagen’s stock relative to Volkswagen’s competitors. In order to measure price discovery empirically, we follow the literature by Barclay and Warner (1993), Cao et al. (2000), Huang (2002), and Barclay and Hendershott (2003) in order to measure the amount of information that is incorporated into stock prices during a given time period. All of the above mentioned papers use the so-called “weighted price contribution” (WPC) measure to determine the share of price discovery happening in different periods of a given trading day. For each stock $s$ and for a given period $i$, we calculate the fraction of the price change over period $i$ relative to the close-to-close price change on each day. We divide the close-to-close trading day period into three sub-periods of particular interest to us in order to understand how much price discovery is happening in each of these periods. The three periods are: 1.) the first 15 minutes after opening, 2.) after the first 15 minutes to closing (i.e., the rest of the trading day), and 3.) close-to-open (i.e., after-hours trading). For each day and each time period $i$, we define the WPC to be:

$$WPC_i = \sum_{s=1}^{S} \left( \frac{|\text{ret}_{i,s}|}{\sum_{s=1}^{S} |\text{ret}_{s}|} \right) \times \left( \frac{\text{ret}_{i,s}}{\text{ret}_{s}} \right)$$  \hspace{1cm} (8)$$

where $\text{ret}_{i,s}$ is the return during period $i$ for stock $s$, and $\text{ret}_{s}$ is the close-to-close return for stock $s$. 

28
We estimate the weighted price contribution for the entire German automobile sector as well as for Volkswagen only in order to understand how fast price discovery evolved throughout October 2008 and how this process differed for Volkswagen relative to the rest of the German automaker sector.

Figure 10 plots the evolution of the price discovery measure WPC for the German automobile sector. As this graph shows, there does not exist a clear pattern in how much price discovery happens at which time during a trading day. Instead price discovery varies across the different time intervals for the period depicted here. What is, however, notable is the steady increase that the weight in price discovery experiences for the period of “15 minutes to close” from October 23, 2008, onwards, and especially in the week after the press release of Porsche. The weight of price discovery happening in this time period increases steadily from about five percent and peaks in the week after the press release at about 60 percent of the overall price discovery. On the contrary, during the week after the press release of Porsche, the weight of price discovery happening in the first 15 minutes after the opening of trading decreases from about 70 percent to almost zero percent. This is a first, clear indication that market participants needed more time than usual to process information in the week right after the press release of Porsche. Tables 1 to 5 in the internet appendix show statistical tests, that confirm these results.26

The more interesting question is what the price discovery for Volkswagen during the corner period looked like specifically. Figure 20 plots the evolution of the weighted price contribution of the first 15 minutes after opening of trading (in blue) versus the weighted price contribution of the rest of the trading hours of the close-to-close period.27 The average weighted price contribution of the first 15 minutes after opening at Volkswagen is 32 percent (i.e., August 1 to September 12, 2008) to 52 percent (i.e., October 8 to October 24, 2008), respectively, in the period before the press release of Porsche. This decreases, as depicted by Tables 7 to 12, on October 27 (i.e., the day after the press release) to 32 percent.28 Throughout the week after the press release, the average weighted price

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26The “Before Press Release period” is defined as August 1 - September 12, 2008 in Table 1, as September 15 - October 24, 2008 in Table 3, and as October 8 - October 24, 2008 in Table 5. We also look at the sub period of October 8-24 because the weeks before October 8 were extremely turbulent for world financial markets. There was Lehman’s bankruptcy on September 15, followed by short selling bans and all kinds of rescue measures around the world. This turbulent time peaked on October 7 with the biggest drop in the Dow Jones Index of all time. After October 7, financial markets started to calm down and we can use this as a relative calm market environment.

27For reasons of visibility we refrain from showing all three shares but concentrate on the first time interval (i.e., the first 15 minutes after opening) and the rest of the time period.

28This decrease is not statistically significant as documented in Tables 8 and 10. Only when we use the time period of October 8-24 as the “Pre-Press Release” period do we find significant differences in the weighted price contribution of Volkswagen before and after the press release of Porsche (see Tables 11 and
contribution of the first 15 minutes in Volkswagen shares stays on a low level with 32 percent. For preferred shares of Volkswagen we do not find significant results in terms of differences before and after Porsche’s press release.

Based on this set of results, we can conclude that market participants seem to have been very uncertain on how to interpret Porsche’s press release and how to trade Volkswagen shares as only 32 percent of all price adjustments happened in the first 15 minutes of that trading day. All trading and major contribution to price discovery happened after these 15 minutes, in a period in which we - as described in the previous section - observe high volatility, abnormal returns, illiquidity, and price dispersion. From this evidence we conclude that Porsche’s press announcement surprised traders and left them visibly confused on how to value the stock, what to expect, and how to behave.

7.2 Market quality

Besides price discovery we also analyze the market quality measures of illiquidity, transaction costs, and informational risk. For this we follow the same methodology as outlined in Section 5 based on Hendershott et al. (2011).

Figure 5 plots the three measures of liquidity and adverse selection, respectively. For realized spreads and adverse selection costs we find a significant increase for Volkswagen on the two days after the press release of about 200 percent, respectively. This indicates that liquidity demanders incurred significant losses of about on average 100 percent after the press release.

Porsche experiences a similarly steep increase in both measures - realized spreads and adverse selection costs - from October 29 onwards. This was the day when they announced to release five percent of their Volkswagen holdings in order to increase the available free float. This seems to have caused liquidity demanders to lose significantly as transaction costs doubled. For the other German automotive companies we do not observe these patterns.

The second row in Figure 5 plots effective spreads, realized spreads, and adverse selec-

12) when using the t-test, the Kolmogorov-Smirnov test, and the Wilcoxon test. All three tests confirm that there is a statistically significant change (i.e., decrease) in the weighted price contribution happening in the first 15 minutes of an average trading day before vs. after the press release of Porsche. For the other two sub periods that capture the time period before the press release, we do not find significant differences when using the t-test, the Kolmogorov-Smirnov test, and the Wilcoxon test (see Tables 8 and 10).
tion costs for both Volkswagen’s ordinary and preferred shares. The different illiquidity measures are more aligned for both preferred shares and ordinary shares before the press release.

7.3 Analysts’ price targets

In order to understand how market participants and experts reacted to the press release, we follow the same procedure as outlined in Section 5: we screen analyst reports to find out what the majority of analysts expected the fundamental price of Volkswagen to be after the press announcement of October 26, 2008. As in Section 5, we present the time series evolution of both means and standard deviations of stock analysts’ opinions about the fundamental value of Volkswagen relative to those of Volkswagen’s competitors such as BMW, Daimler, or Porsche. In fact, if we find the dispersion among experts’ opinions to increase after the press release, this would indicate that the press release of Porsche of October 26, 2008, left market participants notably confused about the true fundamental value and hence subjected them to herding instead of leaving them time for rational decisions.

Figure 3 plots the standard deviation in price target opinions of analysts for Volkswagen (ordinary and preferred), Daimler, and BMW. This figure documents that from the day after the press release of Porsche, the dispersion in analysts’ opinions for the Volkswagen’s stock tripled implying that very skilled stock analysts were unable to narrow down a price target. As we do not observe this kind of pattern for Volkswagen’s competitors or for Volkswagen’s preferred shares, we can conclude that the press release left market participants (including skilled analysts) uncertain and disturbed of what to make of the press release and how to value the stock. Most interestingly, the data on analysts opinions reveals that this uncertainty persisted also in November and December 2008. In these months we document a still abnormally high dispersion in price target opinions, which suggests that the press release left market participants uncertain and confused for quite some time.

Table 5 documents that the difference in dispersion of analysts’ opinions is statistically significant after the press release and only for Volkswagen’s ordinary shares. Dispersion in analysts’ opinions does not differ significantly across Volkswagen’s preferred shares and its competitors.
7.4 Buying vs. selling pressure

As an additional indicator of market participant’s perception of how the price process and/or the situation of a certain stock will evolve, we apply once more the so-called trading pressure variable. For a more detailed description of the respective methodology see Section 5.

Figure 6 plots the evolution of the signed trading volume of Volkswagen (buy- and sell-side trading volume). Interestingly, buy orders were significantly more frequent on October 27, 2008, than on any other day during the time period of September to November 2008. About 5.5 million shares were traded on the buy-side on October 27, 2008, compared to only about 4 million shares that were traded on the sell-side. This gap decreased significantly from October 28 onwards. For example, on October 29, 2008, about 6 million shares were traded on the sell-side compared to 5.5 million shares being traded on the buy-side. Hence, market participants were increasingly uncertain about which direction to trade with the majority tending towards sell-side trades from October 28 onwards.

The same is true for the supply side of the market. Figure 6 plots the evolution of the sizes of bid and ask quotes. The amount and respective quantity of ask quotes slightly exceeded the amount and respective quantity of bid quotes on October 27, 2008, the day after the press release. This turned around on October 29, 2008, on which day we find the amount and respective quantity of bid quotes to exceed the ones of ask quotes. This implies that also the supply side was very uncertain about which direction the stock price of Volkswagen would take and whether the news revealed by Porsche on October 26, 2008, were in fact news in favor of buyers or sellers.

8 Concluding remarks

The episode of October 2008 where Volkswagen briefly became the most valuable company in the world by market capitalization is an interesting and important one. In this paper we argue that Porsche had significant incentives to manipulate the stock price of Volkswagen by creating a short squeeze. Our analysis of the facts shows that the most plausible explanation for the press release on October 26, 2008, was an intention to manipulate the stock price of VW upwards.

The consensus of analyst reports at that time saw the voting stock of VW on a path down to EUR 130 or even less per share in the foreseeable future. As a consequence of
the financial crisis and rising oil prices in fall 2008, the car industry including VW got hit by a severe drop in revenues; the hit starting in early fall 2008 was so dramatic that it led the German Chancellor to agree to support the crisis-stricken automobile industry with government grants as early as November 2008. In fact, the government shortly following its announcement agreed on a so called “cash-for-clunkers scheme”, a government subsidy aimed at promoting sales that helped selling millions of new cars by offering each potential buyer thousands of Euros in tax-payer funded incentives.

At the time Porsche SE announced its press release, its management and all other market participants were left with the information that the automotive industry including VW was hit by a crisis that was certain to diminish the value of the companies affected by it.

In addition, the financial situation of Porsche SE on October 26, 2008 was distressed. Its liquidity had just been reduced significantly by contractual margin calls and repricing losses resulting from its massive derivative scheme in VW stock and it faced further losses including roll-over losses that were already imminent. A EUR 10 billion facility that was about to expire in less than 6 months from the date of the press release had been drawn down in full to meet payment obligations and, worse than that, Porsche SE’s management learned in September 2008 that negotiations with banks on additional funds or even a refinancing failed for the remainder of 2008.

Even more importantly, an analysis of the liabilities and the corresponding liquidity shortages resulting from Porsche SE’s derivative scheme using standard VaR methodology and a simulated probability of default methodology shows that the company had a very high chance of default in the week following its press release even if the stock price of VW ordinary shares remained unchanged at the level it had closed at the end of the preceding trading week.

VW’s ordinary stock was overvalued compared to its peers and consequently sold short by an increasing number of arbitrageurs. In a market environment characterized by questions regarding bank solvency, declines in credit availability, economies worldwide slowing down, global stock markets facing continuous heavy losses and a crisis of the automotive industry at large, the chances of the stock price for VW ordinary shares staying at its still overvalued level relative to its peers and no fundamental data supporting these prices were insignificant. Without additional funding being available, Porsche SE was certain to default under the circumstances in the very near future.
As Porsche SE had effectively insured more than 50 percent of the voting stock holders of VW against falling stock prices by selling cash settled stock options and lacked the funds to back up its contractual obligations (without starting to sell the VW stock it held which would, however, have pushed the stock price downward even more rapidly and would have brought more and more put options into the money thus bankrupting Porsche SE even faster), it was out of alternatives. While it was running out of liquidity and hardly in a position to survive any meaningful period of time under the then prevailing circumstances, it had to find a way to disguise its perilous position and at the same time exercise upward pressure on the price of Volkswagen ordinary shares.

The press release Porsche SE issued tried to achieve just that. It disclosed a market position covering 74.1 percent of the voting stock of VW and announced a plan to acquire more than 75 percent of the company “paving the way for a domination agreement” despite the fact that the evidence shows that literally none of the requirements that would allow thinking about such a plan, most importantly the funding and a legal environment allowing them to bypass the 20 percent shareholder Lower Saxony veto right was met. The release was silent on the billions of Euros in margin calls and losses they had endured in the previous trading week and did not mention the fact that a two digit million amount of put options had been in the money until rolling on the last trading day preceding the press release. By leaving out the actual perilous condition of Porsche SE, the press release created the impression that the company was hedged against rising stock prices and would welcome lower prices as those would allow them to complete the takeover at a lower cost. Nothing in the press release hints to the synthetic forward position in VW voting shares they had created, the risks they were facing as a result of this position and the naked cash settled short puts they had sold covering some 20 percent of VW’s stock. By doing so, it disguised its own interest in the stock in its entirety and hid the circumstances that lead them to put out the press release.

On October 29, 2008, Porsche SE issued another press release announcing its “willingness” to settle up to 5 percent of its options in order to be able to cash in more than EUR 5 billion by utilizing the short-squeeze. This press release and the additional liquidity it offered to the market helped Porsche SE to restock its liquidity reserves and by adding to the supply side at a time where many short sellers had already covered their positions also helped to bring down the stock price to a level allowing Porsche to roll over its derivative positions at more digestible prices prior to the end of the week.
The great deal of evidence we looked at strongly supports that a short squeeze occurred. This had significant ramifications in terms of distorting price discovery and market efficiency. These events have important public policy implications. Going forward, the European Union and Germany in particular will only be able to develop well-functioning and efficient capital markets if it effectively enforces prohibitions of stock price manipulation. It is important that regulators and courts make this a high priority.
References


Harvey, A. C., Chakravarty, T., et al. (2008). *Beta-t-(e) garch*. University of Cambridge, Faculty of Economics.


Figure 1: **Current Ratio**: We define the current ratio as current assets divided by current liabilities. **Quick Ratio**: We define the quick ratio as cash plus marketable securities plus receivables divided by current liabilities. **Cash Ratio**: We define the cash ratio as cash divided by current liabilities. We have plotted the evolution of the three ratios for Porsche and its peer group: Volkswagen, Daimler and BMW.
Figure 2: Probability of Default: The probability of default measure is constructed following Bharath and Shumway (2008)’s distance to default and defined as: 

$$DD = \frac{\ln[(E+F)/F] + r_{t+1} - 0.5\sigma^2}{\sigma_E}$$

where \(E\) equals the market value of company’s equity (prccd\times cshoc), \(F\) equals the sum of the debt in current liabilities and one-half long-term debt (dlc+0.5dltt), \(r\) is the firm’s quarterly stock return computed by using end of quarter prices, and \(\sigma^2\) captures the volatility of the firm’s assets. \(\sigma\) is approximated by \((E/(E+F))\sigma_E + (F/(E+F))(0.05 + 0.25\sigma_E)\), where \(\sigma_E\) is the quarterly percent standard deviation based on the past 12 monthly returns. **Altman’s Z:** We define the Altman’s Z as 1.2T1 + 1.4T2 + 3.3T3 + 0.6T4 + T5, where: T1 = Working Capital/Total Assets, T2 = Retained Earnings/Total Assets, T3 = Earnings Before Interest and Taxes/Total Assets, T4 = Market Value of Equity/Book Value of Total Liabilities, T5 = Sales/Total Assets (see Altman et al. (2000)). Lower values represent an increased probability of default. We also depict the critical bankruptcy level of 1.8 in the figure.
Table 1: Margin calls and liquidity analysis based on the Value-at-Risk price

This table presents the margin calls and the liquidity net of the margin calls based on the VaR price for different time horizons. The VaR prices are computed as \( p_i + (\sigma_i \sqrt{t} \times -1.645) \), where \( p_i \) denotes the price (the closing price is adjusted as price/ajexdi) of either the ordinary or preferred shares and \( t \) denotes the time horizon. The standard deviation \( \sigma_i \) is computed as the standard deviation of the returns of the thirty days preceding and including October 24, 2008. The price of Porsche’s ordinary shares on October 24, 2008, was EUR210.85; the price of preferred shares was EUR 43.98. Daily historical volatility was at 9.32% for ordinary shares and 5.74% for preferred shares. As of this date, Porsche’s liquidity was at EUR2,635 million.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence level</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>VaR price for the ordinary shares</td>
<td>178.53</td>
<td>165.14</td>
<td>154.86</td>
<td>146.20</td>
<td>138.57</td>
<td>131.67</td>
</tr>
<tr>
<td>VaR price for the preferred shares</td>
<td>39.83</td>
<td>38.11</td>
<td>36.79</td>
<td>35.67</td>
<td>34.70</td>
<td>33.48</td>
</tr>
<tr>
<td>Margin calls Strategy one*</td>
<td>-560</td>
<td>-792</td>
<td>-970</td>
<td>-1,120</td>
<td>-1,252</td>
<td>-1,372</td>
</tr>
<tr>
<td>Margin calls Strategy two*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Margin calls Strategy three*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Margin calls Strategy five*</td>
<td>-116</td>
<td>-161</td>
<td>-196</td>
<td>-225</td>
<td>-251</td>
<td>-274</td>
</tr>
<tr>
<td>Margin calls Strategy seven*</td>
<td>0</td>
<td>-2,347</td>
<td>-2,561</td>
<td>-2,741</td>
<td>-2,900</td>
<td>-3,043</td>
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<tr>
<td>Margin calls Strategy eight*</td>
<td>-116</td>
<td>-161</td>
<td>-196</td>
<td>-225</td>
<td>-251</td>
<td>-274</td>
</tr>
<tr>
<td>Total margin calls*</td>
<td>-792</td>
<td>-3,462</td>
<td>-3,923</td>
<td>-4,312</td>
<td>-4,654</td>
<td>-4,964</td>
</tr>
<tr>
<td>Liquidity net of margin calls*</td>
<td>1,842</td>
<td>-827</td>
<td>-1,288</td>
<td>-1,676</td>
<td>-2,019</td>
<td>-2,328</td>
</tr>
</tbody>
</table>

Table 2: Simulated Probability of Default

This table presents the simulated probability of default for 10/27-11/03. “Zero drift” assumes no drift; “Average six day drift” assumes a drift of the average daily return of the six trading days preceding October 24, 2008.

<table>
<thead>
<tr>
<th>Time period</th>
<th>10/27</th>
<th>10/28</th>
<th>10/29</th>
<th>10/30</th>
<th>10/31</th>
<th>11/03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero drift</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.97</td>
</tr>
<tr>
<td>Average six day drift</td>
<td>0</td>
<td>0</td>
<td>0.55</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 3: Analysts opinions about price targets for Volkswagen’s ordinary and preferred shares: 2005-2008: This figure plots the evolution of monthly mean and median price target estimates of stock analysts on the y-axis. The x-axis denotes the time period. The shaded areas in blue and brown around the mean average price targets of ordinary and preferred shares denote the respective confidence intervals. “High Price Target Ord.” denotes the maximum price target given by an analyst in a single month; “Actual Price Ord.” denotes the actual share price of Volkswagen’s ordinary shares. Dispersion in analysts opinions about price targets for Volkswagen’s ordinary and preferred shares: 2005-2008: This figure plots the evolution of the monthly dispersion in analysts’ price target estimates on the y-axis (which is estimated in how much (in Dollar-terms) analysts differ in terms of their opinion on the value of a stock). The x-axis denotes the time period. The blue line denotes the evolution in dispersion of Volkswagen’s ordinary shares; the red line denotes the evolution in Volkswagen’s preferred shares; and the dotted green and grey lines denote the evolution in dispersion at BMW and Daimler, respectively.
Figure 4: EPS Expectation, DAX, and Stock Price Evolution: July-November 2008: This figure plots the evolution of the intradaily share prices of Volkswagen’s ordinary (blue) and preferred (red) shares vs. Volkswagen’s estimated evolution of earnings per share (green) and the DAX index (orange). The x-axis denotes the time period. The left y-axis gives the scaling for the stock prices of Volkswagen; the right y-axis gives the scaling for forecasted earnings per share and the DAX index.

Table 3: Comparison of wedge in share prices for Volkswagen (ordinary vs. preferred shares)

This table compares the differences in distributions of share prices of ordinary and preferred shares for the time period before the press release of Porsche (i.e., before October 26, 2008) and thereafter. Column two shows the p-values of the Wilcoxon ranksum test. Column three depicts the p-values of the Kolmogorov-Smirnov (K-S) test of differences in distributions and column four presents the differences in average values of the respective distributions.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Wilcoxon-test</th>
<th>K-S-test</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Press Release</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>After Press Release</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Table 4: Dynamic return-trading volume relationship test: Common vs. Preferred Shares: We present the results of the regression $R_{i,t+1} = \alpha_i + \beta_1 R_{i,t} + \beta_2 R_{i,t} \times V_{i,t} + \beta_3 R_{i,t} \times V_{i,t} \times D_i + \epsilon_{i,t+1}$ where $i$ indexes the stock of Volkswagen, $R_{i,t}$ is the continuously compounded return based on the closing price, $V_{i,t}$ is the natural logarithm of the total number of shares traded, and $D_i$ is an indicator variable with value one in the $[t-10, t]$ period around the corner date $t$. In columns two and three, as a robustness, we define the period around the corner date $t$ as $[t-5, t]$ and $[t-20, t]$, respectively. We are interested in testing whether the coefficient $\beta_3$ of the interaction term, $R_{i,t} \times V_{i,t} \times D_i$, is positive and statistically significant (see Allen et al. (2006)).

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$D_{t-10,t}$</th>
<th>$D_{t-5,t}$</th>
<th>$D_{t-20,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return$_t$</td>
<td>2.330***</td>
<td>3.460***</td>
<td>2.173**</td>
</tr>
<tr>
<td>Volume$_t \times Return$_t$</td>
<td>-0.220***</td>
<td>-0.301***</td>
<td>-0.205***</td>
</tr>
<tr>
<td>Volume$_t \times Return$_t \times D_i$</td>
<td>0.043***</td>
<td>0.035**</td>
<td>0.039**</td>
</tr>
<tr>
<td>Constant</td>
<td>0.009</td>
<td>0.007</td>
<td>0.009</td>
</tr>
<tr>
<td>Observations</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.186</td>
<td>0.146</td>
<td>0.166</td>
</tr>
</tbody>
</table>

Panel II: Preferred Shares

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$D_{t-10,t}$</th>
<th>$D_{t-5,t}$</th>
<th>$D_{t-20,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return$_t$</td>
<td>8.594*</td>
<td>8.429*</td>
<td>9.429**</td>
</tr>
<tr>
<td>Volume$_t \times Return$_t$</td>
<td>-0.650*</td>
<td>-0.633*</td>
<td>-0.708**</td>
</tr>
<tr>
<td>Volume$_t \times Return$_t \times D_i$</td>
<td>0.028</td>
<td>0.023</td>
<td>0.016</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.006</td>
<td>-0.006</td>
<td>-0.006</td>
</tr>
<tr>
<td>Observations</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.123</td>
<td>0.116</td>
<td>0.106</td>
</tr>
</tbody>
</table>
Effective Spreads, Realized Spreads, and Adverse Selection Costs: 09-10/2008

The first row of figures plots the evolution of effective spreads, realized spreads, and adverse selection risk for BMW, Daimler, Porsche, and Volkswagen for the time period of September and October 2008; the second row plots these measures for VW’s preferred and ordinary shares. Effective spreads are measured as follows for stock $i$ and trade $t$: \( e\text{spread}_{i,t} = q_{i,t} \frac{p_{i,t} - m_{i,t}}{m_{i,t}} \), where \( q_{i,t} \) is the so-called trade direction variable (estimated following Lee and Ready (1991)), \( p_{i,t} \) is the transaction price, and \( m_{i,t} \) is the mid price (i.e., the average between ask and bid quote). Realized spreads are defined as: \( r\text{spread}_{i,t} = q_{i,t} \frac{p_{i,t} - m_{i,t} + 5 \text{min}}{m_{i,t}} \). Gross losses to liquidity demanders due to adverse selection are measured as: \( a\text{dverse}_{i,t} = q_{i,t} \frac{(m_{i,t} + 5 \text{min} - m_{i,t})}{m_{i,t}} \).
Figure 6: **Buy-side vs. sell-side**: This graph plots the evolution of the trading volume of Volkswagen that is traded due to buyer-initiated trades vs. the trading volume of Volkswagen that is traded due to seller-initiated trades. Trading volume in this case is measured as the number of shares traded. In order to differentiate the number of shares traded into buy-side and sell-side trading volume, we apply the algorithm proposed by Lee and Ready (1991). **Sizes of bid quotes vs. ask quotes**: This graph plots the evolution of the quote sizes of Volkswagen for ask vs. bid quotes. Size of quotes in this case is measured as the number of shares quoted at the ask or at the bid.
Figure 7: Cumulative abnormal return: We exhibit the cumulative abnormal return for Volkswagen’s common (LHS) and preferred (RHS) stock around the corner date \([t-10, t+10]\). Abnormal return is defined as the difference between the daily return in the corner period and the pre-corner \([t-65, t-10]\) average daily return. In the figures we have accumulated the abnormal return across the corner period, i.e., at date \(t-10\) we have plotted the abnormal return at that date, at date \(t-9\) we have plotted the sum of the variable values at dates \(t-10\) and \(t-9\), etc. We furthermore computed a measure of abnormal returns, defined as the daily return in the corner period in excess of the average daily return for the German automotive industry. Results are the same. Cumulative abnormal trading volume (standardized): We exhibit the cumulative abnormal trading volume for Volkswagen’s common (LHS) and preferred (RHS) stock around the corner date \([t-10, t+10]\). Abnormal trading volume is defined as the difference between daily trading volume in the corner period and the pre-corner \([t-65, t-10]\) average daily trading volume. We standardize this variable with the standard deviation of the pre-corner period daily volume. In the figure we have accumulated the abnormal trading volume across the corner period, i.e., at date \(t-10\) we have plotted the abnormal trading volume at that date, at date \(t-9\) we have plotted the sum of the variable values at dates \(t-10\) and \(t-9\), etc. Daily illiquidity: We define the daily illiquidity measure for Volkswagen’s common (LHS) and preferred (RHS) stock as \(ILLIQ_{i,t} = |R_{i,t}|/VOLD_{i,t}\), where \(VOLD_{i,t}\) is the daily dollar trading volume (in million of dollars), \(R_{i,t}\) is the daily absolute stock return (see Amihud (2002)). We further compute a measure of abnormal illiquidity, defined as the daily illiquidity measure in the corner period in excess of the average daily illiquidity measure for the German automotive industry. Results are the same. Daily price dispersion (high-low) as a percentage of closing price: Daily price dispersion for Volkswagen’s common (LHS) and preferred (RHS) stock is the difference between the high and low prices within a given trading day as a percentage of the closing price. We further compute a measure of abnormal price dispersion, defined as the daily price dispersion measure in the corner period in excess of the average daily price dispersion measure for the German automotive industry. Results are the same.
Figure 8: Daily volatility: We define the daily volatility measure for Volkswagen’s common (LHS) and preferred (RHS) stock as the standard deviation of intra-daily returns (on a minute by minute basis). Abnormal volatility is defined as the difference between daily volatility in the corner period and the pre-corner \([t-65, t-10]\) average daily volatility. We compute also a measure of abnormal volatility, defined as the daily volatility measure in the corner period in excess of the average daily volatility measure for the German automotive industry. Results are the same.
Figure 9: **Value-weighted average fee:** This graph shows the value-weighted average fee on securities loans of the German automotive industry for the time period of September to November 2008. **Utilization:** This graph shows the utilization of securities loans of the German automotive industry for the time period of September to November 2008. Utilization is defined as the ratio of the value of open loans to the total value of lendable assets (y-axis is in percent.) **Average Tenure:** This graph shows the average tenure of securities loans of the German automotive industry for the time period of September to November 2008. **Demand for securities loans:** This graph shows the total value of open securities loans of the German automotive industry for the time period of September to November 2008.
Figure 10: Price discovery process for German automobile industry: 10/2008. This figure plots the evolution of the price discovery measure “weighted price contribution” (WPC) for the German automobile sector for the period of October 2008. The WPC is plotted for three distinct subperiods of a given trading day: 1.) the first 15 minutes after opening, 2.) after the first 15 minutes to closing (i.e., the rest of the trading day), and 3.) close-to-open (i.e., after-hours trading). For each day and each time period $i$, the WPC is defined to be: $WPC_i = \sum_{s=1}^{S} \left( \frac{|ret_{i,s}|}{\sum_{s=1}^{S} |ret_{i,s}|} \right) \times \left( \frac{ret_{i,s}}{ret_s} \right)$ where $ret_{i,s}$ is the return during period $i$ for stock $s$, and $ret_s$ is the close-to-close return for stock $s$.

Price discovery process for German automobile industry: 08-10/2008: This figure plots the evolution of the price discovery measure “weighted price contribution” (WPC) for the ordinary and preferred shares of Volkswagen as well as Volkswagen’s competitors for the period of August to October 2008. The WPC is plotted for the trading period of the first 15 minutes after opening. For each day and each time period $i$, the WPC is defined to be: $WPC_i = \sum_{s=1}^{S} \left( \frac{|ret_{i,s}|}{\sum_{s=1}^{S} |ret_{i,s}|} \right)$ where $ret_{i,s}$ is the return during period $i$ for stock $s$, and $ret_s$ is the close-to-close return for stock $s$. 

Table 5: Comparison of dispersion in analysts’ opinion for Volkswagen (ordinary shares) vs. its competitors

These tables compare the distributions of the standard deviation of price target opinions of analysts in shares of Volkswagen (ordinary vs. preferred), Daimler, and BMW for the time period of 2005-2008. We compare the standard deviation in price target opinions both for the time period before the press release of Porsche (i.e., before October 26, 2008) and thereafter. Column two shows the p-values of the Wilcoxon ranksum test. Column three depicts the p-values of the Kolmogorov-Smirnov (K-S) test of differences in distributions and column four presents the differences in average values of the respective distributions.

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<th>K-S-test</th>
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